SOME ESTIVAL FAUNAL CHANGES IN A TEMPORARY POND

SOME ESTIVAL FAUNAL CHANGES IN A TEMPORARY POND

By

HAROLD WAYNE CROWDER

Bachelor of Science

Oklahoma Agricultural and Mechanical College

Stillwater, Oklahoma

1932

Submitted to the Department of Zoology

Oklahoma Agricultural and Mechanical College

In Partial Fulfillment of the Requirements

For the Degree of

MASTER OF SCIENCE

1940

APPROVED:

John D Mizelle
In Charge of Thesis

R.O. Whitenton
Head of the Department of Zoology

D.C. McIntosh
Dean of the Graduate School

PREFACE

This thesis is an outgrowth of reviewing literature on plankton studies and limnological methods as well as an organization of the findings concerning an ecological investigation of a temporary pond. The work is an attempt to add information to the field of study which deals with biota and biotic changes in habitats of this type. Much of the literature reviewed deals with investigations on lakes of various kinds. From these it was found that conditions of physical and chemical stratification and other phenomena are more outstanding than those in ponds. Ponds have not been extensively studied in North America, however, many interesting and peculiar features are attributed to them by various writers (mostly European).

It is the purpose of the writer to discuss the history of limnology, methods of collecting, enumeration of plankters, environmental factors affecting freshwater fauna and finally the results of the problem undertaken. It is the hope of the investigator that this thesis may stimulate others to do research in this interesting field.

The writer is grateful to Dr. John D. Mizelle of the Zoology Department (Oklahoma Agricultural and Mechanical College) for his aid in direction of the work and organization of the data obtained in this investigation. Mention should also be made of Professor R. O. Whitenton, Head of the Department of Zoology of the same institution, and other members of the departmental staff who have had some small part in the preparation of this work. The writer also wishes to acknowledge the various authors listed below, for their generous cooperation in furnishing reprints and/or identifying species. The investigators who have so aided the writer are: E. A. Birge and C. Juday, University of Wisconsin; W. L. Tressler and R. Bere, University of Buffalo; P. S. Welch, C. Goodrich, F. Eggleston, and H. van der Schalie, all of the University of Michigan; R. R. Langford, University of Ontario; W. E. Allen, Scripps Institution of Oceanography; C. B. Wilson, State Teacher's College, Westfield, Massachusetts; E. J. Wimmer, Kansas State College; R. E. Coker, University of North Carolina; W. A. Clemens and W. Ricker of the Pacific Biological Station; E. P. Creaser, United States Department of the Interior; G. L. Clarke, Harvard University; D. C. Chandler, University of Arkansas; L. A. Ewers, Coffee College, (Nevada, Missouri); S. F. Light, University of California; Stillman Wright, Utah State Agricultural College, and H. I. Featherly, Oklahoma Agricultural and Mechanical College.

H. W. C.

TABLE OF CONTENTS

HISTORICAL REVIEW OF DEVELOPMENT OF LIMNOLOGY[1]

Limnology as a study has existed only about 40 years. Although the subject deals exclusively with physical, chemical, and biotic conditions in fresh water, its present concepts and methods are often applied to, and have been in part taken from, studies of a marine nature. Early biological observations and inventions of early biological apparatus have contributed to the study of limnology with much the same importance as they have to other branches of biology. Thus, the early knowledge of marine and fresh-water species by pre-Aristotelian men and the invention of the microscope by Anton van Leeuwenhoek encouraged biological studies especially of a microscopic nature.

Otto Friedrick Müller in his work entitled "Animalcula Infusoria Fluviatilia et Marina" presented to the world, in 1776, the first worthwhile classification of microscopic organisms. In 1836 "The Infusion Animalcules as Complete Organisms" by Ehrenberg, was another forward step in the study of smaller aquatic forms. Needham and Lloyd, in 1930, credit Liljeborg and Sars with the discovery of plankton by drawing nets through the Baltic waters. Johannes Muller and his pupils, in 1845, studied plankton of the North Sea and later Peter Erasmus Müller discovered microcrustacea in Swiss lakes. Hensen, in 1887, gave the name plankton to

---

[1] Most of this material is taken from Welch (1935).

debris and all small animals and small plants found in natural waters. Subsequently Haeckel included in its meaning all pelagic forms large or small. Later Haeckel proposed the terms "benthos" for bottom forms and "nekton" for free-swimming forms (capable of marked horizontal progression). These terms (benthos and nekton) are used today in this sense and the term plankton has been restricted to include aquatic organisms which are capable of vertical but not marked horizontal movement. Welch (1935) outlined the classification of plankton as follows: phytoplankton--plant plankton; zooplankton--animal plankton; limnoplankton--lake plankton; heleoplankton--pond plankton; macroplankton--plankton visible to the naked eye; net plankton--plankton secured with a No. 25 silk bolting-cloth net; and nannoplankton--plankton which passes through the meshes of a No. 25 silk bolting-cloth net. Anton Fritsch began lake investigations in Bohemia in 1871. F. A. Forel (1841-1912) of Lausanne, Switzerland is considered the father of limnology and wrote about 116 papers, examples of which are, "Instruction a l'etude de la fauna profunde du Lac Leman", and "Handbuch der Seenkunde Allgemeine Limnologie." In 1887, Forel's work led to the formation of the Swiss Limnological Commission which formed a part of the Swiss Natural History Society. Other contemporary and later workers were: Zschokkle on the Alpine lakes of Switzerland; Sir John Murray on the Scottish fresh-water lakes; Victor Hensen in the

North Atlantic Ocean; Apstein on the Holstein lakes; Woltereck and his students at Lunz, Austria; and Wesenberg-Lund and his students on the Danish lakes.

The first European fresh-water biological station was established in the Bohemian forest by Anton Fritsch in 1888. Another station, in 1891, was established at Plön, Germany, by O. Zacharias. Thereafter, stations of this type were established at various places in Europe and America.

In North America, Stimson, in 1870, published an account of deep-water fauna of Lake Michigan. Ferrill and Smith, in 1871, worked on invertebrates of Lake Superior and Milner, in 1874, wrote on the fisheries of the Great Lakes. The Allis Lake Laboratory, the first fresh-water biological station in America was founded at Milwaukee, Wisconsin in 1886. Forbes went westward in 1883 and worked on the Rocky Mountain lakes. Whipple worked in the New England States and Reighard, in 1893, did research in Michigan waters. On Lake Michigan H. B. Ward, in 1894, conducted work similar to that of Reighard. In 1928, Lake Erie investigations were undertaken jointly by the U. S. Bureau of Fisheries, the New York State Conservation Department, the Ontario Department of Game and Fisheries, the Health Department of the City of Buffalo, the Buffalo Society of Natural Sciences, and the Ohio Department of Game and Fisheries. The works of Kofoid and Forbes (19th century) on the Illinois River, Needham on the New York lakes, and of Birge and Juday on the Wisconsin lakes have added materially to the general knowledge of limnology. There are at present about 20 fresh-water biological stations in America (Welch 1935) and in a report, Needham, in 1930, stated that eleven American Universities offer special study in the field of limnology.

Birge and Juday (1926) worked on the organic content of lake water. W. E. Allen (1927, 1929) made studies on the collecting of marine phytoplankton. W. L. Tresseler with Ruby Bere (1935, 1936, 1937, 1938) worked on New York lakes, and about the same time Frank E. Eggleston (1935) wrote on the deep water fauna of Lake Michigan. Paul S. Welch (1938) wrote papers on Bog Lakes, and in the same year R. R. Langford published works on distribution of Crustacea of lakes in Ontario (Langford, 1938). Ricker (1938) of the Pacific Biological Station, wrote concerning methods of pelagic lake collecting.

Very few limnological studies have been made in Oklahoma. Lester Duck (1937) of Alva, wrote "Some Copepods of Oklahoma" and other students have written short papers on phases of plankton studies.

Since this thesis deals with community changes in certain aquatic forms which involve strict taxonomic categories, mention of authorities on groups involved is thought to be worthwhile. The Copepoda, Cladocera, Phyllopoda, and Ostracoda are predominant forms concerned in the present study. Gastropoda, Pelecypoda, Amphibia, and Pisces have been noted.

Copepoda[2] probably have been studied ever since the microscope was invented. First mention was probably made by Stephen Blankaart in 1688. O. F. Müller, in 1785, is given credit for the first scientific description of the group. "Histoire des monocles qui se trouve aux environs de Geneve" published by Jurine, in 1820, contains descriptions of many species which are still considered valid. A more serious study came in 1850, when Baird wrote "Natural History of the British Entomostraca." Shortly afterward, Claus began very accurate work on the Copepoda. S. A. Forbes is given credit for having laid the foundation for exact work on this group in North America. Dwight Marsh has written numerous papers among which is "On the Cyclopidae and Calanidae of Central Wisconsin" in 1893. F. W. Schacht, in 1897, wrote "North American Species of Diaptomus" and E. B. Forbes, in 1897, wrote "Contribution to a Knowledge of North American Fresh-Water Cyclopidae." C. B. Wilson, of the State Teacher's College at Westfield, Massachusetts, is the present outstanding authority on North American forms. He is the author of numerous copepod publications including "Copepods of the Woods Hole Region" (1932) which is monumental. Stillman Wright, U. S. Bureau of Fisheries, Utah State Agricultural College, Logan, Utah, is an active worker on thermal and chemical conditions in water. (Wright,

[2] Taken from work of Marsh in Ward & Whipple's Fresh-water Biology (1918).

1936, 1937) R. E. Coker, (1934) University of North Carolina, at Chapel Hill, published critical work on temperature and environmental effects on copepods. S. F. Light, University of California, Berkeley, is revising the Diaptomus of North America (personal communication).

The Cladocera[3] were probably first thoroughly described by the German, Schaeffer in 1755. In 1785, O. F. Müller, a Danish naturalist issued a systematic work which described many of the Cladocera. The Norwegian, Sars, probably has contributed more than any other man to the taxonomy of the group. Present workers are E. A. Birge (1918) author of the above history, and Chancey Juday, both of University of Wisconsin.

The Phyllopoda[4] were first described by scientists in the 18th century and some papers were written on them by J. C. Schäffer from 1752-1756. In 1913, A. S. Pearse, Duke University (Durham, N. C.) wrote "Some Notes on Phyllopod Crustacea." A recent worker is Edwin Creaser U. S. D. I.

As to the Ostracoda,[5] Linnaeus, in 1748, and Baker, in 1753, made attempts at classifying these forms. In 1894, G. W. Müller published a work on the Ostracoda of the Gulf of Naples, describing 125 species. Later in 1900 he published a work on the fresh-water Ostracoda of Germany in

---

[3] This review is from Birge (1918).

[4] This review is from Pearse (1918).

[5] This review is from Sharpe (1918).

which he described 65 species. Two present workers are Norma Furtos, Cleveland Heights, Ohio, and W. L. Tresseler, University of Buffalo.

The Gastropoda and Pelecypoda[6] owe their early classification to Cuvier in 1795. First descriptions of importance to North America, however, are those of Thomas Say in 1817. C. S. Refinesque, a contemporary of Say, described many species, chiefly Pelecypoda. D. A. Conrad and Isaac Lea established foundations for the present knowledge of American mollusks. Some recent investigators in the field were Gould, William Stimpson, W. G. Binney, and G. W. Tryon. H. A. Pilsbry, Academy of Natural Sciences, Philadelphia, Pennsylvania, is the leading student on North American Mollusca today. Other present active workers are Calvin Goodrich and Henry van der Schalie, both of the Museum of Zoology, University of Michigan at Ann Arbor; W. J. Clench, Harvard University, Cambridge, Massachusetts; and F. C. Baker, curator emeritus of Natural History, University of Illinois, Urbana.

Since this paper deals with ecological changes in a temporary pond it is well to note that little study has been made on this type of community according to Wimmer (1929). Scott, in 1910, studied fauna in a solution pond. Reed and Klugh, in 1924, worked on the hydrogen-ion concentration of a granite and limestone pool near Kingston, Province of

---

[6] This review is from Pratt (1935).

Ontario. Griffiths, in 1916 and 1922, and Atkins and Harris, in 1924, studied the heleoplankton and chemical factors in quarry pools and ponds. Other workers are Alexander, Rylov, Nordquvist, Schaferna, Fric, Diefenbach and Sachse.[7]

Most of the present investigators listed above, have dealt with the biotic community rather than strict taxonomic considerations alone, and there seems to be an increasing interest on the part of taxonomists of fresh-water fauna with reference to methods of collecting, and various effects of environmental factors as wind, temperature, turbidity, light, and chemical phenomena in relation to faunal changes and distribution.

---

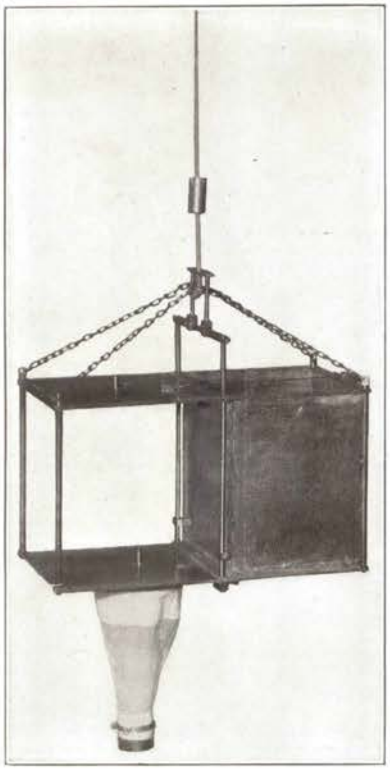
[7] This review is from Wimmer (1929).

REVIEW OF APPARATUS AND METHODS USED IN AQUATIC WORK

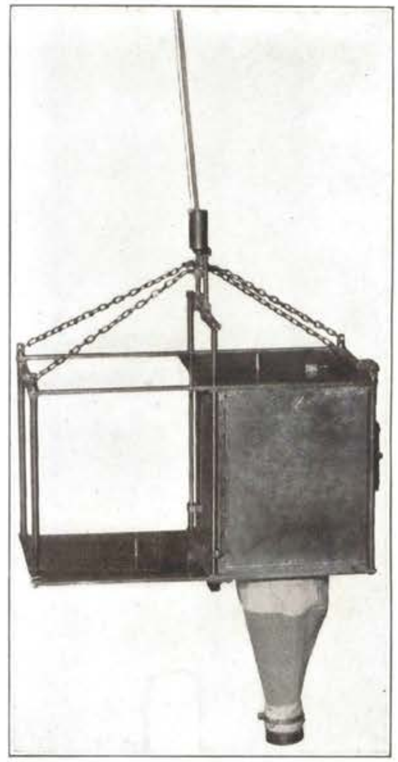
In limnological work there are not only different kinds of equipment for collecting biota but also instruments and methods for measuring environmental factors as temperature, pH, CO_2, O_2, depth, turbidity, etc. Early methods of collecting plankton were crude and inefficient. Bottles, jars, and nets, made of various cloth materials, were used with varying success. Nets first to be used were of the simple tow-net type and were usually made of muslin. Later a modification of the tow-net which had a screen front, was invented to facilitate collecting in areas containing large amounts of debris and plant life. These nets were used for horizontal sampling. In 1916 Juday designed, and he and Birge used, a closing net made of No. 20 silk bolting cloth to take vertical samples of plankton. Difficulties in securing samples from a known volume of water together with the inability to take a representative sample from a given depth, stimulated investigators to demand more accurate apparatus. Gradually, metal collecting bottles were developed and these were found to be the answer to the above problems. In 1916 a ten liter plankton trap (Fig. 1) was designed by C. Juday and manufactured by the Foerst Scientific Specialties Company of Chicago. It is called the Juday-Foerst plankton trap and was especially made for taking the net plankton. This apparatus was so successful according to Ricker (1938) that it readily replaced the closing net used by Birge and Juday, and is now widely employed by various workers including W. L. Tresseler in New York, W. E. Ricker of British Columbia, E. J. Wimmer of Kansas, L. L. Langford of Ontario, and others. The improvement of this device over the closing net is manifest in its ability to take a ten liter sample from any given depth and concentrate the contents by means of straining through an attached net made of No. 20 silk bolting cloth. (Foerst Mechanical Specialties Company, 1935) The closing net could not secure a representative sample of plankton from one subsurface level since it was open at only one end and had to be pulled through a column of water. Its efficiency is given as 80 per cent. (Foerst Mechanical Specialties Company, 1935)

There is also a Kemmerer-Foerst sampler which is similar to the Foerst-Improved water-sampler to be described later. The device consists of a closing bottle, less the net, which is capable of taking water samples at given depths. The contents are strained through a No. 20 silk bolting cloth net for collecting the net plankton. For nannoplankton 500 cc. of the strained sample is centrifuged at 15,000 revolutions per minute for 6 to 7 minutes in a Foerst centrifuge, designed by Juday in 1926. (Fig. 2). In either case a fraction of the concentrate is counted and the total number of organisms per sample are calculated. The Foerst-Improved water-sampler (Fig. 3) which comes in 1200, 2000, and 3000 cc. sizes is very similar in operation to the Kemmerer-

Plankton Trap



Open.



Closed.

A general idea of the plankton trap and the method of operating it may be obtained from the accompanying picture. It consists essentially of a box with upper and lower frame works which carry sliding doors that close the ends of the box. The box part is made of thin brass and has a capacity of 10 liters of water. The top and bottom are closed by sliding doors which operate in grooves in the side pieces of the frame work. The lower door has an opening from which a band of brass, which extends down, and to this the net is attached by a clamp which is operated with a screw.

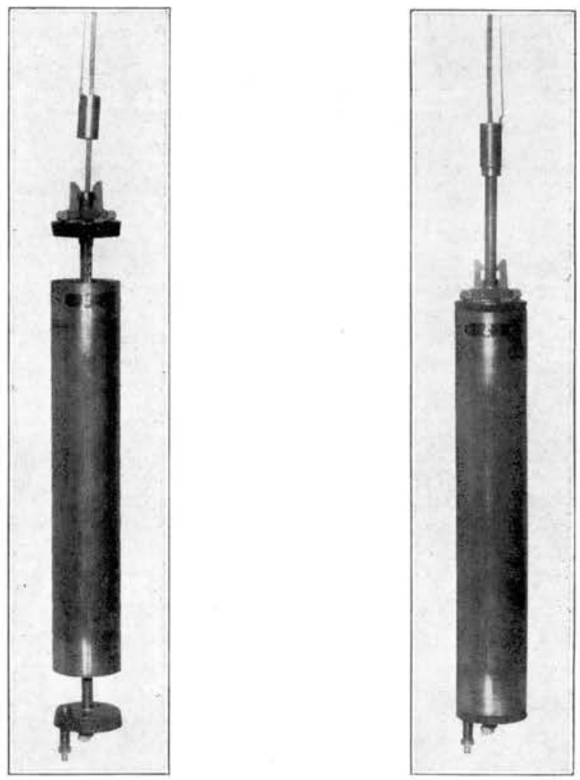
This trap was designed for the purpose of ascertaining the efficiency of both the hand and the power pumps in securing the more active swimmers among the plankton organisms. The opening is so large that there is relatively little disturbance of the column of water which passes thru the open trap in its descent, if the apparatus is lowered carefully. In making a catch the trap is lowered slowly and carefully to the desired depth and a messenger is promptly sent down the line to release the closing device, closing the box. Then the trap

Fig. 1. Juday-Foerst plankton trap

Foerst Electric Centrifuge

Fig. 2. Foerst centrifuge

Foerst Improved Water Sampler



Open. Closed.

A device for obtaining samples of water at various depths. Operated by sending a messenger down retaining line which closes bottle. Has outlet at bottom end for releasing water, by pressing small tube controlled by coiled spring.

Fig. 3. Foerst-Improved water sampler

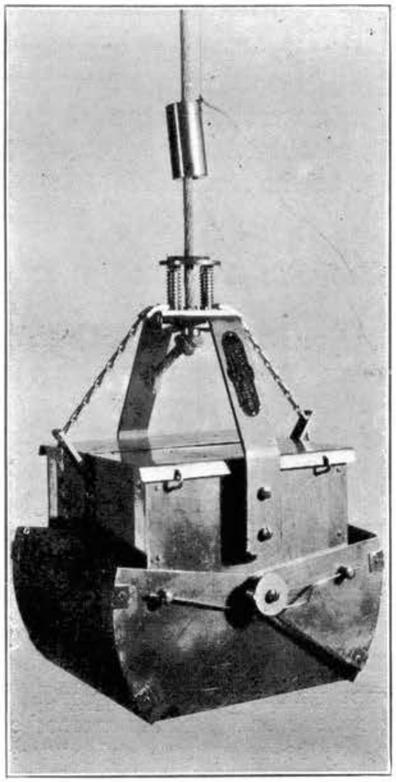
Foerst sampler. It is composed of a brass cylinder, two rubber stoppers (one at each end), a central rod held in place by two spiders (one at each end), a closing mechanism, and a petcock in the lower stopper for removing the sample. A released messenger operating on the sash cord, attached to the central rod, operates the closing device and permits acquisition of samples from a given depth. The sample is concentrated by pouring through a plankton net at the surface.

After a period of plankton collecting (1912-1915) in the San Joachin River, W. E. Allen of the Scripps Institution of Oceanography was impressed with the need of a closing bottle of his own choosing. About 1924, a design was worked out and the Allen closing bottle was produced. It is now manufactured by the Barbour Stockwell Company of Cambridge, Massachusetts. Its construction is similar to that of the Foerst-Improved Water-sampler. The bottle has a metal cylinder and two valves which are held in place by a central rod centered by a spider at each end. There is also a closing device, operated by a messenger (weight), and a faucet for drawing off portions of the sample which may be strained through a plankton net. The bottle (open) is lowered to the desired depth, closed, raised, and the contents examined for zooplankton or phytoplankton. In addition there are various pumps (Fordyce, Clock, Bunwell No. 1, and the thresher tank-pump used for collecting plankton samples. Use of the pumps involves straining through nets after arrival of the samples to the surface. (Reighard 1918)

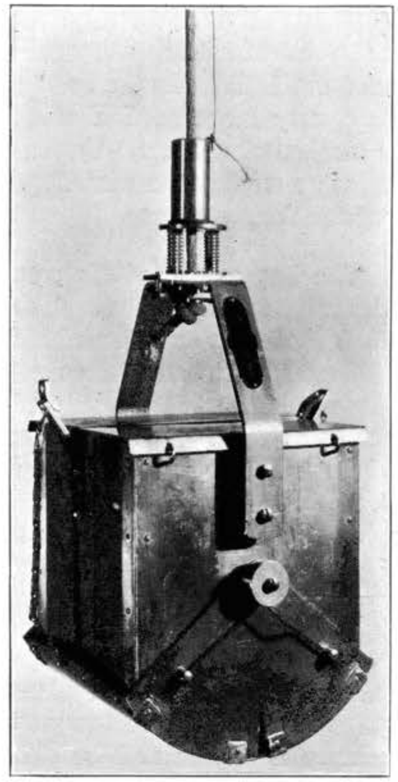
Plankton nets are made of No. 6, 10, 18, 20, or/and 25 silk bolting cloth. They are of a funnel shape and may be small, medium, or of large size. When unattached to collecting devices the top is held open by a heavy wire hoop. The bottom is usually open for reception of a container for holding the concentrate. Silk nets should always be shrunk before using. It is common knowledge that the efficiency of a net varies inversely with its age and its efficiency lowers somewhat after being used repeatedly in a series of catches. (Ricker, 1938). The concentrated sample is killed and preserved in 70-80 per cent alcohol or very dilute formalin (4-5 per cent).

A type of collecting apparatus for bottom forms is known as the dredge. It is generally a heavy metal structure with two jaws held open by a device and closed automatically or by a messenger. The Ekman dredge (Fig. 4) is designed for taking samples from soft bottoms (mud or bog material). In contrast, the Peterson dredge is designed for sandy or gravelly bottoms. In the work done aboard the U. S. Bureau of Fisheries motor boat Fulmar, a Peterson dredge was used most of the time. Its weight was 22.5 kilograms and covered a surface area of 625 sq. cm. The dredge was operated by a winch, a steel cable, and a davit. At the outer end of the davit, the cable passed over a meter wheel

Ekman Dredge



Open.



Closed.

Designed for obtaining samples of mud, for quantitative study of the bottom fauna. The dredge is lowered until it rests on the bottom; the jaws are then released by sending a messenger down the retaining line releasing the springs, the jaws biting into the mud and ordinarily securing enough to fill the dredge two thirds full. This dredge can be operated only on soft bottoms. It is most successful and useful in exploring that great area of an ordinary lake bottom which is covered with lake mud and vegetable debris.

Fig. 4. Ekman dredge

which registered the depth (Eggleton, 1935). Other simpler dredges are in use as the cone dredge designed by Birge, in 1895 and the improved cone dredge designed by Wolcott, in 1901. Jacob Reighard designed the tow-net on runners and the triangle dredge with teeth for digging into the mud. (Reighard, 1918). In addition, collections are often taken in shallow water and along the shore by crude dippers and screen-bottom boxes. Also larger animal forms such as fish are collected by means of seines.

A Sedgewick-Rafter cell (1 cc.) and a Whipple micrometer in conjunction with a microscope are generally used in making reliable plankton counts and plankton estimates according to Langford (1938). Also used are large counting cells (25 cc.) with a Leitz travelling binocular which can easily be shifted from low to high power (Langford, 1938). Concentrates of samples are mixed thoroughly and a small portion of the sample is counted. Results may be expressed in actual counts, standard areal units, or standard volumetric units. A machine used at the Laboratory of the Fresh-Water Biological Association for work of this type has several interesting features. A low power binocular microscope (about 25X) is arranged so that plankters in a glass trough may be moved across the field of vision. Movement of the trough is operated by foot and the distance of organisms from the microscope lenses is easily adjusted by the right hand. Tapping keys (5) leading to a registering device records the numbers of different organisms counted. About

1000 animals may be dealt with in a sample and rapid counting is facilitated through use of this apparatus. W. A. Clemens (1926) thinks it timely for biologists to agree on certain lines of procedure in plankton investigations. He suggests that a committee composed of representatives from various countries meet and recommend standard apparatus and methods through the use of which research work should be done. The following outline is suggested by Clemens.

1. Four lines of plankton investigation
    a. Systematic, that is, the identification and classification of organisms.
    b. Distribution, that is, geographical relationships of plankters.
    c. Ecological, here taken to include vertical distribution; in these studies attempts should be made to correlate environmental factors with life histories of the organisms and to combine experimental work with observation.
    d. Quantitative; these studies have as an object to obtain information concerning general productivity or conservation of particular animals such as fish, clams, and oysters.
2. Standard methods of procedure as to nets, collecting samples and enumerating.
3. Preparation of bibliography of publications dealing with plankton.
4. Plans for coordination of organizations for plankton investigations.

Fig. 5. Photograph of the temporary pond

MATERIALS AND METHODS

Welch (1935) states,

> A pond should be defined as a quiet body of water in which the littoral zone of floating-leaved vegetation extends to the middle of the basin and in which the biota is very similar to that of the littoral zone of lakes.

Two well-recognized types of ponds are (1) temporary, which dry up in certain seasons of the year, and (2) permanent ponds which are comparatively stable with reference to the presence of water.

The present investigation deals with observations on plankton and other biota from a temporary pond situated about two and one-half miles northwest of Stillwater, Oklahoma, and known locally as the Airport Pond. This body of water is subcrescentic in shape, about 75 feet long (not following the shore line), approximately 50 feet in maximum width, has a maximum depth of 3 feet (near southwest shore), and is bordered by a gently sloping shore line (Fig. 6). The northern one-third of the pond is very shallow and is usually well supplied with vegetation. The bottom is composed of muck, a few inches in depth. Drainage (rain) water enters the pond through an inlet on the northwest side.

During this investigation (June and July, 1938, 1939) the pond was surrounded by luxuriant, true-prairie grasses which grew at varying distances from the water's edge. Along the north and west shore line and also in the adjacent shallow water, heavy growth of water rush (*Juncus debilis*) were present. Along the south and east shores smartweeds (*Polygonium*

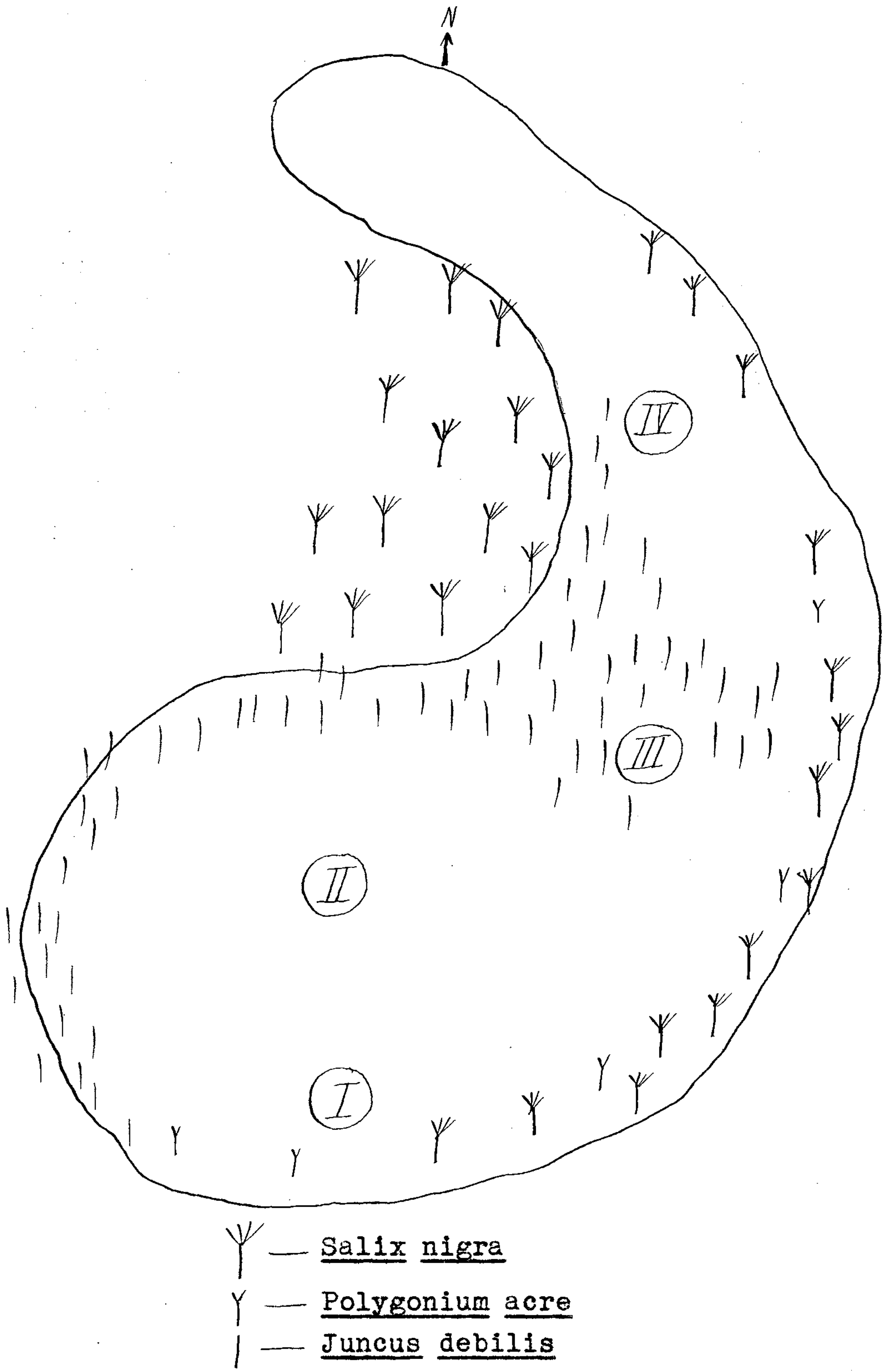
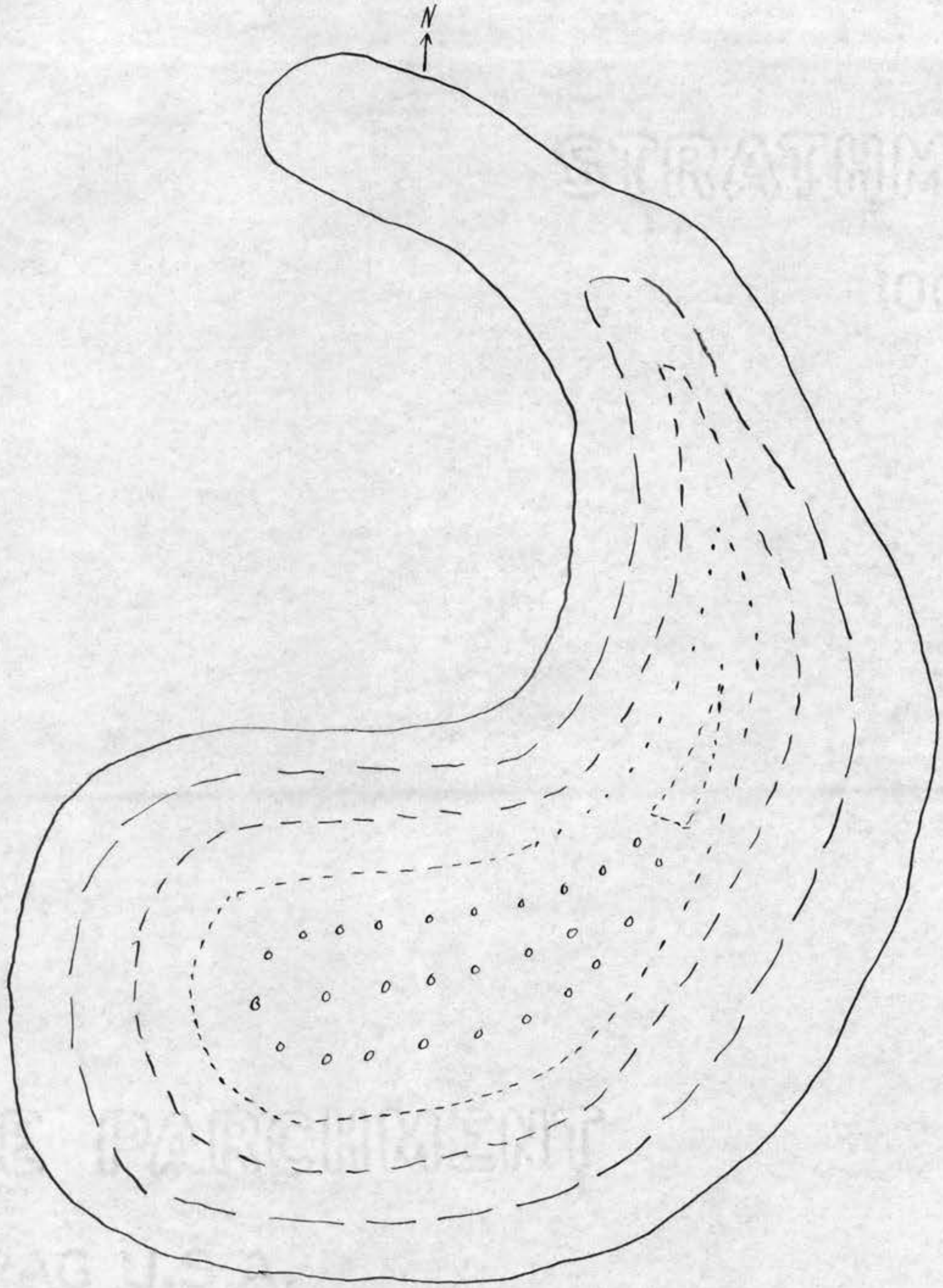


Fig. 6. Sketch of temporary pond showing vegetation and collecting stations



______ 1 ft. .... 2 ft.

_ _ _ _ _ 1½ ft. o o o o o o 2½ ft.

Fig. 7. Sketch of temporary pond showing average depths thruout the area.

acre) grew in scant abundance. Except for a large gap on the southwest side, small (about 10 ft. high) willow trees (Salix nigra) surrounded and also shaded parts of the pond. (Fig. 7). The smaller plant forms as algae were not abundant in 1938 as compared with the large growths which were present in the summer of 1939. These consisted largely of Spirogyra and other lower plant forms.

In making a survey of any lake or pond direct attempts should be made toward accuracy since many factors enter into the biotic production of a body of water. Allen (1929) suggests that there should be a continuity of space, methods, personnel, and selected features of investigations which appear in plankton studies. He further states that space units should be carefully considered since too few stations will not give full information about every region in the body of water. Also the same methods should be used in all stations, same personnel should be employed for all work, and increased interest should not change from one group of organisms to another over a period of time.

A tentative selection of four collecting stations (Fig. 6) was carefully made so that species showing marked habitat preferences in a community of this type might be taken. All four of these stations were used in making collections during the summer of 1938. In 1939, however, Stations I and IV were eliminated and only Stations II and III were collected from. Reasons for this change are due to the fact that results for 1938 showed Stations I and IV to be essentially duplicates of II and III respectively. Station I was chosen near the shore in shallow water where there was no large vegetation. Station II was selected in the deepest (about 30 inches) part of the pond. Station III was established in shallow water in abundant vegetation. Station IV was located in an area of much the same nature as Station III. Late in the summer of 1938, Station IV was abandoned because of drying. Each station was examined once a week at approximately the same time and surface, deep, and bottom samples were taken. Because of drying, deep-water samples could not always be taken in Stations III or IV (1938). In order to prevent confusion the stations were examined in their numerical sequence.

In taking plankton samples the collectors waded and avoided disturbing the water as much as possible. Samples were collected from the surface and also a point near the bottom for each station, when feasible. During the summer of 1938 a wide-mouth gallon jug similar in construction to Meyer's bottle (Reighard, 1918) was used for this purpose and 20 gallons of water were taken for each sample. In 1939 a Foerst-Improved water-sampler was used and 30 liters were used as a unit for samples. Plankton counts were made on the basis of 30 liter samples for each of the two summers. This size sample is considered adequate since many investigators use smaller samples. W. L. Tressler used 20 liter samples in a quantitative study of Long Island Lakes.

After acquisition of the water in this work, the plankters were strained out by pouring the sample through a muslin plankton net and concentrated in an attached 30 cc. bottle. Collections were killed and preserved in 5% formalin.

For bottom sampling a screen (1/8 in. mesh) bottom box, 12" x 16" x 6" and a shovel were used to collect bottom samples (5 sq. ft. and 2-3 in. deep). The sample was placed in the box, the mud washed away, and the animals collected and preserved in 5% formalin.

In collecting larger organisms as fish, tadpoles, and crayfish, several hauls with seines (3/16 in. mesh and 1/4 in. mesh) were made. Collections were then bottled, formalized, and labeled for further study.

In enumerating plankton, each concentrated sample was placed in a graduated cylinder and diluted to 30 cc. with tap water. The concentrate was then agitated by blowing gently on a pipette extended into the liquid. Immediately a 1 cc. sample was drawn into the pipette and transferred to the Sedgewick-Rafter counting cell (1 cc.) and counted. Five such counts were made, averages taken and calculation performed on the basis of 30 liters of pond water. For charting and graphing the counts of the 20-gallon collections were calculated on basis of 30 liters so that comparisons could be made in quantity and quality for the two summers' work.

During the gathering of data for this thesis, temperatures of the surface water as well as that of the deep regions were taken at each station. For checking deep temperatures during 1938 the water was brought to the surface in containers and temperatures were ascertained with an ordinary centigrade thermometer. In the summer of 1938 a deep-sea reversing thermometer was used. Air temperature was taken only during the second summer and it ranged from 1-5^{o} C higher than the surface temperatures of the water. These temperatures are shown in Tables I and II and also in the graphs.

In this investigation two methods were used to check transparency. Collections were made between 2:00 and 4:00 o'clock p.m. and light conditions recorded. During the summer of 1938 a crude Secchi disc type of instrument was used. A piece of tin about 4 cm. in diameter was fastened at right angles to a meter stick. At each station it was submerged, and with the eyes 6 cm above the water's surface the readings were made. These consisted of an average between depth readings for disappearance and reappearance of the disc on lowering and raising it. During the summer of 1939, however, a Jackson candle turbidimeter was used. Readings were made in a darkened room and the turbidity in parts per million of Fuller's earth was calculated from the tables given by Wolman et al (1936) in "Standard Methods of Water Analysis." The Secchi disc and turbidity readings cannot be compared except with reference to high and low light penetrations.

The only chemical phase considered in this investigation was the determination of pH of the water. In 1938 the pH was found by a Hellige Standard Color Disc

Colorimeter using either brom thymol blue or phenol red as indicators. In 1939, the Lamotte Block Comparator was used with same indicator solutions. Records of this data are likewise placed in the graphs and Tables I and II.

TABLE I

GENERAL FIELD DATA SHEET, SUMMER 1938

C	Date	Samples Stations				Depths Stations				Secchi disk (cm.) Stations			
		I	II	III	IV	I	II	III	IV	I	II	III	IV
1	4:30 P.M. June 15	3	3	3	3	24	30	18	12	11	15	16	14
2	2:00 P.M. June 20	3	3	3	3	30	34	20	13	9	12	11	13
3	2:00 P. M. June 27	3	3	3	3	30	33	18	11	15	13	15	14.5
4	2:00 P. M. July 5	3	3	3	3	25	29	15	9	12	12	17	17
5	2:00 P. M. July 13	3	3	3	1	23	26	10	5	17	19	15.5	
6	2:00 P.M. July 18	3	3	3	1	22	23	9	4	15.5	14.5	14	
7	2:00 P.M. July 27	3	3	2	1	20	20	8	5	15	17	11	

Surface Temp. C° Stations				Deep Temp. C° Stations				pH Stations				Wind and Light
I	II	III	IV	I	II	III	IV	I	II	III	IV	
34	33	32	32	27	26	29	29	6.6	6.6	6.4	6.2	Slight S. Poor
37.5	37	37	35.5	26	25	25	31	6.4	6.4	6.4	6.4	Gentle S. E. Moderate
29	28	28	27	25	25	28	25.5	7.2	7.2	7.2	7.2	Moderate E. Poor
32	32	34	33.5	29	28	30.5	31.5	7.1	7.1	7.1	7.1	Strong S. Bright
36	36	38	38	29	29	32	37	7.2	7.3	7.2	7	Gentle S. E. Bright
29	29	29	29	29	27	28	28.5	7.2	7.1	7.3	7	Moderate N.E. Bright
33.5	33	36	38	30	29	35	37.5	7.2	7.4	7.2	7.2	Moderate S.W. Bright

TABLE II

GENERAL FIELD DATA SHEET, SUMMER 1939

C	Date	Samples Stations II	Samples Stations III	Depths Stations II	Depths Stations III	Turbidity Readings Stations II	Turbidity Readings Stations III	Surface Temp. C° Stations II	Surface Temp. C° Stations III	Deep Temp. C° Stations II	Deep Temp. C° Stations III	pH Stations II	pH Stations III	Wind and Light
1	2:30 P.M. June 10	3	2	30	12	Less than 25 P.P.M.		29	29	28.5	---	7.9	7.9	Moderate W. Moderate
2	2:30 P.M. June 19	3	1	24	12	Less than 25 P.P.M.		28.5	28.6	27.8	---	8	7.8	Moderate SE Moderate
3	2:30 P.M. June 26	3	2	24	12	45	45	28	28.2	26	---	7.2	7.2	Moderate S Moderate
4	1:30 P.M.	3	2	42	24	90	95	26.5	28	26	---	6.8	6.9	Moderate S Bright
5	2:30 P.M. July 10	3	2	30	18	Less than 25 P.P.M.		29.5	30	29.2	---	7.4	7.2	Strong NE Bright
6	9:00 A.M. July 17	3	2	30	18	32	35	27.5	28.5	27.5	---	7.4	7.4	Strong S Bright
7	4:00 P.M. July 25	3	2	30	18	Less than 25 P.P.M.		34	34	34	---	7.6	7.6	Moderate SE Bright

TEMPERATURE AND ITS POSSIBLE EFFECTS ON FRESH-WATER COMMUNITIES

Possibly no other environmental factor affects vertical and horizontal distribution of plankton as much as temperature. Studies of lake temperatures have been made by many limnologists and some of their findings are discussed in the following lines.

Temperatures are generally taken by a common centigrade thermometer or by the Negretti-Zambra deep-sea reversing thermometer. The latter is used by foremost investigators as Tressler, Wimmer, Chandler, and others. The study of temperature data has generally shown stratification in most lake waters according to various writers as Welch and Tressler. Tressler (1934) explains that there is an upper layer called the epilimnion in which little change is noted in temperature. Below the epilimnion occurs a narrow region called the mesolimnion or thermocline where the temperature drops rapidly. Below the thermocline is the hypolimnion in which the temperature drops gradually as the botton is approached. Lakes which are stratified are generally in temperature regions, but tropical and subtropical deep lakes may also exhibit this phenomena. Langford (1938) reports that the above regions are important in the life of water fauna, for organisms are often above, below, or in the thermocline at certain times or according to size and habits of organisms. Maxima of plankton are generally in either the hypolimnion or epilimnion and less abundant in the thermocline. Tressler (1934) explains further that circulation by wind during the summer is confined to the epilimnion due to the great difference in density above and below the thermocline. Later in the fall the epilimnion goes deeper, due to warming and wave action. Stratification may become obliterated and the entire lake have a uniform temperature. This condition is known as the fall overturn and complete circulation is present. A second thermocline appears in winter, and in the spring another overturn takes place. Surface temperatures may depend on the weather while deep temperatures vary but little except in shallow lakes and ponds where water temperatures tend to duplicate that of the air. In the latter poor circulation in hot weather produces an upper layer which is warmer than lower layers and a diminutive thermal stratification results. Welch (1938) discovered that as the summer progresses, bottom temperatures increase and may come within one or two degrees of the surface temperature; then, no thermal stratification is possible. Since water in shallow ponds responds rather readily to air temperature changes during long protracted periods of calm, clear, hot weather, surface temperature may rise to heights which may be lethal to many organisms (Welch, 1935). In a study made on bog lakes Welch (1938) found that many clams, plankton organisms, and other invertebrates were killed under such circumstances. He further states that Charles Creaser reported that even fishes may suffer severely from such conditions. It is common knowledge that high temperatures cause increased plant activity, producing more oxygen and food than ordinarily. Coffing (1937) reports that Allen and Eddy discovered the amount of phytoplankton to vary directly somewhat with temperature. Higher temperatures also bring about greater decomposition and consequent chemical changes which may affect zooplankton. Langford (1938) repeats the statement of Marsh in 1897: "It appears to be probable that temperature is the controlling cause of both diurnal and seasonal migration."

TRANSPARENCY, TURBIDITY, AND LIGHT EFFECTS ON AQUATIC ORGANISMS

Transparency is defined as the ability of a substance to transmit light rays so that the material can be seen through. Welch (1935) says that there are difficulties involved in methods and instruments for qualitative and quantitative measuring of light penetration in water. Historically, Welch (1935) presents several facts of advancement in this phase of investigation. In 1865 A. Secchi of Rome, Italy, devised a method for studying the transparency of Mediterranean waters. It consisted in lowering a white plate (20 cm. in diameter) into the water and noting the place at which it disappeared, and reappeared on lifting. Average of the two depth readings was considered limit of visibility. Later, Forel used either a white zinc or white crockery plate based on the same principle as that of Secchi. In 1883, the Physical Society of Geneva, Switzerland established a committee which substituted an incandescent lamp for the white Secchi disc. Early photographic methods by Forel in 1873 and later photographic methods by Knudsen, in 1922, were used to measure intensity of light under water. A more recent development is the photo-electirc cell. Also the pyrlimnometer designed by Birge and Juday in 1929 and 1931 and the bathysphere invented by Beebe and Barton are used to determine the penetration of light. According to Welch (1935) the work of Hans Peterson on Norwegian fjords showed that transparency was generally uniform throughout the upper water of the epilimnion which is kept in circulation by the wind. The thermocline and hypolimnion regions were found stratified into transparent and less transparent layers alternately. These layers varied from a few centimeters to several meters in thickness. Marked decrease in transparency was found toward the bottom because of rising of flocculent materials. Transparency, according to Tressler (1934) is governed by color of water, amount of sediment in suspension, amount of plankton, time of day, and season of year. Clarke (1938) suggested that curves representing seasonal change in transparency may be compared to abundance of plankton and detritus indirectly. Also he thinks that the amount of light from the sun and the angle of solar rays govern transparency, thus making depth of the "photic zone" and the distribution of radiation to change from month to month. It is further noted by Clarke (1938) that the greatest range of daily and seasonal variations in light are found in shallow ponds.

Turbidity is a phase of transparency and Welch (1935) states that turbidity is due to plankton growths or to syspended inanimate matter and varies greatly with seasonal productivity and inflowing sediment which is dependent on the nature of the surrounding terrain. He points out that most suspended matter settles but often, light flocculent material may remain suspended due to wind and movement of pond fauna. Ponds with mucky bottoms may have cloudy material in deep waters. Ponds with clay bottoms or those receiving inflowing claybearing waters are likely to have high turbidities. Also sudden variations due to rains may take place in turbidity. Turbidity generally increases until the bottom is reached and as turbidity varies, so varies the transparency in an inverse manner. Incidentally, Welch (1935) suggests that delayed settling of fine suspended material in the epilimnion facilitates its oxidation and thereby controls some of the chemical conditions in the water. Turbidity varies throughout the seasons of the entire year because of changing weather conditions.

Light having its effect on temperature as well as plant and animal forms warrants some discussion in regard to migration and distribution. Langford (1938) writes that in 1897 Marsh says:

> *Epischura* prefers warm water but avoids bright light. In the daytime during the hot months it is most abundant in the upper water layers but not at the immediate surface. In the darkness of the evening it is no longer repelled from the surface by the light.

Langford also reports that there seems to be a maximum in the upper layers because of positive phototropism but scarcity near the surface because of intense light of the daytime. Some species do not seem to be affected by extreme light and marked differences are found in existing light conditions in regions of maximum numbers. A study of light effects on *Daphnia* (Clark 1930) has been made in such a manner as to note phototropic and geotropic tendencies and to gain information concerning diurnal migrations. Change in light intensity caused *Daphnia* to move and direction seemed to be affected by direction of light and gravity pull. Juday in 1903 found young Daphnia near the surface during the daytime and adults in the deeper waters. Langford (1938) says that Dice in 1914 states:

> Young individuals of Daphnia are more strongly positively phototropic and more negatively geotropic than adults.

He noted that younger forms sink less rapidly in water than do adults and therefore a downward movement takes place in the ageing of the individual. It is the opinion of many workers (e.g. Russell) according to Clark (1930) that light is a most important factor in vertical distribution. Two methods suggested by Clark (1930) for checking this phenomenon are: (1) Observations by means of tow nets and (2) Experimental methods in the laboratory under various light conditions. Clark (1930) states:

> Diurnal migration may be due simply to a positive phototropism and negative geotropism produced by the rising sun in the morning and to a reversal of these tropisms when the sun sets at night.

The general conclusion, however, is that many experiments and observations are yet needed to discover the facts about light in the study of limnology. It is also true that photosynthesis governs chemical conditions of the water and possibly plays an important role in the distribution of animal life.

CHEMISTRY OF FRESH-WATER AND POSSIBLE EFFECTS ON DISTRIBUTION OF PLANKTON

The chemical phenomena are likewise important in regard to lake and pond productivity. According to Welch (1935), a Swedish chemist Arrhenius in 1887 set forth the idea that molecules of an electrolyte put into solution are largely broken up into their radicals, each radical carrying a negative or positive charge. Hydrogen is an acid radical and in an ionized solution it produces certain concentration. When the hydrogen ion concentration is high enough, an acid condition prevails, and when low, an alkaline condition is present. A pH of 7 represents a neutral condition. Readings above 7 mean alkaline conditions and readings below 7 indicate acid conditions. The Lamotte Block Comparators with brom thymol blue or phenol red as indicators is common apparatus used by such workers as Stillman Wright, Paul Welch, and others for checking these conditions. The pH may range from 4.4 to 9.4 and vary in different parts of a lake or pond. It is claimed that rainwater collecting CO_2 from the air and by washing over soil into a body of water causes considerable change in pH. CO_2 may be checked by the Seyler method as given by Birge and Juday in 1911. According to Wimmer (1929) dissolved oxygen may be found by the Winkler method devised by Winkler in 1888. Other factors as nitrogen, phosphorus, and various chemicals are often determined but only the three pH, O_2, CO_2 are discussed here. W. L. Tressler (1937) found that a correlation between CO_2 and pH existed in lakes during the summer. When debris is decomposed CO_2 is produced, thus using up the O_2 in the lower waters and producing CO_2 which brings about an acid condition. But if large amounts of actively working phytoplankton are present the CO_2 is utilized and the acidity removed. Tressler (1937) also noted that alkaline lakes were more productive than acid lakes because all of the regions were aerated providing O_2 for animals and lacked the high CO_2 content in the lower depths. The presence of plants which produce O_2 in daytime help aerate the waters. Bodies of water are also aerated by wind action thus preventing accumulations of CO_2 which lower the pH. Wimmer (1929) states that ponds often develop chemical stratification because circulation is poor, CO_2 being concentrated in the lower layers and O_2 in the upper layers.

In regard to effects on plankton, according to Langford (1938) there seems to be a tendency for plankton to move from a region of low O_2 to high O_2 content and from a region of high CO_2 to low CO_2 region. Langford (1938) quotes Birge and Juday in 1911 who state in the introduction to their study of dissolved gases,

> The animal plankton has not shown any close correlation with dissolved gases considered either with reference to kind or quantity. These gases seem to have no chemotactic effect on the zooplankton nor do the gaseous products of decomposition as they exist in lakes appear to have any unfavorable effect on the animals, such as might determine their distribution in the water of the lake. The zooplankton is excluded from water whose supply of oxygen is too small; but sensitivity to deficient oxygen does not appear until the supply of the gas is much reduced.

More recently it is suggested by Wimmer (1929) that hydrogen-ion (which is governed by CO_2 content) has played an important part in ecology. He reports that Shelford in 1923 and Brown and Jewel in 1924 worked on reactions of fish to various pH. Juday, Wilson and Fred in 1924, according to Wimmer (1929), studied hydrogen-ion concentration in deep lakes and Reed and Klugh (1924) found variations in pH in limestone pools which might seem to have governed plankton distribution. Lowndes (1928) says that pH may be altered without serious effect but more than probable there is an optimum value for each species. Since pH changes considerably at times, plankton must be able to withstand these changes if they are to survive. He thinks that a high pH may influence infusoria and other foods of plankton. However, it is Lowndes opinion that calcium and magnesium carbonates may be present or come in from streams which feed a pond and that these compounds in the presence of a high pH seem to have toxic effects. When no calcium or magnesium is present, life cycles of organisms seem to be unchanged or unaffected by the pH itself. Many experiments are needed to show the magnitude of effects resulting from changes in pH.

DISCUSSION

The objectives in this work were to ascertain the types of organisms present, their seasonal abundance, and the summer faunal changes in the temporary pond under consideration. The predominant forms, on which counts were made, were planktonic. These are definitely known to have important influence in food chains and the balance of life in aquatic communities. The larger forms were collected for qualitative information with reference to faunal changes. Seven weekly collections were made for each summer. These began on June 15 and terminated on July 25 in 1938. In 1939, collections began on June 10 and terminated on July 25.

The predominant Copepoda included four species, namely, Diaptomus clavipes, D. saltillinus, Cyclops robustus, and C. prasinus. At the beginning of the summer of 1938, Diaptomus were numerous (see graphs 1-8) in stations 1 and 2 and less abundant in stations 3 and 4. They reached a population peak in all stations from June 15 to the 27th, then gradually declined in numbers, and were absent in all collections on July 18 and July 25. Members of this genus were more abundant in deep samples than in surface collections except in station 4 where the water was very shallow. In the latter station a reversal of vertical distributional relationships were present. The observations for stations 1, 2, and 3, agree with those of Dice as given by Langford (1938). Reasons for the reversal of stratal distribution probably involve an interaction of several factors. In 1939, no

Diaptomus were found. Populations of Cyclops were also greater during the first part of the summer of 1938 as noted for Diaptomus. The peak, however, was reached earlier than in the last-named genus. Numbers declined steadily after the peak until a period from June 25 to July 1, after which they steadily (in most cases) increased for the rest of the collecting period. Populations of this genus did not follow this trend in the summer of 1939. For the first part of the summer, graphs (9-11) show a gradual decrease from an apparent high reached earlier in 1938. From July 19 to the 26th, a low was reached, after which there was a marked increase in numbers and a second population peak was evident about the middle of July. From this time on, a decrease was noted. The vertical distribution of Cyclops is essentially the same as that for Diaptomus except that the reversal noted for the latter in station 4 occurred in stations 3 and 4 for Cyclops. During the first part of 1938, nauplii (Copepoda) were numerous in the same manner as were the adult forms. In general, there was a decrease in nauplii until between June 27 and July 1. Following this, there was a slight increase on July 5. Slight increases and decreases were apparent during the rest of the summer collecting period. In 1939, the distribution was similar to that of 1938 with the exception that there was a marked high on June 27 and an abrupt fall to a minimum on July 25. The graphs (1-11) show a converse situation with reference to vertical distributional relationships of nauplii and adult Copepoda. An exception to this is apparent in that a reversal of distributional relationships for adults forms in stations 3 and 4 were absent for nauplii in all stations.

The Cladocera were thinly distributed during the summer of 1938. Forms collected were Moina brachiata, Scapholeberis mucronata, Simocephalus exspinosus, Pleuroxus denticulatus, and members of the genera of Ceriodaphnia, Chydorus, and Diaphanosoma. During the second summer the forms of Moina, Pleuroxus, Chydorus, and an additional form (Bosmina) were taken. Slightly increased numbers of Cladocera over populations in 1938 was due to Bosmina and Chydorus. There was a slight tendency for Cladocera to occupy the upper waters rather than the lower regions.

Ostracoda were composed of two species, namely, Physocypria globula and Pionocypris helvetica. Numbers of these species were low and found during the entirety of both summers. Only one evident increase was present in each summer. This came for the various stations from June 27 to July 13. Greater numbers of these forms were taken from deep samples.

During the summer of 1938, a conchostracan (Cyzicus morsei) was found in large numbers in bottom samples from stations 3 and 4. These Phyllopoda, however, were absent in 1939, and it is believed that their populations were decimated by invading fish. A sphaeriid (Musculium elevatum) and specimens of a snail (Helisoma trivolvis)were found in large numbers during both summers. However, the sphaeriid was present mainly in stations 1 and 2 and the snails were evident only in stations 3 and 4. Another snail (Physa ampullacea) was taken infrequently in the stations (3 and 4) in shallow water where vegetation was present. Crayfish (Cambarus simulans) and tadpoles of Rana catesbeiana were present during the entire investigation.

The distribution of the organisms in the temporary pond studied, cannot be fully explained on the basis of the evidence gained during the investigation, principally because of the time element involved. According to Welch (1935) plankters generally show two annual maxima (spring and autumn) but only one may occur. He further says that Entomostraca probably includes the largest numbers of species with a great diversification of plankton in the summer. He cites Wesenberg-Lund as follows:

> Nowhere do the variations in the composition of fauna seem to be so great from year to year as in ponds. It is a well-known fact that phyllopoda may one year be very numerous in a given pond; in the next year or even in a series of years, not a single specimen can be found.

Welch further suggests that the same is true of Planaria, Cladocera, Rotifera, Flagellata, Ostracoda, and Copepoda. Reasons for fluctuation in numbers of such forms are not forthcoming from these authors. Chapman, in 1931, according to Welch (1935) noted that there was diverse fauna with high reproductive potentials in pond organisms. He also noted that such factors as temperature, space, gaseous content, competition for food, enemies, and accumulation of waste become severe in a restricted space such as exists in a temporary pond. In spite of the insufficient evidence on which to base conclusions, it may be said that many environmental factors probably played a part in the seasonal as well as the vertical distribution of the plankters in this study. There seemed to be a tendency for the younger forms as nauplii of the Copepoda to occur in greater numbers in the upper waters as suggested by Dice (Langford, 1938). This was not true of the older forms. Both Diaptomus and Cyclops were found in greater numbers in deep samples except in the stations mentioned earlier with reference to reversals. It is interesting to note that there is a rather sharp difference in the behavior of these two genera of Copepoda in that a reversal of stratal distribution was found for Diaptomus only in station 4 but in both stations 3 and 4 for Cyclops.

Little thermal stratification was evident in the pond because of comparatively shallow depths and its accessibility to wind action. This points to the fact that temperature probably played a minor role in distribution. Although oxygen and carbon dioxide were not measured, it is believed that circulation was sufficient to allow for free exchange of these gases with the atmosphere. In regard to pH, the record seems to show no correlation between the acid and alkaline conditions and the population fluctuations. According to Wimmer (1929) Whipple stated, in 1927, that he believed horizontal distribution was rather uniform but that vertical distribution was dependent on wind. In this investigation little correlation can be made in this regard.

Langford (1938) after studying distribution of plankters in Lake Nipissing says:

> It is believed then, that no one factor is at all times the controlling agent in this case, but rather an interplay of factors responsible for the reactions exhibited.

Welch (1935) says in regard to the law of the minimum,

> Existence and production of animal and plant life depend upon the proper qualitative and quantitative composition of the environment for each component organism. Liebig's law of the minimum, originally applied to plants, may be stated as follows: Each organism requires a certain number of food materials, and each of these materials must be present in a certain quantity. If one of these food substances is absent, the organism dies; if not absent but present in minimal quantity, the growth will be minimal. This result holds even though ample amounts of all of the other required substances are present.

Welch (1935) also suggests that Liebig's law of the minimum is the foundation of Blackman's law of limiting factors, which refers to the dependence of one factor upon another.

One point may be outstanding with reference to faunal changes which were evidently due to climatic factors. The pond studied is ordinarily of a temporary nature. However, rainfall was sufficient during 1938 to prevent the pond from drying so that two species of fish (Lepomis cyanellus and Gambusia affinis) invaded the community from a nearby lake during heavy spring rains. Gambusia affinis was noted first in the pond about July 8 (1938) by John Mizelle (personal communication). Small Lepomis cyanellus were first noted about July 15 of the same summer. These animals were able to live over the ensuing winter and increase their numbers to a degree thought to be great enough to affect the Conchostraca and plankton present. Incidentally, the algae and diatoms were more numerous during 1939, than in 1938. In addition, Rana catesbeiana tadpoles were also able to winter over and developed into sizeable forms during the summer of 1939.

Since Diaptomus disappeared during the first summer, and did not reappear during the second summer, together with the fact that Conchostraca present in 1938, were wholly absent during 1939 suggests that these forms suffered very keen competition brought about by the invading fish and frogs.

The increase in Cyclops, Ostracoda, and Cladocera during the second summer suggests that natural cycles of productivity and/or a combination of biotic factors favored these species whereas they were detrimental to Diaptomus and Cyzicus.

SUMMARY

The predominant fauna taken from the Airport Pond in weekly collections over a period of two months in each of the summers of 1938, 1939, showed peculiarities apparently typical of biotic production in a temporary pond. The findings express evidence of variations in population densities of Copepoda, Cladocera, Ostracoda, and Phyllopoda. These fluctuations are apparently due to natural, seasonal, life cycles, and an interplay of environmental factors as temperature, light, chemical phenomena, etc. The presence of spring and fall maxima of plankton with decreased numbers in midsummer conform to the findings of important investigators in lake waters. A significant factor of interest in this problem is the successful invasion and population of a temporary pond by fish in numbers sufficient to alter the biotic composition of the community during the summer of 1939. Tadpoles of Rana catesbeiana were able to develop to metamorphosis because of the failure of the pond to dry up during the winter of 1938. Since planktonic forms are known to be food for predatory fish and frogs in this case, the balance of life in a community of this type may be expected to vary according to numbers of these larger forms present.

BIBLIOGRAPHY

Allen, W. E. 1927. An improved closing bottle for subsurface sampling of fluids. Science, New Series 65(167):66-67.

____________ 1929. Ten years of statistical studies of marine phytoplankton at the Scripps Institution of Oceanography. Science 70(1818):416-419.

Birge E. A. 1918. The water fleas (Cladocera). Ward and Whipple's fresh-water biology, Chap. 22:676-739. John Wiley & Sons, New York.

Birge, E. A. and Juday, C. 1926. Organic content of lake water. Bull. Bur. of Fish. 42(Doc. 1012):185-205.

Clarke, G. L. 1930. Change of phototropic and geotropic signs in <u>Daphnia</u> induced by changes of light intensity. Jour. of Exp. Biol. 7(2):109-131.

____________ 1932. Quantitative aspects of the change of phototropic sign in <u>Daphnia</u>. Jour. Exp. Biol. 9(2):180-211.

____________ 1938. Seasonal changes in the intensity of submarine illumination off Woods Hole. Ecology 19(1):89-106.

Clarke, G. L. and Ginn, D. G. 1937. Seasonal production of zooplankton off Woods Hole with special reference to <u>Calanus finmarchicus</u>. Biol. Bull. 73(3): 464-487.

Clemens, W. A. 1926. Suggestions as to the standardization of plankton methods. Proc. 3rd Pan-Pacific Sci. Congress, pp. 183-184.

Coffing, C. 1937. "A quantitative study of the phytoplankton of the White River Canal, Indianapolis, Indiana." Butler Univ. Bot. Stud. 4(2):13-31.

Coker, R. E. 1934. Some aspects of the influence of temperature on copepoda. Science 79(2049):323-324.

Duck, L. G. 1937. Some copepoda of Oklahoma. Proc. Okla. Acad. Sci. 17:34-35.

Eggleton, F. E. 1935. The deep-water bottom fauna of Lake Michigan. Papers Mich. Acad. Sci. Arts and Letters 21:599-612.

____________ 1937. Productivity of the profundal benthic zone in Lake Michigan. Papers Mich. Acad. Sci. Arts and Letters 22:593-611.

Ewers, L. A. 1930. The larval development of freshwater copepoda. The Franz Theodora Stone Laboratory, Ohio State Univ. Press, Columbus.

Foerst Mechanical Specialties Company 1935. Limnological apparatus, pp. 1-15, Chicago.

Jordan, Harry E. et al. 1936. Standard methods of water analysis. Lancaster Press, Lancaster, Pa.

Langford, L. L. 1938. LVI. Diurnal and seasonal changes in the distribution of the limnetic crustacea of Lake Nipissing, Ontario. LVII. The food of the Lake Nipissing cisco Lesscichthys artedi (Le Seur) with special reference to the utilization of the limnetic crustacea. Biological Series No. 45, publication of the Ontario Fisheries Research Laboratory, pp. 1-143.

Lowndes, A. G. 1928. Fresh-Water copepoda and hydrogen-ion concentration. Ann. Mag. of Nat. Hist. 1(4):457-460.

Marsh, C. D. 1918. Copepoda. Ward and Whipple's Fresh-Water Biology, Chap. 23:741-778. John Wiley & Sons, New York.

Ortmann, A. E. 1918. Higher crustaceans (Malacostraca). Ward and Whipple's fresh-water biology, Chap. 25:828-850.

Pearse, A. S. 1918. The fairy shrimps (Phyllopoda). Ward and Whipple's Fresh-Water Biology, Chap. 21:661-675. John Wiley & Sons, New York.

Pratt, H. S. 1935. Mollusca. A manual of the common invertebrate animals. 15:559. P. Blakeston's Son & Co., Philadelphia.

Reighard, J. 1918. Methods of collecting and photographing. Ward and Whipple's fresh-water biology, Chap. 3:61-89. John Wiley & Sons, New York.

Ricker, W. E. 1938. Seasonal and annual variations in quantity of pelagic net plankton, Cultus Lake, British Columbia. J. Fish. Res. Bd. Can., 4(1):33-47.

____________ 1938. On adequate quantitative sampling of the pelagic net plankton of the lake. Ibid. 4(1):19-32.

Sharpe, R. W. 1918. Ostracada. Ward and Whipple's Fresh-Water Biology, Chap. 24:790-827. John Wiley & Sons, New York.

Tressler, W. L. and Bere, Ruby 1934. Plankton studies in some lakes of the Mohawk-Hudson watershed. Report of a biological survey of the Mohawk-Hudson watershed. Suppl. 24th Ann. Rep. New York State Cons. Dept. (9):250-266.

__________ 1934. Plankton studies in some lakes of the Raquette River watershed. Biological survey of the Raquette watershed by the New York State Cons. Dept. pp. 222-224.

__________ 1935. A limnological study of some lakes in the Delaware and Susquehanna watershed. Report of a biological survey of the Delaware-Susquehanna watersheds. Suppl. 25th Ann. Rep. New York State Cons. Dept. (10):222-236.

__________ 1937. A limnological study of Chautauqua Lake. A biological survey of the Allegheny and Chemung watersheds. Suppl. 27th. Ann. Rep. New York State Cons. Dept., pp. 196-213.

__________ 1938. A quantitative study of the plankton of the bays of Long Island. A biological survey of salt waters of Long Island. Part I, New York State Cons. Dept., a joint survey with the U. S. Bur. Fish. pp. 177-189.

__________ 1939. A limnological study of four Long Island lakes. A biological survey of fresh waters of Long Island. Suppl. 28th Ann. Rep. New York State Cons. Dept., pp. 102-108.

Walker, B. 1918. The Mollusca. Ward and Whipple's fresh-water biology. Chap. 29:957-1020. John Wiley & Sons, New York.

Welch, P. S. 1935. Limnology. McGraw Hill Book Company, New York.

__________ 1938. A limnological study of a bog lake which has never developed a marginal mat. Trans. Amer. Micros. Soc. 57(4):344-357.

__________ 1938a. A limnological study of a retrograding bog lake. Ecology 19(3):435-453.

Wilson, C. B. 1932. The copepods of the Woods Hole region Massachusetts. U. S. Nat. Mus. Bull. (158):5-11.

Wimmer, E. J. 1929. A study of two limestone quarry pools. Trans. Wis. Acad. Sci. Arts and Letters 24:365-399.

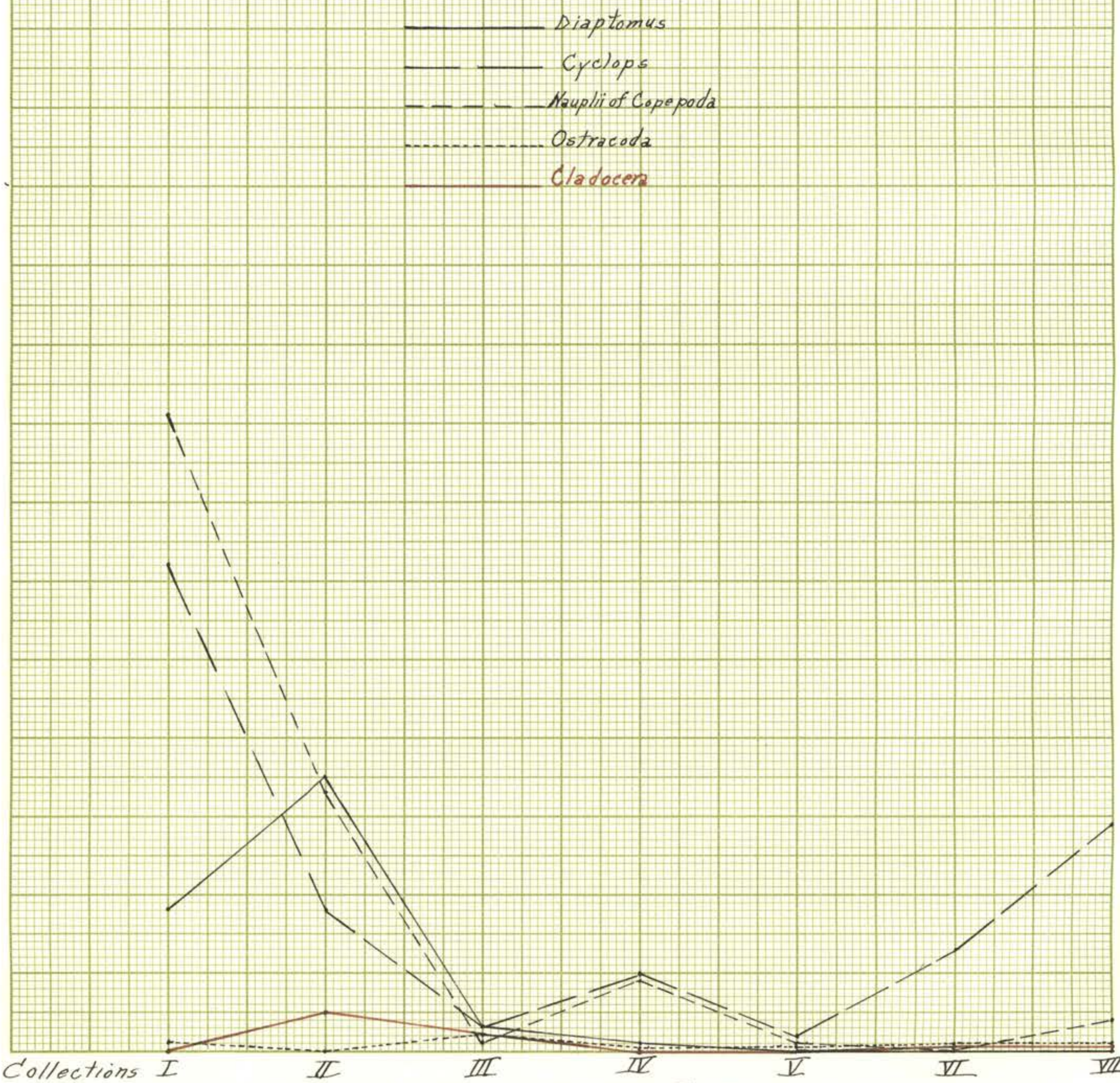
Wright, S. 1936. Thermal conditions in some waters of Northeast Brazil. Annaes da Academia Brasileira de Sciencias 8(3):164-173.

_________ 1937. Chemical conditions in some waters of Northeast Brazil. Annaes da Academia Brazileira de Sciencias 9(4):278-305.

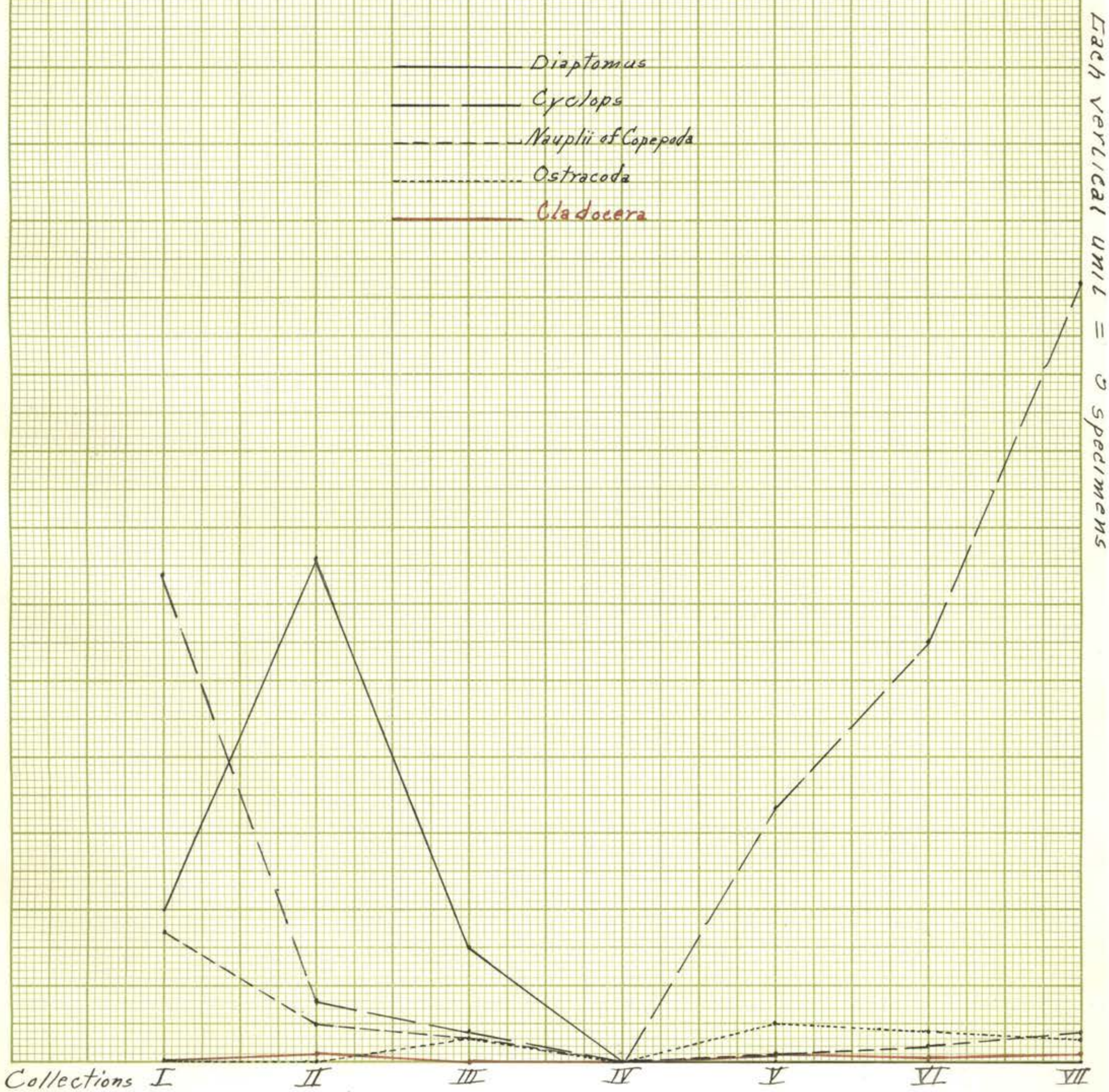
Wright, S. and Tidd, W. 1933. Summary of limnological investigations in western Lake Erie in 1929 and 1930. Trans. Amer. Fish. Soc. 63:272-285.

1938

Date	June 15	June 20	June 27	July 5	July 13	July 18	July 25
Temperature -	34°	37.5°	29°	32°	36°	29°	33.5°
pH	6.6	6.4	7.2	7.1	7.2	7.2	7.2
Secchi disc R -	11cm.	9cm.	15cm.	12cm.	17cm.	15.5cm.	15cm.
Wind -	Slight S.	Gentle S.E.	Moderate E.	Strong S.	Gentle S.E.	Moderate N.E.	Moderate S.W.
Light -	Poor (Cloudy)	Moderate (Cloudy)	Poor (Cloudy)	Bright (Sunshine)	Bright (Sunshine)	Bright (Sunshine)	Bright (Sunshine)

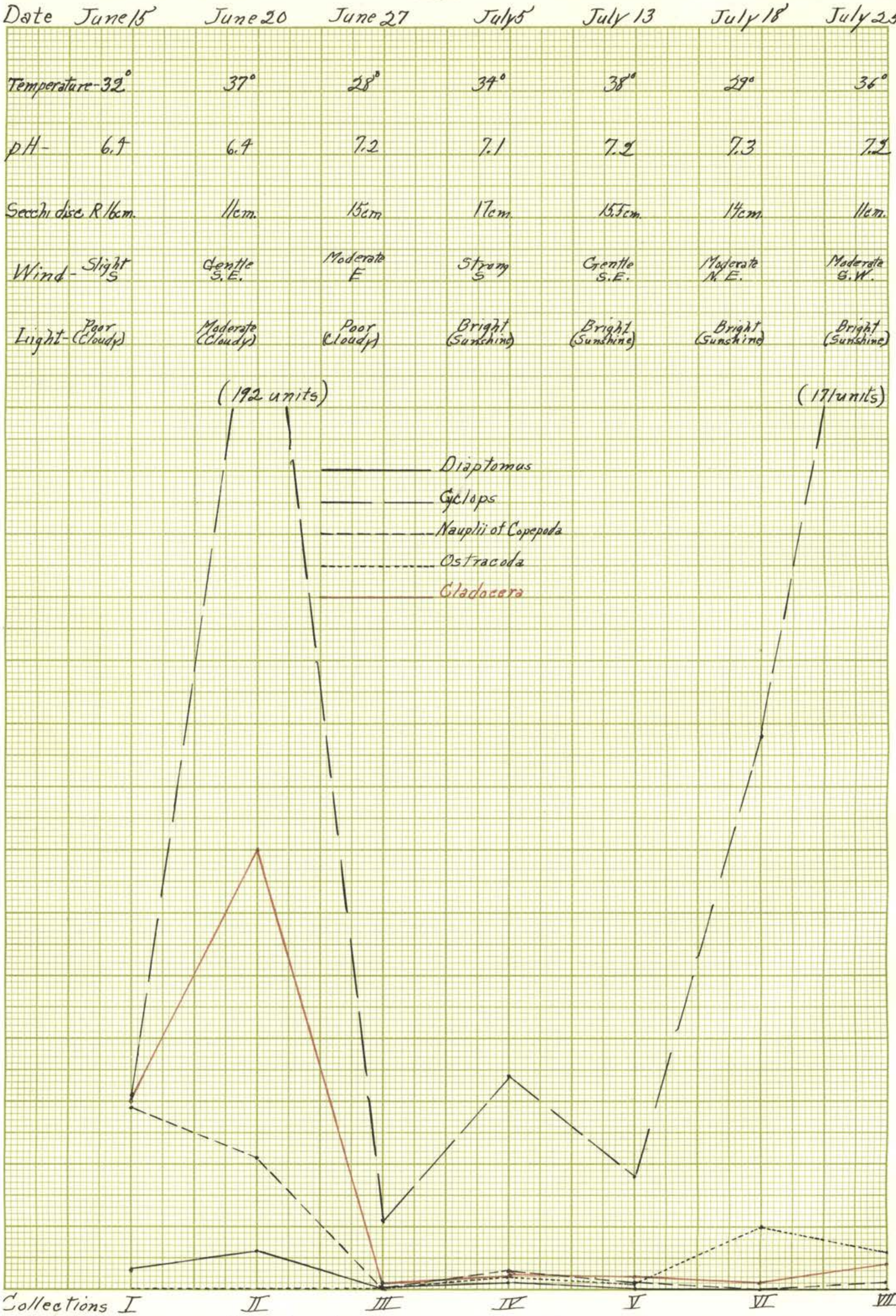


Date	June 15	June 20	June 27	July 5	July 13	July 18	July 25
Temperature	27°	26°	25°	29°	29°	29°	30°
pH	6.6	6.4	7.2	7.1	7.2	7.2	7.2
Secchi disc R.	11cm.	9cm.	15cm.	12cm.	17cm.	15.5cm.	15cm.
Wind	Slight S	Gentle S.E.	Moderate E	Strong S	Gentle S.E.	Moderate N.E.	Moderate S.W.
Light	Poor (Cloudy)	Moderate (Cloudy)	Poor (Cloudy)	Bright (Sunshine)	Bright (Sunshine)	Bright (Sunshine)	Bright (Sunshine)
Depth	2ft.	2.5ft.	2.5ft	25in.	23in	22in	20in.

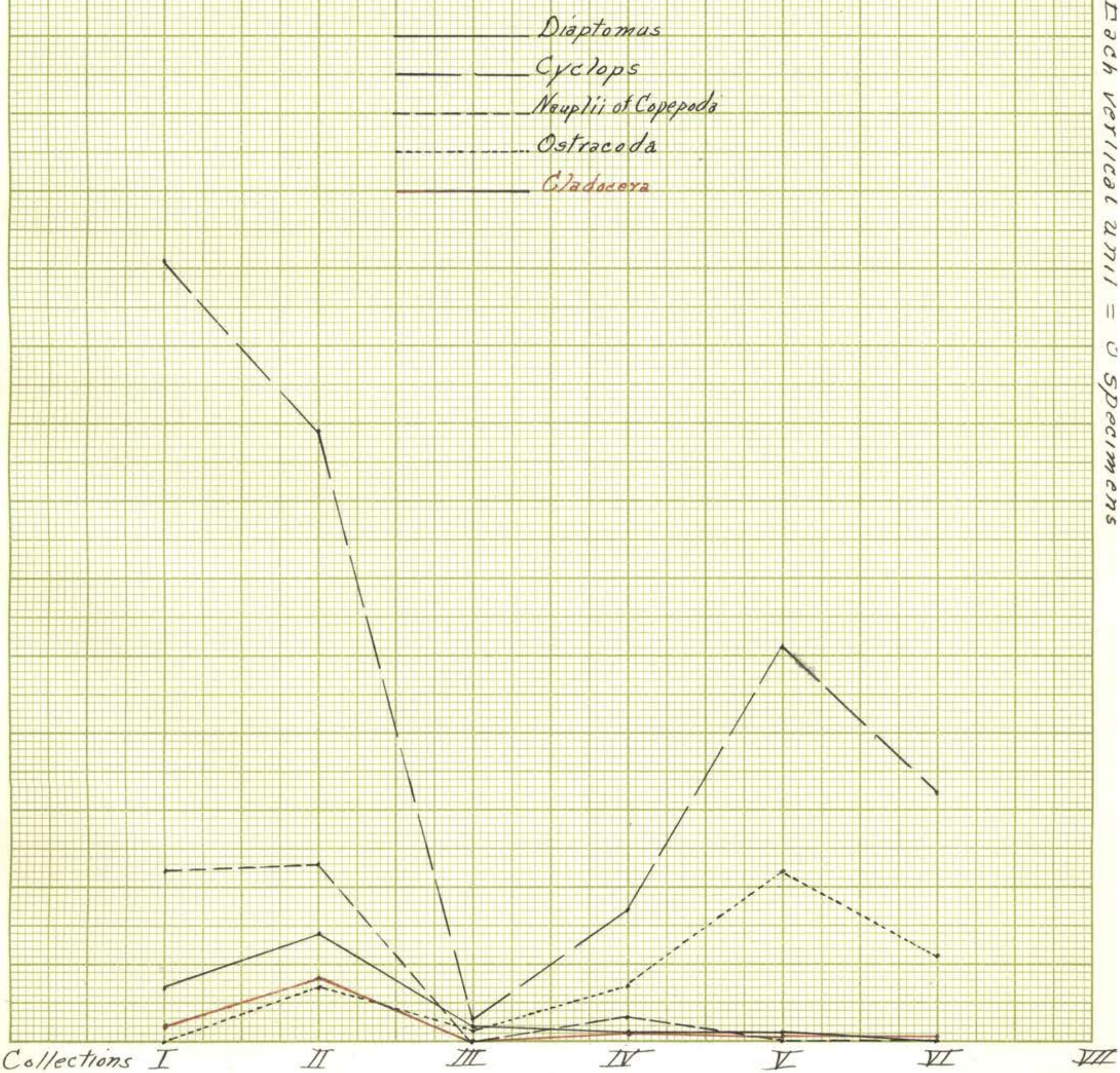


Date	June 15	June 20	June 27	July 5	July 13	July 18	July 25
Temperature	33°	37°	28°	32°	36°	29°	33°
pH	6.6	6.4	7.2	7.1	7.3	7.1	7.4
Secchi disc R	15cm.	12cm	13cm	12cm.	19cm	14.5cm.	17cm.
Wind	Slight S	Gentle S.E.	Moderate E	Strong S	Gentle S.E.	Moderate N.E	Moderate S.W.
Light	Poor (Cloudy)	Moderate (Cloudy)	Poor (Cloudy)	Bright (Sunshine)	Bright (Sunshine)	Bright (Sunshine)	Bright (Sunshine)

Date	June 15	June 20	June 27	July 5	July 13	July 18	July 25
Temperature	26°	25°	25°	28°	29°	27°	29°
pH	6.6	6.4	7.2	7.1	7.3	7.1	7.4
Secchi disc R	15cm.	12cm	13cm	12cm.	19cm.	14.5cm.	17cm.
Wind-	Slight S	Gentle S.E.	Moderate E	Strong S	Gentle S.E.	Moderate N.E.	Moderate S.W.
Light-	Poor (cloudy)	Moderate (Cloudy)	Poor (Cloudy)	Bright (Sunshine)	Bright (Sunshine)	Bright (Sunshine)	Bright (Sunshine)
Depth	25 ft.	34 in.	33 in.	29 in	26 in	23 in.	20 in.


Date June 15 June 20 June 27 July 5 July 13 July 18 July 25
Temperature- 32° 37° 28° 34° 38° 29° 36°
pH- 6.4 6.4 7.2 7.1 7.2 7.3 7.2
Secchi disc R 16cm. 11cm. 15cm 17cm. 15.5cm. 14cm. 11cm.
Wind- Slight S Gentle S.E. Moderate E Strong S Gentle S.E. Moderate N.E. Moderate S.W.
Light- Poor (Cloudy) Moderate (Cloudy) Poor (Cloudy) Bright (Sunshine) Bright (Sunshine) Bright (Sunshine) Bright (Sunshine)
(192 units)
(171 units)
Diaptomus
Cyclops
Nauplii of Copepoda
Ostracoda
Cladocera
Collections I II III IV V VI VII

Date	June 15	June 20	June 27	July 5	July 13	July 18	July 25
Temperature	29°	25°	28°	30.5°	32°	28°	35°
pH	6.4	6.4	7.2	7.1	7.2	7.3	7.2
Secchi disc R.	16cm.	11cm.	15cm.	12cm.	15.5cm.	14cm.	11cm.
Wind	Slight S	Gentle S.E.	Moderate E	Strong S	Gentle S.E.	Moderate N.E.	Moderate S.W.
Light	Poor (Cloudy)	Moderate (Cloudy)	Poor (Cloudy)	Bright (Sunshine)	Bright (Sunshine)	Bright (Sunshine)	Bright (Sunshine)
Depth	1.5ft	20in	18in	15in	11in.	9in.	8in

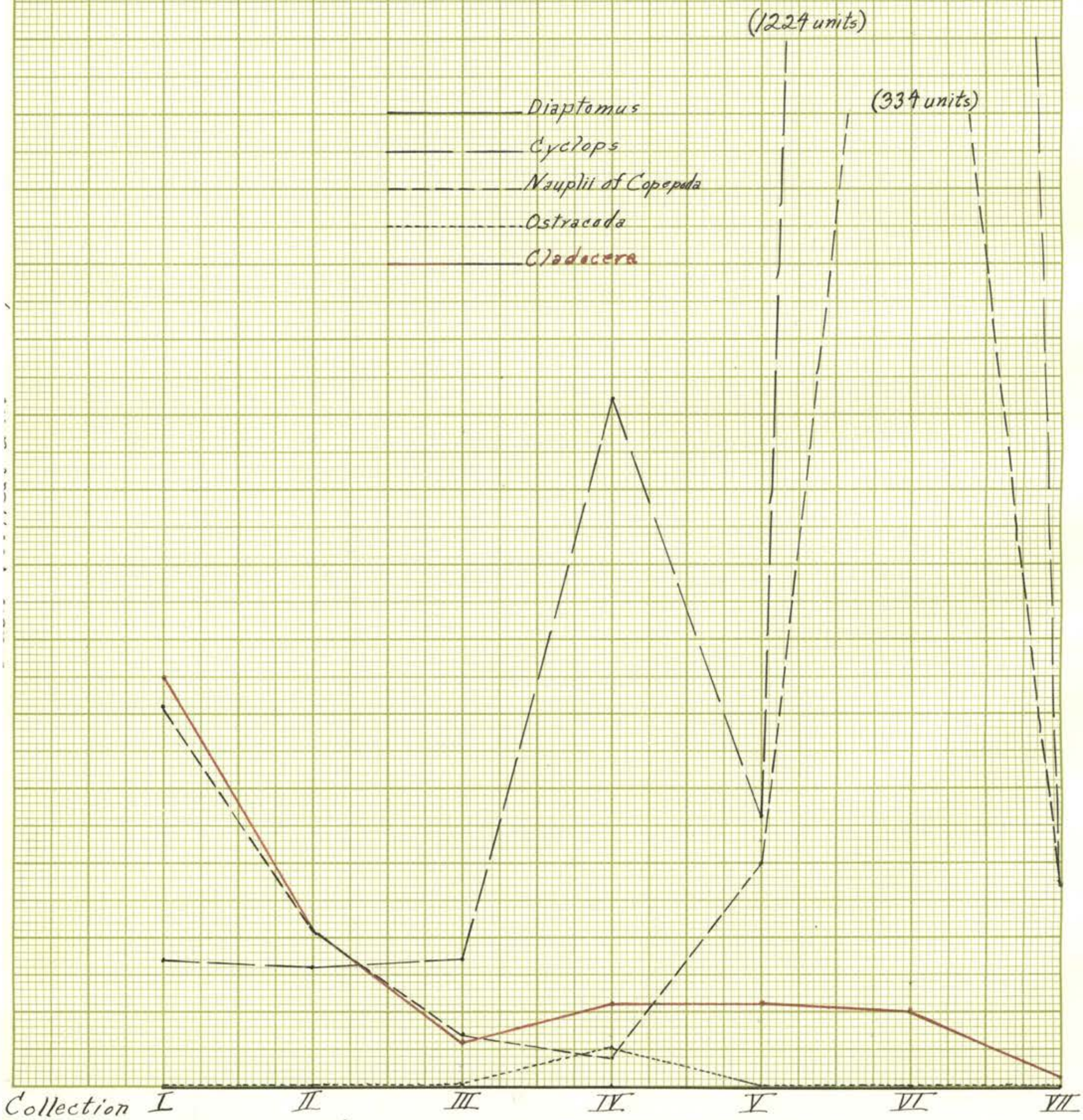


1938

Date	June 15	June 20	June 27	July 5	July 13	July 18	July 25
Temperature	32°	35.5°	27°	33.5°	38°	29°	38°
pH	6.2	6.4	7.2	7.1	7	7	7.2
Secchi disc R	14cm.	13cm.	14.5cm	17cm.	Too shallow	Too shallow	Too shallow
Wind	Slight S	Gentle S.E.	Moderate E	Strong S	Gentle S.E.	Moderate N.E.	Moderate S.W.
Light	Poor (Cloudy)	Moderate (Cloudy)	Poor (Cloudy)	Bright (Sunshine)	Bright (Sunshine)	Bright (Sunshine)	Bright (Sunshine)

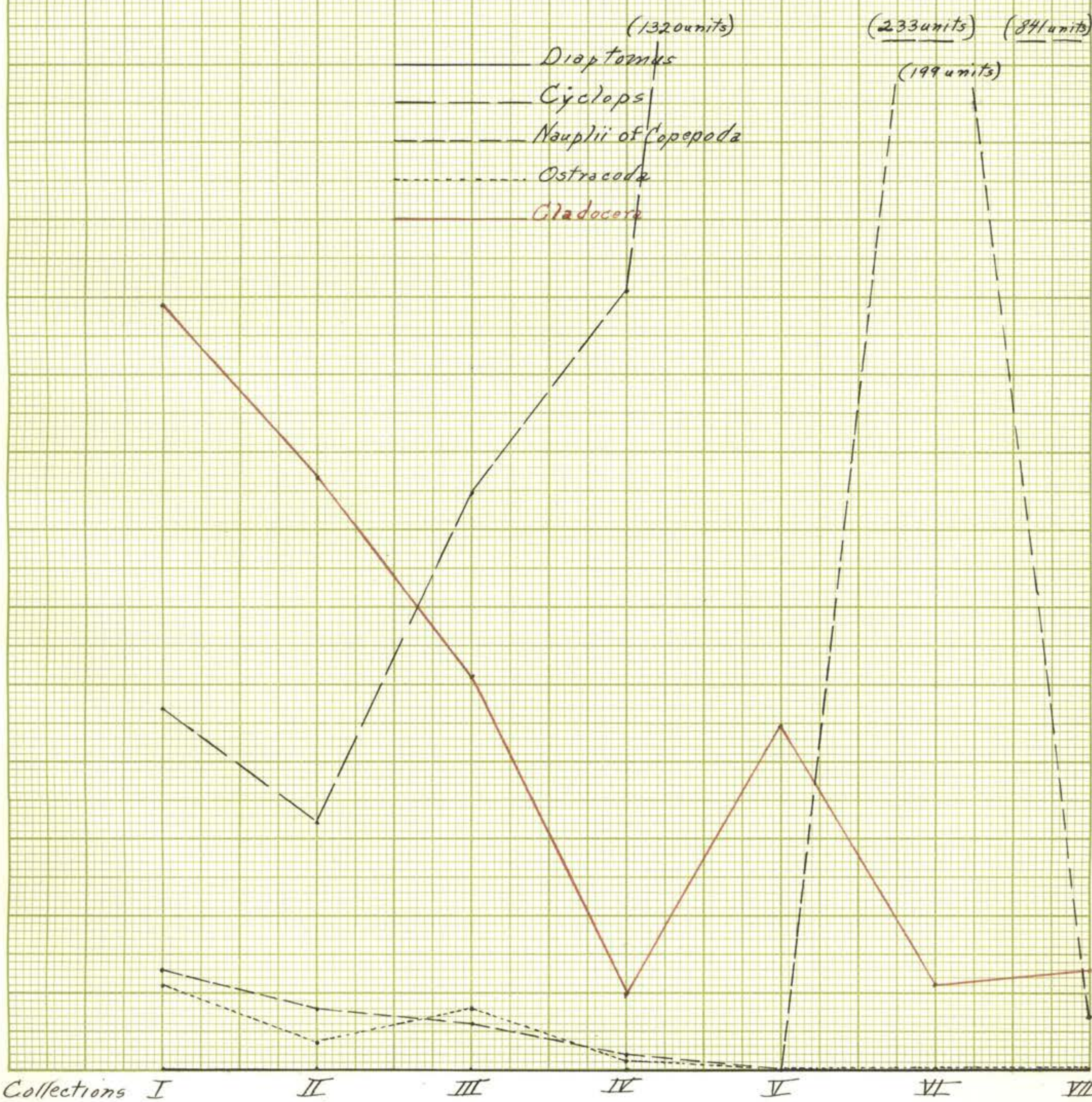
Date	June 15	June 20	June 27	July 5	July 13	July 18	July 25
Temperature	29°	31°	25.5°	31.5°	37°	28.5°	37.5°
pH	6.2	6.4	7.2	7.1	7	7	7.2
Secchi disc	R-14cm	13cm	14.5cm.	17cm.	Too shallow	Too shallow	Too shallow
Wind	Slight S	Gentle S.E.	Moderate E	Strong S	Gentle S.E.	Moderate N.E.	Moderate S.W.
Light	Poor (Cloudy)	Moderate (Cloudy)	Poor (Cloudy)	Bright (Sunshine)	Bright (Sunshine)	Bright (Sunshine)	Bright (Sunshine)
Depth	12in.	13in.	11in.	9in.	5.5in.	4in.	5in.

Date	June 10	June 19	June 26	July 3	July 10	July 17	July 25
Temperature	28.5°	28.5°	28°	26.5°	29.5°	27.5°	34°
pH	7.9	8	7.2	6.8	7.4	7.4	7.6
Turbidity	Less 25 P.P.M.	Less 25 P.P.M.	45 P.P.M.	90 P.P.M.	Less 25 P.P.M.	32 P.P.M.	Less 15 P.P.M.
Wind	Moderate W	Moderate S.E.	Moderate S	Moderate S	Strong N.E.	Strong S	Moderate S.E.
Light	Moderate (Cloudy)	Moderate (Cloudy)	Moderate (Cloudy)	Bright (Sunshine)	Bright (Sunshine)	Bright (Sunshine)	Bright (Sunshine)



1737

Date	June 10	June 19	June 26	July 3	July 10	July 17	July 25
Temperature	28.5°	27.5°	26°	26°	29.2°	27.5°	34
pH	7.9	8	7.2	6.8	7.4	7.4	7.6
Turbidity	Less 25 P.P.M.	Less 25 P.P.M.	45 P.P.M.	90 P.P.M.	Less 25 P.P.M.	32 P.P.M.	Less 25 P.P.M.
Wind	Moderate W	Moderate S.E.	Moderate S	Moderate S	Strong N.E.	Strong N.E.	Moderate S.E.
Light	Moderate (Cloudy)	Moderate (Cloudy)	Moderate (cloudy)	Bright (Sunshine)	Bright (Sunshine)	Bright (Sunshine)	Bright (Sunshine)
Depth	30 in.	2 ft.	2 ft.	3.5 ft	2.5 ft	2.5 ft	2.5 ft



Graph No. 10 Station I Deep

Date	June 10	June 19	June 26	July 3	July 10	July 17	July 25
Temperature	29°	28.6°	28.2°	28°	30°	28.5°	34
pH	7.9	7.8	7.2	6.9	7.2	7.4	7.6
Turbidity	Less 25 P.P.M.	Less 25 P.P.M.	45 P.P.M.	95 P.P.M.	Less 25 P.P.M.	35 P.P.M.	Less 25 P.P.M.
Wind	Moderate W	Moderate S.E.	Moderate S	Moderate S	Strong N.E.	Strong S	Moderate S.E.
Light	Moderate (Cloudy)	Moderate (Cloudy)	Moderate (Cloudy)	Bright (Sunshine)	Bright (Sunshine)	Bright (Sunshine)	Bright (Sunshine)