LIMNOLOGICAL STUDIES OF BUCKEYE LAKE, OHIO[1]

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The State of Ohio contains only a few small lakes and of these, one of the most important from a fishing and recreational standpoint is Buckeye Lake, located approximately thirty miles east of Columbus. In the summer of 1930 the Division of Conservation of Ohio sponsored and financed an intensive study of this lake under the direction of Mr. E. L. Wickliff, Chief of the Bureau of Scientific Research. The following account deals with the chemical, physical and hydrographical features of the lake and with its contained microscopic life. Investigations were carried out during the period between June tenth and September tenth, 1930. The senior author is responsible for the collection of plankton samples and for the chemical, physical and zooplankton parts, the second author determined the phytoplankton and the junior author the bottom organisms. Samples of bottom organisms were collected by Mr. Lewis Roberts while the zooplankton counts were made by Mrs. E. C. Tressler, who also assisted in the routine work of the laboratory. Dr. E. B. Ruth and Mr. Wilbur Titterington assisted with the identification of bottom organisms. The authors wish to acknowledge with appreciation the assistance of Mr. David Wickliff who greatly furthered the work of the laboratory by his interest in the investigations and in the loan of boats and equipment.

THE LAKE

Detmers (1912) gives the following description of the location of Buckeye Lake: "Buckeye Lake is situated in Licking, Fairfield and Perry counties in ranges 17 and 18, townships 17, 18, and 19. It is a long irregular body of water with its longest

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diameter from east to west extending from 82° 25′ 27″ to 82° 31′ 12″ west longitude, approximately 7⅛ miles from east to west and varying in width from one fourth mile in the eastern portion to a mile and one half at the extreme western end and covering an original estimated area of 4,200 acres (1,700 hectares). Originally used as a reservoir for the Ohio Canal, on May 21, 1894, the General Assembly of Ohio passed an act reserving the reservoir for a public park and summer resort known as Buckeye Lake.

"The site of the lake was a more or less completely tree-covered, impassable swamp. It lay diagonally across the southeast corner of township 17 and almost half across the southern border of township 19. In the center of this area was a long, narrow lake fed by several small streams of which the largest were Buckeye and Honey creeks. The lake drained into the south fork of the Licking River."

The drainage belongs to two systems, the Licking-Muskingum and the Scioto River systems. The principal streams feeding the lake are Buckeye and Honey creeks and the southwest feeder, although there are numerous smaller streams. The main outlet is the overflow near Buckeye Park.

Buckeye Lake has a maximum depth of seven meters and a mean depth of two and a half meters. In only two places does the maximum depth exceed four meters and these are of very limited area. The bottom is, with few exceptions, of a muddy character, although in some places where dredging has been recently done, there are some sand and gravel. The whole lower, eastern portion ends in a large swamp area through which a channel has been dredged to Thornport. There are also large areas of swamp in Honey Creek, Buckeye and Maple Swamp sanctuaries (see Figure 1, which gives the principal weeded and swampy areas). Extending from Seller's Point to Onion Island is the remains of the old tow path, the middle wall of which comes to within half a meter or less of the surface. Winds which sweep down the lake at times cause large waves which thoroughly stir up the entire lake and aid in keeping the water turbid.

METHODS

Weekly readings were made at two stations on the lake, one at a spot directly in front of the laboratory (station 1) where the water was between 2½ and 3½ meters deep, another in the

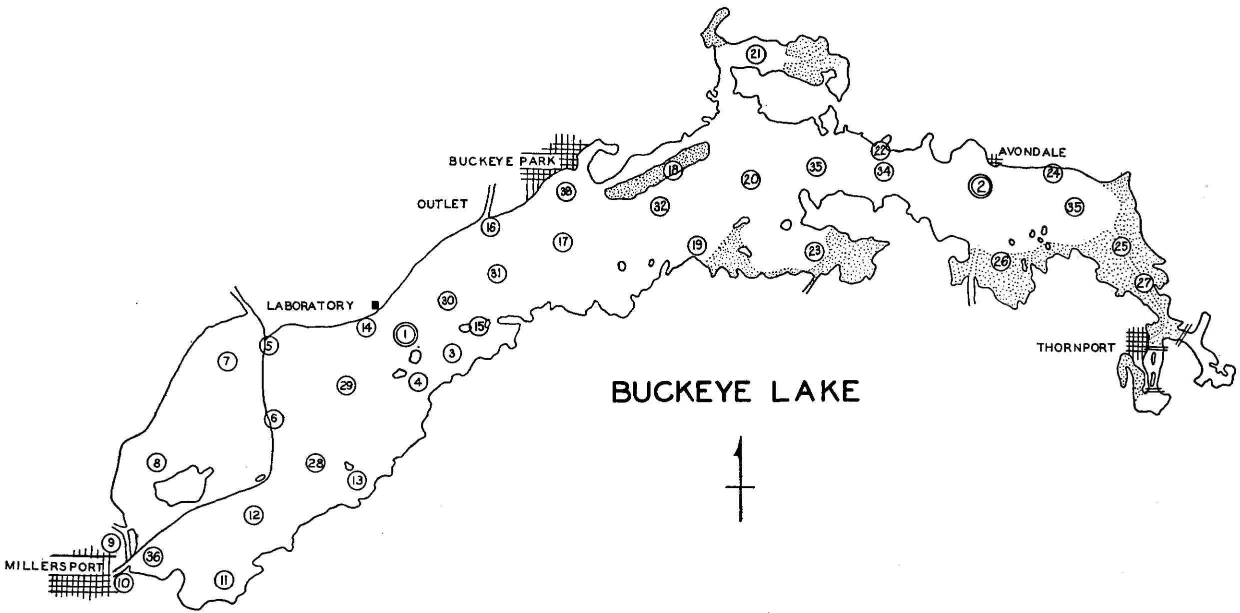

Fig. 1. Map of Buckeye Lake.

deep area off Avondale at the eastern end of the lake (station 2) where five to six meters could be counted on. At station 2, samples were taken at the surface and near the bottom as well but at all other stations surface samples only were secured. Surface samples were taken at a depth of between fifteen and twenty-five cm. Other stations at various points on the lake are shown in Figure 1. Horizontal variation in plankton and environmental factors was investigated on two occasions and a twenty-four-hour series was made to determine diurnal variation.

Temperatures were taken with a Negretti-Zambra deep-sea reversing thermometer and transparency by means of a 10 cm. Secchi disc. Color determinations were made with the standard platinum cobalt solution as recommended by the American Public Health Association (1925). Silica was determined according to Atkin's modification (1923) of the method of Dienert and Wandenbulke (1923) and phosphorus by Atkin's method (1923). Other chemical procedures followed methods recommended by the American Public Health Association (1925) or by Birge and Juday (1911). Water samples for chemical analysis and for plankton were obtained by means of a Kemmerer-Foerst water sampler. One liter of water was centrifuged with a Foerst centrifuge and the plankton obtained was made up to 20 cc. for phytoplankton counting. Duplicate samples of one liter each were also centrifuged and particulate organic matter determined by loss on ignition. Three liter samples of lake water were evaporated to determine the total amount of dry residue. A ten-liter Juday-Foerst plankton trap was used to collect zooplankton and an Eckman dredge 20 cm. by 20 cm. was employed in the collection of bottom samples.

RESULTS OF PHYSICAL MEASUREMENTS

Temperature.—Temperatures at station 1 are shown in Figure 2. The temperature of the water rose steadily as the summer progressed until a maximum was reached about the last of July or the first of August. In Figure 2, air temperatures are shown by the wavy line superimposed on the water temperature curve. These temperatures represent the approximate daily maximum air temperature at the laboratory. It will be noted that while the temperature of the water followed the general trend of the air temperature, there were no sudden changes. A maximum of 29.0° C. was observed on August 5, at station 1. The maximum at station 2, at the eastern end of the lake, was 28.6° C. which occurred on July 29. At station 19, on July 30, a maximum of 30.2° C. was noticed, while on July 12, at 4 p. m. three inches below the surface at a spot about 30 meters off the laboratory, a maximum temperature of 31.0° C. (88° F.) was recorded. The temperature probably reached somewhat higher figures but these were the maxima recorded. The minimum temperature at station 2 was 20.4° C. which occurred on August 26, while the minimum at station 1 was 21.1° C. on August 22. The surface water was considerably cooler at the extreme eastern end of the lake in the channel between the marsh areas. On July 17, at station 27, a temperature of 21.0° C. was noted, which was over six degrees lower than the temperature taken a few minutes later at station 24 in the open waters of the lake where the temperature was 27.6° C. These low temperatures were correlated with high transparency and were possibly due to the protection given by

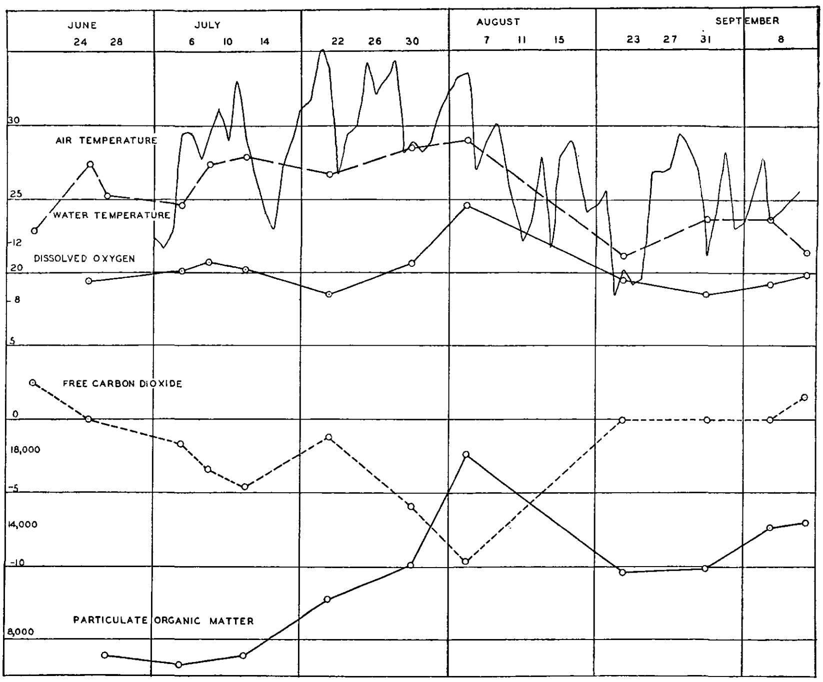

Fig. 2. Summer fluctuations of physical and chemical factors and particulate organic matter at station 1. Temperatures are shown in degrees Centigrade, chemical factors in parts per million, organic matter in milligrams per cubic meter.

the rooted aquatics both from the sun and from wave action and stirring up of bottom water.

In general the temperatures at the eastern station followed those taken at station 1. The maxima and minima occurred at about the same time, although minor fluctuations did not always agree. The maximum amount of vertical stratification in temperature was noticed on June 14, at station 2, where the surface water showed a temperature of 25.6° C., while the water at 6.25 meters depth was 18.6° C.

Transparency.—The waters of Buckeye Lake are of very low transparency. The maximum reading taken with the Secchi disc was only

0.75 meters at station 1. The readings at station 2 were always lower than at station 1 and both stations showed a decline in transparency as the summer progressed, station 1 declining to a transparency of 0.3 meters by the end of the summer. When it is considered that an ordinary lake will show transparencies of from three to 10 meters or more and that the maximum transparency recorded for a lake amounts to 41 meters (Lake Masyuko in Japan), the extremely low transparency of Buckeye Lake may be appreciated. Lakes which are on the average much shallower than Buckeye often have transparencies of from 1 to 3 meters. The low transparency in Buckeye Lake is due to several factors: the enormous phytoplankton crop during the summer, the action of the wind in stirring up the bottom sediments and the amount of organic matter present in the water. On standing for two or three days, the lake water would clear up remarkably, the supernatant liquid showing little color, so that this factor was not important in this instance. In the swamp areas, where the wind had little effect, the readings were considerably higher. At station 27, transparency reached a maximum of 1.75 meters but as this was also the depth of the water at this place, the transparency was undoubtedly considerably greater, since the disc could be clearly seen on the bottom. In the lake itself, these figures were never approached.

Color.—The color of the water after filtering (true color) was about 25 on the platinum-cobalt scale. This is not at all high; many lakes in northern Wisconsin will show colors as high as 200 or 300 units on this scale. The absence of bog waters or of inflow from such regions accounts for the low color of the water of Buckeye Lake.

RESULTS OF CHEMICAL ANALYSIS

Dissolved Oxygen.—The seasonal variation of dissolved oxygen at station 1 is shown in Figure 2. In most lakes, oxygen becomes reduced during the summer months due to the inability of water of higher temperature to hold as much gas in solution. In Buckeye Lake, however, oxygen increased with the increase in temperature and its maximum amount coincided with the period of maximum temperature. This unusual condition was due to the enormous crop of phytoplankton which increased to a maximum at the same time. The greatest amount of dissolved oxygen recorded during the summer was found at station 1 (14.6 p.p.m. on August 5, 188% saturation). The highest figure for station 2 was 12.8 p.p.m. on August 26. On August 26, station 2 also showed the high figure of 11.6 p.p.m. (148% saturation). The minimum oxygen tension observed at station 2 occurred on July 29, at a depth of 5 meters. Here only 1.9 p.p.m. was present, due to decomposition of bottom debris. The bottom waters were never completely saturated during the summer at this station and were usually between 50% and 75% saturated. On July 29, the bottom water was only 23% saturated. In a bog hole on Cranberry Island, the lowest oxygen tension was recorded (1.4 p.p.m., or 15% saturation).

Carbon Dioxide.—Figure 2 indicates summer variation of free carbon dioxide at station 1. Station 2 showed essentially the same changes. Station 1, however, had a much more even curve than station 2, due to the fact that at station 2 carbon dioxide was constantly replaced by decomposition in the deep hole. High winds mixed the lake from surface to bottom, thus bringing up the accumulated carbon dioxide from the deep hole. For this reason free carbon dioxide was observed at the surface at station 2 as late as July 22, while none was observed during the months of July or August at station 1. The times of minimum free carbon dioxide will be noted to have occurred at the same period as maxima for temperature, oxygen and organic matter. The activity of the lake was at its height at this time in early August. On August 5, the greatest deficiency of free carbon dioxide observed anywhere on the lake occurred at station 1 (9.7 p.p.m.). (That is to say, 9.7 p.p.m. of carbon dioxide would be required to make the water neutral to phenolphthalein). On August 27, a maximum amount of 31.0 p.p.m. was noted in the bog hole on Cranberry Island. The maximum amount observed in the lake itself was at station 2, at 5 meters on August 26, (9.0 p.p.m.).

Fixed carbon dioxide, determined as methyl orange alkalinity, showed some increase as the summer progressed (from 87.2 p.p.m. on June 19, to 95.5 p.p.m. on September 10, at station 1). Station 2 showed an increase of about the same order of magnitude (86.3 on June 28, to 96.5 on August 6). These figures show the waters of Buckeye Lake to be "hard" and largely account for the superabundance of phytoplankton forms.

Hydrogen Ion.—The pH in a general way varied inversely as the free carbon dioxide. The neutral point for free carbon dioxide, however, did not agree very closely with the pH value at the same time, due to the presence of buffers in the water which prevent any sudden change in the pH. The maximum pH observed for the lake was 8.9 on August 5, at station 1. The lowest pH recorded in the lake was 7.3 on July 6, and August 26, at a depth of 5 meters at station 2. Station 1 varied between pH 8.2 and pH 8.9 during the summer. On August 27, at the Cranberry Island bog hole, a pH of 6.8 was recorded. Dachnowski (1939) recorded a minimum pH of 4.0 for certain parts of this bog.

Chlorides.—Determinations of chlorides were made during most of the summer but only a trace was ever observed when correction for the blank on the reagents had been made. This lack of chlorides is due to the freedom from pollution which Buckeye Lake enjoys, a fact also borne out by the low nitrite nitrogen figures.

Nitrogen.[2] Free ammonia nitrogen was present to a maximum amount of 0.146 p.p.m. observed on July 30, at 5 meters at station 2. The remainder of the determinations showed figures ranging from a trace to 0.130 p.p.m., the latter amount occurring in one of the sanctuaries. Ammonia steadily decreased throughout the summer. The same decrease was noted in a shallow Wisconsin lake (Tressler and Domogalla, 1931) and is probably due to the increase in the activity of the denitrifying bacteria in the warmer water. In Buckeye Lake,

[2]The determinations of nitrogen, silica and phosphorus were made by Mr. Harold M. Whitacre to whom acknowledgement is hereby made.

ammonia nitrogen had fallen to 0.006 p.p.m. at stations 1 and 2, while at other stations only a trace remained.

Tests for nitrite nitrogen were made from time to time but indicated either none at all or a trace, which shows the lake to be largely free from sewage pollution.

Organic nitrogen increased somewhat throughout the summer due to the increasing amount of plant material in the lake. On June 26, the surface waters showed 0.470 p.p.m. of organic nitrogen, while on August 21, this had increased to 0.704 p.p.m. Nitrates showed the result of large amounts of plant material in the lake which use up this form of nitrogen. Amounts ranged from somewhat greater than 1.00 p.p.m. to 0.050 p.p.m. The lower figures were observed toward the end of the summer.

Silica.—Dissolved silica in the water ranged from 1.6 p.p.m. to 8.0 p.p.m. Dissolved silica is low in summer due to its utilization by the diatoms in building their shells (Birge and Juday, 1911). There was little rainfall during the summer to add to the amount of silica and this also tended to keep the amount low (Pearsall, 1923).

Phosphorus.—A few determinations of soluble phosphorus showed results ranging from a trace to 0.400 p.p.m., the high amount occurring in one of the sanctuaries. The surface waters of the lake gave an average soluble phosphorus content of about 0.030 p.p.m. The data are insufficient to draw any conclusions as to the summer variation, although determinations made when the activity of the lake was at its height, showed higher figures for both stations 1 and 2 than later in August. The great numbers of plant organisms evidently caused this depletion.

THE ZOOPLANKTON

Ten liters of water collected with a Juday-Foerst plankton trap were reduced to 20 cc. and two 1 cc. samples were counted for zooplankton forms. Results were expressed as the number of organisms per cubic meter.

Buckeye Lake does not support a great variety of zooplankton forms; only seventeen species belonging to sixteen genera were found during the summer. Of these there were two species of copepods, nine of Cladocera and six rotifers. The complete list of species identified during the summer of 1930 is given below.

Copepoda

Cyclops viridis americanus Jurine
Ergasilus versicolor Wilson

Cladocera

Alona quadrangularis (Müller)
Bosmina longirostris (Müller)
Camptocercus rectirostris Schoedler
Ceriodaphnia sp.
Chydorus sphaericus (Müller)
Daphnia retrocurva Forbes
Daphnia sp.
Leptodora kindtii (Focke)
Pseudosida bidentata Herrick
Sida crystallina (Müller)

Rotifera

Brachionus bakerii Ehrenberg
Conochilus sp.
Diglena sp.
Polyarthra trigla Ehrenberg
Rattulus styalatus (Gosse)
Synchaeta sp.

Miscellaneous

Cypria dentifera Sharpe
Hyalella sp.

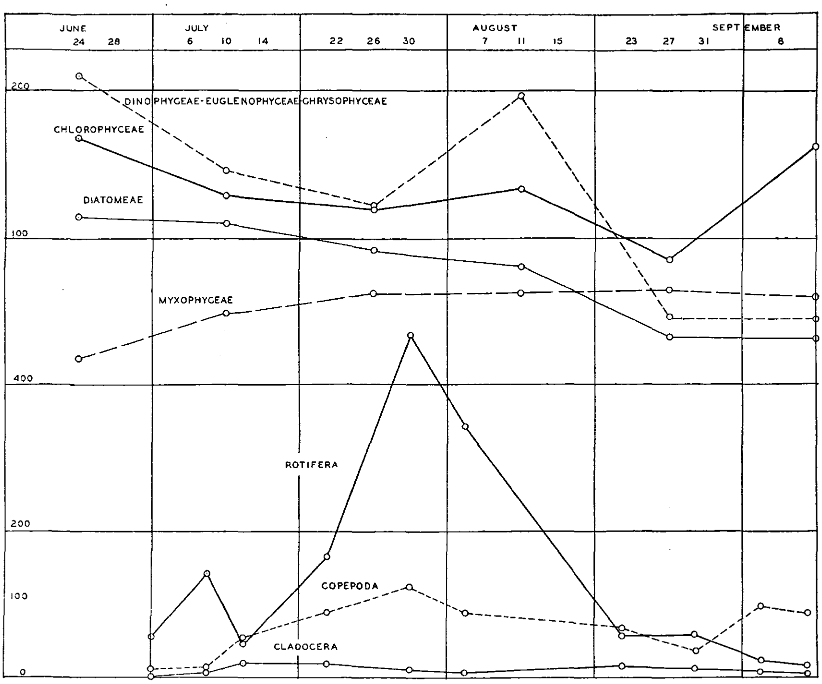

Fig. 3. Summer fluctuations of plankton groups. Phytoplankton is shown as the average number of organisms, in thousands per liter, during each of the two-weeks periods; zooplankton as the average number of organisms per liter.

Summer Fluctuations.—Figure 3 indicates the summer distribution of the various groups of zooplankton at station 1. It will be noted that the time of maximum abundance of the copepods and rotifers was during the midsummer slightly before the period of maximum activity of the lake. Cladocera were never very abundant at any time and appeared in greatest numbers about the middle of July. At station 2 the Cladocera showed very slight fluctuations during the summer. In the weedy areas of the lake there were large numbers of cladocerans but these were forms restricted to such environments and were never found in the limnetic region. The most abundant limnetic cladoceran was

Pseudosida, the summer distribution of which is shown in Figure 4. This cladoceran never exceeded 20,000 individuals per cubic meter. Immature Cladocera were found during the early part of the summer but disappeared after the first week in August from the samples at station 1. The large form, *Leptodora kindtii* was very abundant at the first part of the summer but was seldom taken in the counts, due in all probability to its ability to see and avoid the trap and smaller tow nets. A tow made with a meter net in July showed a pure culture of this large cladoceran in large numbers. The only abundant copepod was *Cyclops*, which was present in fairly large numbers during the entire summer and reached a maximum at one meter depth on August 6, at station 2 (196,000 per cubic meter). At station 1 *Cyclops* had maxima on July 21, (60,000 per cubic meter) and on September 10 (68,000 per cubic meter). Nauplii were found throughout the entire summer in considerable abundance. At station 2, nauplii reached their maximum on September 4, (132,000 per cubic meter) and had shown a steady increase in numbers from the beginning of the summer. At station 1 they were most abundant during July and showed no regular increase during the summer. Of the rotifers, by far the most abundant was *Brachionus bakerii*, which reached a maximum at station 1 on July 30, of 578,000 per cubic meter and was present in large numbers during the entire summer. The summer distribution of some of the other rotifers which were more or less abundant is shown in Figure 4.

Vertical Distribution.—Buckeye Lake is so shallow, even at the deepest part off Avondale, that vertical distribution of zooplankton is of very little significance. There is no thermocline to effect distribution and conditions, except in the case of light, are very much alike from surface to bottom. On rough days one expects to find few animals at or near the surface and the same is true on very bright days. At station 2, the greatest number of organisms occurred at 1 meter depth at all times during the summer with two exceptions, on July 14, which was a cloudy day, the number at the surface exceeded those at 1 meter. On August 18, however, there were more organisms at the surface on a clear sunny day. No explanation is offered for this anomaly of distribution. At station 1, with the exception of the first few observations in July, there were always more copepods at the 3 meter level than at 1 meter. The total number of organisms at station 1, was at most times greater at 1 meter than near the bottom, due to the greater proportion of rotifers in the upper layers.

Horizontal Distribution.—On July 28, a clear sunny day, with no wind, a series of fifteen stations were sampled starting at the western end of the lake and continuing to the eastern end. These samples were taken with the trap at a depth of ¾ meters and between the hours of ten a. m. and noon, so as to avoid differing light intensities. The results indicated a very uneven distribution of organisms, as has been shown on other lakes. Swarming, wind action and other factors play a part in this unequal horizontal distribution of the plankton. Small lakes, with even bottom contours, have been shown to show a fairly regular horizontal distribution of plankton. Buckeye Lake, however, has many islands and is of irregular shape.

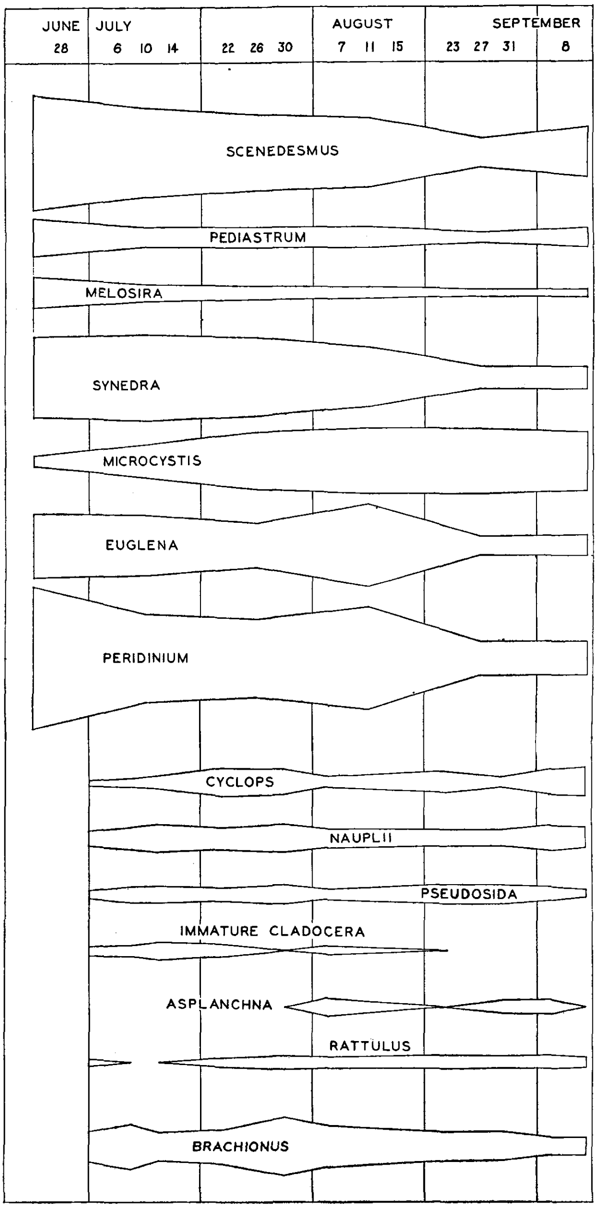

Fig. 4. Summer fluctuations of some of the more abundant genera of plankton organisms. Phytoplankton is shown as the average number of organisms per liter during each of the two-weeks periods; zooplankton as the average number of organisms per cubic meter.

PHYTOPLANKTON

A liter sample of water was collected in the Kemmerer-Foerst water sampler and run through a Foerst centrifuge to obtain the smaller organisms. Each centrifuged sample of plankton was made up to a constant volume (usually 20 cc.). After thorough shaking and mixing of the contents of the sample, one cubic centimeter of the material was withdrawn by a pipette and transferred to a Sedgwick-Rafter cell for counting. Ten random counts from each of two transfers from the sample were made, thus securing twenty counts for each liter sample. The number of algal organisms per liter of sample was then computed and recorded.

A number of stations were established for the survey from which collections were made regularly in some cases and intermittently in others.

In order to be able to make numerical comparisons among numbers of organisms counted, it is necessary to select some standard units. At best, these units can be only approximate in their comparative value and to a certain extent must be arbitrarily chosen. Perhaps some approximation on the basis of gross size furnishes a fairly usable unit. It is almost impossible to make comparisons with the data secured by other workers in cases where no mention is made of the kind of unit used in counting. In this report each unicellular alga is counted as one, regardless of size. Rather definite colonies, such as *Pediastrum*, *Scenedesmus* (4-celled), *Coelastrum*, *Oocystis* and *Microcystis*, are counted as units also in spite of the fact that the number of cells in different colonies varies considerably. The filament forms of varying lengths and sizes and the indefinite colonial forms are the most difficult to enumerate satisfactorily. For some filamentous forms a convenient space on the counting cell was arbitrarily chosen as a unit, the length depending upon the individual cell length of the filament.

The arbitrarily chosen units for some of the filamentous and colonial forms are as follows: *Melosira* 300 μ, *Oscillatoria* 300 μ, *Lyngbya* 300 μ, *Anabaena* 300 μ, *Aphanizomenon* 300 μ, *Dinobryon* 5 cells, *Merismopedia* 16 cells, *Crucigenia* 8 cells.

The following list represents all the algae that could be identified definitely to species. Some occurred very rarely and in too small numbers to enter into the computation of prevalent algae during the survey. In some cases identification was uncertain and such forms are listed merely as "spp."

Chlorophyceae

Actinastrum hantzschii Lagerh.
Ankistrodesmus falcatus (Corda) Ralfs
Closterium acerosum (Schr.) Ehr.
C. acutum Breb.
C. ehrenbergii Menegh.
C. kuetzingii Breb.
C. pronum Breb.
Coelastrum microporum Naeg.
C. sphaericum Naeg.

Cosmarium granatum Breb.
C. radiosum Wolle
C. spp.
Crucigenia emarginata (W. and G. S. West) Schm.
C. rectangularis (Naeg.) Gay
Lagerheimia citriformis (Snow) G. M. Smith
L. genevensis Chodat var. subglobosa (Lemm.) Chodat
L. subsalsa Lemm.
Micractinium pusillum Fres.
Oocystis borgei Snow
Pandorina morum Bory
Pediastrum biradiatum Meyen
P. boryanum (Turp.) Menegh.
P. duplex Meyen
P. simplex Meyen
P. tetras (Ehr.) Ralfs
Pleodorina illinoisensis Kofoid
Pleurotaenium coronatum (Breb.) Rabenh.
P. trabecula (Ehr.) Naeg.
Scenedesmus acuminatus (Lagerh.) Chodat
S. armatus (Chodat) G. M. Smith
S. bijuga (Turp.) Lagerh.
S. denticulatus Lagerh.
S. dimorphus (Turp.) Kuetz.
S. obliquus (Turp.) Kuetz.
S. quadricauda (Turp.) Breb.
Schroederia setigera (Schroeder) Lemm.
Selenastrum bibraianum Reinsch
Sorastrum spinulosum Naeg.
Spondylosium papillosum W. and G. S. West
Sphaerocystis schroeteri Chodat
Staurastrum spp.
Tetraedron enorme (Ralfs) Hansg.
T. minimum (*A. Br.*) Hansg.
T. muticum (A. Br.) Hansg.
T. regulare Kuetz.
Treubaria varia Tiffany and Ahlstrom
Trochiscia aspera (Reinsch) Hansg.
Volvox globator L.

Myxophyceae

Anabaena circinalis (Kuetz.) Rabenh.
A. flosaquae (Lyng.) Breb.
Aphanizomenon flosaquae (L.) Ralfs.
Chroococcus minutus (Kuetz.) Naeg.
C. turgidus Naeg.
Coelosphaerium kuetzingianum Naeg.
Gloeotrichia natans (Hedw.) Rabenh.
Lyngbya aestuarii (Mert.) Liebm.
L. major Menegh.
Merismopedia elegans A. Br.

M. glauca (Ehr.) Naeg.
M. tenuissima Lemm.
Microcystis aeruginosa Kuetz.
M. flosaquae (Wittr.) Kirch.
M. marginata (Menegh.) Kuetz.
Nostoc linckia (Roth) Born.
Oscillatoria limosa Ag.
O. princeps Vauch.
O. tenuis Ag.
Phormidium retzii (Ag.) Gom.

Diatomeae

Asterionella gracillima (Hantz.) Heib.
Caloneis trinodis (Lewis) Boyer
Cocconeis placentula Ehr.
Cymbella affinis Kuetz.
C. ventricosa Kuetz.
Fragilaria capucina Desm.
Gomphonema constrictum Ehr.
G. parvulum (Kuetz.) V. H.
Gyrosigma acuminatum (Kuetz.) Cleve
Melosira crenulata (Ehr.) Kuetz.
M. distans (Ehr.) Kuetz.
M. varians Ag.
Meridion circulare (Grev.) Ag.
Navicula cryptocephala Kuetz.
N. cuspidata Kuetz.
N. lanceolata Kuetz.
N. radiosa Kuetz.
N. spp.
Nitzschia linearis W. Smith
Surirella splendida (Ehr.) Kuetz.
Synedra pulchella (Ralfs) Kuetz.
S. ulna (Nitz) Ehr.
Tabellaria fenestrata (Lyng.) Kuetz.

Euglenophyceae

Euglena oxyuris Schm.
E. spirogyra Ehr.
E. spp.
Phacus longicauda (Ehr.) Duj.
P. pleuronectes (O. F. M.) Duj.

Dinophyceae

Ceratium hirundinella (O. F. M.) Schrank
Peridinium spp.

Chrysophyceae

Dinobryon sertularia Ehr.
Synura uvella Ehr.

PERIODICITY AND RELATIVE ABUNDANCE

Transeau (1916) established the class "ephemerals" for the plankton algae collected in his survey of the ponds and streams of Illinois. Taking the organisms as a whole, he found plankton species most abundant in May and June, with a lesser maximum in October. The reports of Birge and Juday (1922) for Wisconsin, Burkholder (1929, 1930) for eastern Lake Erie, Muenscher (1928, 1930) for New York and unpublished data for western Lake Erie all indicate rather definite plankton periodicity in large bodies of water. Eddy (1927) has reported monthly abundance of some plankton forms in small lakes in central Illinois. It is unfortunate that the survey of Buckeye Lake did not extend through a longer period, from the standpoint of data for periodicity. It will not be possible to make definite comparisons with previous workers because of the limited season covered in this survey.

In reporting the periodicity of phytoplankton in Buckeye Lake, the time covered by the survey has been divided into periods of two weeks. The first half and the last half of each month are used arbitrarily as the two-weeks periods and the number of individuals is recorded for each period (Figures 3 and 4). The connecting lines in the graphs do not represent actual gradations between successive periods: they merely connect successive two-weeks enumerations. It is interesting to note that as a whole the Chlorophyceae are more abundant in June and September, corresponding to Transeau's findings for Illinois (*supra*). The Diatomeae begin with a maximum in June, gradually decreasing to a minimum in early September. The Myxophyceae show an early minimum in June with a maximum in July and August. The Dinophyceae-Euglenophyceae-Chrysophyceae group (including the genera *Peridinium*, *Ceratium*, *Euglena*, *Phacus*, *Dinobryon* and *Synura* and for convenience considered here as a single class) show two maxima: one in June and the other in early August, with a marked drop to a minimum in late August and early September.

The periodicity of a few common genera (*Synedra*, *Melosira*, *Microcystis*, *Scenedesmus*, *Pediastrum*, *Peridinium* and *Euglena*), which occurred rather consistently throughout the survey, is shown in Figure 4. These genera indicate a periodicity quite comparable to that of the groups to which each belongs (Figure 3). The periodicity and abundance of other genera will be discussed later under the proper class of algae.

It is not known what effect the extremely dry season of 1930 had upon the abundance of plankton algae. The water in Buckeye Lake was lower than any previously known record.

Chlorophyceae.—The two most abundant genera of this class are *Scenedesmus* and *Pediastrum* (Figure 4). The former is represented by seven species and the latter by five species. Next in abundance is *Cosmarium*, occurring throughout the season in gradually increasing quantities until the end of the survey. *Tetraedron*, together with *Cosmarium*, is at variance with the Chlorophyceae considered as a whole. The remaining genera (Table II) of the Chlorophyceae occurred in too small quantities to warrant individual consideration.

The Chlorophyceae is the dominant group for Buckeye Lake for the whole season (Figure 3; Table I). Occasional cycles of *Peridinium* and *Euglena* are very abundant during certain periods (see below) and at these times the green algae seem scarce by comparison. The dominance of the Chlorophyceae in Buckeye Lake is in striking contrast to conditions in Lake Erie, where the diatoms are the evidently preponderant group. In addition the maximum abundance of this group is not reached in Lake Erie until September. The relative rapidity with which the water of Buckeye Lake becomes warm in the spring is perhaps an important factor in the Chlorophycean maximum in June in such a relatively small lake.

TABLE I

Classes of Plankton Algae in Buckeye Lake. Average Number of Organisms, in Thousands per Liter of Water. During Each of the Two-weeks Periods

	June 25–30	July 1–15	July 16–31	August 1–15	August 16–31	September 1–10
Chlorophyceae	168	129	120	133	87	162
Diatomeae	114	110	92	81	32	31
Myxophyceae	18	48	62	62	65	60
Dinophyceae, Euglenophyceae, Chrysophyceae	208	146	123	196	46	45

TABLE II

Chlorophyceae. Average Number of Organisms, in Thousands per Liter, of Genera of Chlorophyceae, During Each of the Two-weeks Periods

	June 25–30	July 1–15	July 16–31	August 1–15	August 16–31	September 1–10
Scenedesmus	105.0	80.0	68.0	62.0	26.0	46.0
Pediastrum	34.0	17.0	16.0	16.0	8.0	18.0
Cosmarium	10.0	10.0	15.0	26.0	33.0	66.0
Tetraedron	8.0	9.0	10.0	14.0	14.0	22.0
Crucigenia	4.0	2.0	4.0	3.0	2.0	4.0
Closterium	2.0	3.0	2.0	1.0	0.3	0.0
Oocystis	1.0	3.0	4.0	3.0	0.3	5.0
Coelastrum	2.0	0.6	1.0	1.0	0.3	1.0
Sphaerocystis	1.0	0.2	0.03	0.2	0.0	0.0
Staurastrum	3.0	1.0	2.0	2.0	0.3	1.0
Pandorina	0.5	2.0	1.5	2.0	0.0	0.0
Kirchneriella	0.0	0.3	0.4	0.2	0.3	0.0
Euastrum	0.0	0.8	0.3	0.01	0.0	0.0
Eudorina	0.0	0.0	0.1	3.0	0.3	1.0
Dictyosphaerium	0.0	0.05	0.0	1.0	0.0	0.0

Eddy (1927) found in a small lake in Illinois a maximum of Pediastrum in July, with a marked rise in June over May and a marked decline in August. A second smaller maximum was noted in October. This July maximum in Illinois is, however, less than one half the phytoplankton productivity in Buckeye Lake for the same period. Muenscher (1929) reports a maximum of 500,000 organisms (nannoplankton) per liter in Lake Champlain in early August. A representative station from Lake Erie might show a maximum of 400,000 organisms per liter in August, with a count of 35,000 in September. The maximum production of Chlorophyceae at any one time for Buckeye Lake occurred in August with a count of 272,000 per liter. This should not be confused with the average counts for the two-weeks periods, mentioned above.

Diatomeae.—Ranking second to the Chlorophyceae, the diatoms occur rather regularly throughout the season but with relatively few species in abundance (Figure 3; Table I). The enormous "waves" of

TABLE III

Diatomeae. Average Number of Organisms, in Thousands per Liter, of the Genera of Diatomeae, During Each of the Two-weeks Periods

	June 25–30	July 1–15	July 16–31	August 1–15	August 16–31	September 1–10
Synedra	75.0	81.0	72.0	54.0	20.0	21.0
Melosira	29.0	14.0	11.0	9.0	5.0	6.0
Navicula	7.0	7.0	3.0	3.0	5.0	2.0
Surirella	2.0	1.5	0.4	0.5	1.0	0.0
Gyrosigma	1.0	5.0	4.0	7.0	1.0	1.0
Asterionella	0.5	0.5	0.0	0.0	0.0	0.0
Tabellaria	0.0	0.0	2.0	0.0	0.0	0.0
Amphora	0.0	0.1	0.04	0.0	0.0	0.0
Nitzschia	0.0	0.0	0.5	0.0	0.0	0.0
Cocconeis	0.0	0.0	0.5	0.0	0.0	0.0

Stephanodiscus, *Asterionella*, *Tabellaria* and *Fragilaria*, so characteristic of Lake Erie, were missing in the survey of Buckeye Lake. *Stephanodiscus* was not observed at all and the other genera occurred only sparingly in June and July. The dominant diatom throughout the season is *Synedra*, followed not closely by *Melosira* and *Navicula*. These genera are most abundant at the beginning of the season and apparently least abundant in late August and early September. Some other data for previous years indicate a rise in numbers for a short time during late September. *Surirella*, a diatom found perhaps more frequently in water with a higher organic content, follows the general seasonal distribution of the class as a whole. *Gyrosigma* is present throughout the season, though never abundant and is more common during early August. *Cymbella*, *Cocconeis* and *Nitzschia* were rarely observed. (Figure 4; Table III).

The autumn maximum of productivity of diatoms reached in Lake Erie is notably absent in Buckeye Lake. From a representative Lake Erie habitat there may be 300,000 organisms per liter in September and nearly 600,000 per liter in October, corresponding to only 31,000 in

September (no data for October) in Buckeye Lake. The month of August furnishes an interesting comparison (New York data from Muenscher, 1929); Buckeye Lake 159,000; Lake Erie 328,000; Lake Champlain 70,000; Upper Saranac Lake 40,000; Lower Saranac Lake 60,000; Middle Saranac Lake 50,000; Lake Placid (on July 10, 10,000 organisms per liter). Maximum numbers are considered only.

TABLE IV

MYXOPHYCEAE. AVERAGE NUMBER OF ORGANISMS, IN THOUSANDS PER LITER, OF THE GENERA OF MYXOPHYCEAE, DURING EACH OF THE TWO-WEEKS PERIODS

	June 25–30	July 1–15	July 16–31	August 1–15	August 16–31	September 1–10
Microcystis	9.0	28.0	52.0	58.0	60.0	53.0
Anabaena	3.0	2.0	2.0	2.0	1.0	1.0
Lyngbya	2.0	12.0	3.0	3.0	3.0	3.0
Coelosphaerium	0.5	2.0	4.0	0.3	0.0	0.0
Aphanizomenon	1.0	3.0	0.6	0.3	0.0	0.0
Merismopedia	0.0	0.1	1.0	2.0	2.0	4.0
Gomphosphaeria	2.0	0.0	0.1	0.0	0.0	0.0
Oscillatoria	0.0	0.0	0.0	0.0	0.1	0.0

TABLE V

DINOPHYCEAE, EUGLENOPHYCEAE, CHRYSOPHYCEAE. AVERAGE NUMBER OF ORGANISMS, IN THOUSANDS PER LITER, OF THE GENERA OF DINOPHYCEAE, EUGLENOPHYCEAE AND CHRYSOPHYCEAE, DURING EACH OF THE TWO-WEEKS PERIODS

	June 25–30	July 1–15	July 16–31	August 1–15	August 16–31	September 1–10
Peridinium	129.0	80.0	70.0	92.0	28.0	27.0
Euglena	58.0	55.0	38.0	77.0	16.0	19.0
Ceratium	14.0	7.0	6.0	15.0	1.0	0.0
Phacus	5.0	3.0	2.0	3.0	2.0	0.0
Dinobryon	0.5	0.3	0.04	0.0	0.0	0.0
Synura	0.0	0.0	1.0	0.0	0.0	0.0

Myxophyceae.—It has been established in numerous collections that the blue green algae are decidedly summer and autumn forms. In the Buckeye Lake survey there is a steady rise in abundance from a low minimum in June to a maximum in late August and early September. In Lake Erie the Myxophycean maximum occurs in September (1938). When one considers the temperature of the water, however, it might be just as well to consider the blue greens "warm water" forms. Their absence in spring and early summer seems to be accounted for pretty largely on the basis of low temperature of water.

In the Buckeye Lake survey *Microcystis* is the only member of the plankton consistently present (Figure 4; Table IV). *Anabaena*, though not very abundant at any time is present in largest numbers in early summer. The very shallow water along shore in 1930, particularly in protected places, became warm much earlier in the year than is usually the case. *Lyngbya* occurs most abundantly in early July. Both *Coelosphaerium* and *Aphanizomenon* are absent in late August and early September. For other genera see Table IV.

TABLE VI

GROUPS OF ZOOPLANKTON IN BUCKEYE LAKE. AVERAGE NUMBER OF ORGANISMS, IN THOUSANDS PER CUBIC METER, IN EACH OF THE TWO-WEEKS PERIODS

	July 1–15	July 16–31	August 1–15	August 16–31	September 1–10
Copepoda	34.0	108.0	88.0	53.0	93.0
Cladocera	11.0	16.0	7.0	15.0	7.0
Rotifera	52.0	316.0	342.0	59.0	20.0

TABLE VII

ZOOPLANKTON ORGANISMS IN BUCKEYE LAKE. AVERAGE NUMBERS OF ORGANISMS, IN THOUSANDS PER CUBIC METER, OF THE GENERA OF COPEPODA, CLADOCERA AND ROTIFERA FOR EACH OF THE TWO-WEEKS PERIODS

	July 1–15	July 16–31	August 1–15	August 16–31	September 1–10
Copepoda					
Cyclops	13.0	61.0	58.0	39.0	61.0
Nauplii	21.0	45.0	30.0	14.0	32.0
Cladocera					
Daphnia	0.5	0.25	0.0	0.0	0.25
Pseudosida	5.0	13.0	4.0	14.0	6.0
Ceriodaphnia	0.0	0.5	0.0	0.0	0.0
Immature Cladocera	6.0	2.0	2.0	2.0	0.25
Rotifera					
Asplanchna	0.0	0.0	9.0	2.0	2.0
Polyarthra	0.0	0.5	6.0	2.0	1.0
Brachionus	51.0	312.0	324.0	51.0	13.0
Rattulus	0.25	4.0	4.0	6.0	4.0

Muenscher (1929) reports a maximum of 500,000 organisms per liter during early August in Lake Champlain and 400,000 in Lake Placid. In Lake Erie a maximum for the same period may be 500,000 per liter, while in Buckeye Lake the count runs only as high as 154,000 for the same month.

Dinophyceae.—Peridinium and *Ceratium* are unusually well represented in this survey (Figure 4; Table V). Their curve of distribution indicates a first maximum in June with a second in early August. The autumn maximum, characteristic of Lake Erie, is absent. The decline in late August and early September is very marked.

Peridinium occurs at times in tremendous quantities, the largest count being 672,000 on August 1. On the same day the count for *Ceratium* was 14,000 organisms per liter.

Euglenophyceae.—*Euglena* is the dominant genus, reaching a maximum in early August with a lesser maximum in June and early July (Figure 4). *Phacus* occurs rather regularly, though in much smaller numbers throughout the season.

Chrysophyceae.—*Dinobryon* and *Synura* are the only representatives of this class, the former occurring throughout June and July, the latter in late July only. They are perhaps not an important part of the phytoplankton.

If these last three classes of phytoplankton are considered as a unit, we get the high maximum of productivity in June, declining rapidly till the end of the survey in September (Figure 3; Table I; Table V).

DIURNAL CHANGES IN THE LAKE

Small bodies of water, shallow streams and fish ponds have been shown to exhibit marked changes in their chemistry during the 24 hours, while it has long been known that certain plankters perform daily, vertical migrations from one region of the lake to the other. At the time that Buckeye Lake was investigated little was known about the diurnal changes in a good sized lake and especially of the factors which caused the changes and differences in distribution of various plankton organisms. Even today,. the subject is still more or less shrouded in mystery and no complete explanation has been given to explain many of the very complex migrations exhibited by some organisms.

On August 12–13, a 24-hour series of surface samples were taken every hour from a point about 100 meters off the laboratory. Zooplankton, phytoplankton, temperature, dissolved gases, pH and alkalinity were investigated. The chemical determinations were made immediately after the collection of the water. The results of chemical determinations and migrations of certain zooplankters are shown in Figure 5.

The following weather report for Columbus, kindly submitted from the Weather Bureau Office by Mr. W. H. Alexander, indicates that the afternoon of August 12 was quite similar to the forenoon of August 13, with the possible exception of the amount of sunshine.

"August 12, 1930, was a clear day with 100% of possible sunshine; the temperature ranged from 54 (the minimum) to 78 (the maximum) degrees Fahrenheit, averaging 66, or 8 degrees below normal; the wind was from the north and northwest with an average hourly velocity of 5.9 miles per hour, the highest velocity for the day being 14 miles.

"August 13, 1930, was also a clear day but with only 88% of the possible sunshine; it began clouding in the late afternoon and evening; the temperatures ranged from a minimum of 48 to a maximum of 85, giving an average of 72 or 2 degrees under the normal for the day; the winds were rather variable though the prevailing winds were from the northwest and the average velocity was 5.4 miles per hour with a maximum for the day of 14 miles from the south."

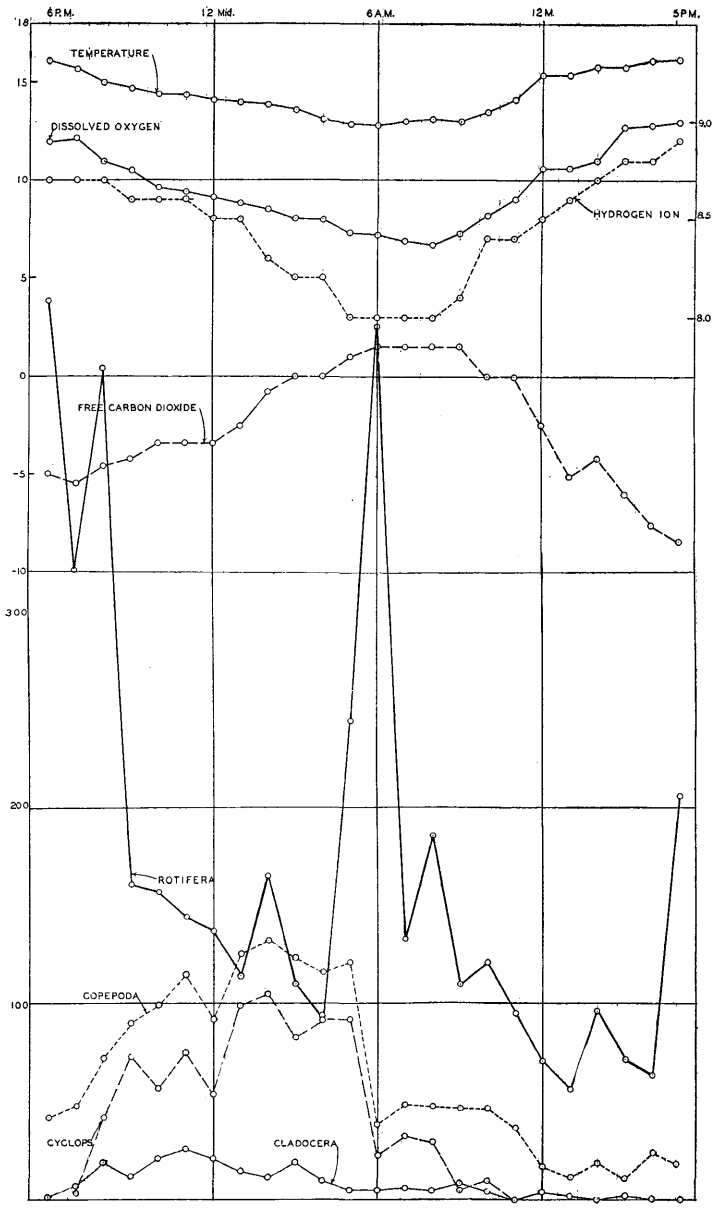

Fig. 5. Diurnal changes in physical and chemical factors and in zooplankton at the surface on August 12–13, 1930. Temperature is shown in degrees Centigrade, chemical factors in parts per million, plankton in organisms per liter; time is eastern standard time.

Physical and Chemical Changes.—The days selected for the observations thus turned out to be ideally suited for such an investigation. Water temperature was observed to lag behind air temperature during the 24 hours. The variation in water temperature amounted to only 3.4° C. while that of the air was 13.9° C. at the laboratory, clearly illustrating the difference in specific heat of the two mediums. The activity of the green plants in the water caused marked fluctuations in dissolved oxygen, free carbon dioxide and pH. Dissolved oxygen varied between 6.7 p.p.m. and 13.0 p.p.m., the lowest figure having been reached at 8 a. m., before the sun had been up long enough to make its presence felt in photosynthesis. The percentage of saturation showed even greater fluctuations and varied between 77% and 159%. This variation was due to the fact that the period of least oxygen occurred at a time when the water was able to hold more dissolved gas due to its lower temperature. Methyl orange alkalinity, as would be expected, remained at a practically constant level during the entire time. Free carbon dioxide, however, showed rather remarkable changes from hour to hour as the activity of the green plants varied with the amount of sunlight. By the first of August and for some time before, free carbon dioxide had been exhausted at the surface and a decided deficiency was noted at most times. During the 24 hour series, carbon dioxide varied from a deficiency of 5.0 p.p.m. at the start to actual free carbon dioxide between four and ten a. m. By 5 p. m. that afternoon a deficiency of 8.4 p.p.m. had been built up due to photosynthesis of the green plants. The pH varied inversely with the free carbon dioxide and ranged between 8.0 and 8.9.

The Zooplankton.—At the bottom of Figure 5 is shown the diurnal distribution of the major groups of zooplankton. The only copepod present was *Cyclops viridis americanus* and this species is represented separately as being the principal migrant. The graph marked "Copepoda" includes the immature stages as well as adults of this species. Both of these curves show higher numbers of individuals at the surface during the hours of darkness. In very bright light the adult copepods deserted the surface completely and were absent from nine a. m. until late afternoon. The nauplii, on the other hand, although not nearly as abundant at the surface during the hours of intense sunlight, were nevertheless present in fair numbers. Light intensity seems therefore, to be an important factor in the migration of adult copepods in Buckeye Lake.

The rotifers showed a distinctly different type of migration. The time of maximum numbers at the surface will be seen in Figure 5 to coincide with the time of sunrise and sunset, or at a time of diffuse light. Sume crustaceae have also been shown to prefer diffuse light (Juday, 1902), but in Winona Lake, where these observations were made, there was no morning increase observed to correspond with the evening maximum. The rotifers in Winona Lake were found by Juday to show no indication of a diurnal migration. This is perhaps due to the different genera there (*Mastigocera, Polyarthra, Asplanchna, Keratella, Triarthra* and *Notholca*). In Buckeye Lake by far the greatest number of rotifers were of the genus *Brachionus.*

The Cladocera, which never reached any great number in the open water of the lake, followed in general the migrations of the copepods, being at the surface during the night and deserting it with the appearance of the sun during the daytime.

The Phytoplankton.—It is difficult for one to appreciate the significance of the "peaks" of the curves in the diurnal periodicity of the phytoplankton, due to the fact that collections were made but once each hour on this particular occasion. Factors other than those incident to the mere changes from hour to hour are not known. The Chlorophyceae reached a corresponding peak at 3:00 p. m., 5:00 p. m., 7:00 p. m. and 2:00 a. m., being consistently lowest from 4:00 a. m. until noon. The Myxophyceae and Diatomeae were fairly regular throughout the 24 hours. The three other classes were most abundant immediately after noon. The quantity of Chlorophyceae and Dinophyceae-Euglenophyceae-Chrysophyceae was considerably lower, on the average, at noon of August 13, than at 1:00 p. m. the preceding day. The available sunshine decreased also. Very little variation was noted in the diatoms and blue-greens.

PRODUCTIVITY

Buckeye Lake is a eutrophic lake which exhibits extremely high productivity during the summer months. Particulate organic matter, shown for station 1 in Figure 2, ranged from 6600 mgs/m^3 to 18,100 mgs/m^3 at this station. At station 2 the surface waters ranged from 5,900 to 13,600 mgs/m^3. 18,100 mgs/m^3 was the maximum amount of organic matter observed at any time in the lake in 1930. That this figure represents a truly enormous amount, may be appreciated when it is recalled that Birge and Juday (1934) in a study of 529 Wisconsin lakes found particulate organic matter to range from 230 to 12,000 mgs/m^3 with a mean of only 1,360. The time of maximum organic matter in Buckeye Lake occurred at the same time as the maximum zoo- and phytoplankton abundance and in general the summer variation followed very closely the total counts for these organisms. During the height of activity of the lake in early August, the water was so densely populated with algae that it truthfully may be said to have appeared like pea soup. This overpopulation is reflected in the high organic matter and in the extremely low transparency of the water at this time.

In its vertical distribution, particulate organic matter at station 2, showed a greater amount at the surface than at 5 meters in three instances and more at the bottom in two; at other times the amount was about the same at both depths. The larger amount at the surface may be explained by the greater amount of plankton at this level, while stirring up of bottom debris may account for the larger amount at the bottom on the two occasions. The vertical distribution of organic matter has been shown to be very variable in different lakes.

The horizontal distribution of organic matter was very irregular. In general, the stations at the western end and in the sanctuaries showed more organic matter and the least amount was observed at stations 25 and 27 (1,700 and 2,300 mgs/m^3 respectively). This is reflected in the greater transparency found at these stations. The organic matter was also low in the bog hole on Cranberry Island (2,100 mgs/m^3). Station 1 in Buckeye Lake varied between 168,300 and

212,800 mgs/m^3 of dry residue while station 2 showed a maximum of 228,400 mgs/m^3 at 5.5 meters on August 18. The surface waters of station 2 varied between 177,000 and 201,700 mgs/m^3 of dry residue. Lake Wingra, a small lake of comparable depth in Wisconsin, averaged 271,000 mgs/m^3 for the year (Tressler and Domogalla, 1931). Other factors besides the plankton enter into these results. These are the debris which is stirred up from the bottom by high winds and which accounts for the higher figures obtained at 5 meters at station 2 and drainage from the land, which was not a factor of importance during the first part of the summer.

The combined results of particulate organic matter and dry residues show very clearly the extreme eutrophy of Buckeye Lake during the summer months.

BOTTOM ORGANISMS

Procedure.—An Eckman dredge, 20 cm. by 20 cm. was used to collect samples of the bottom. The date, approximate depth and position of the station were recorded at the time the sample was taken and in most cases the nature of the bottom (mud, sand or gravel) was recorded. The samples were placed in four gallon pails and covered with lake water. Within an hour of the time the samples were taken they were washed through a net made of silk bolting cloth, No. 36, which had 13 strands to the centimeter. The sample, washed free of mud, was then transferred to a quart or two-quart jar, marked and left at the laboratory for removal and identification of the organisms. Samples which were not immediately examined were preserved by the addition of formalin. It was found that the counts of *Tanypus* and *Chironomus* larvae and *Limnodrilus* were made about as well from formalin as from fresh material. Such soft bodied forms as the Hydracarinae and *Chaoborus* were, however, largely lost in formalin material.

The laboratory procedure was as follows: About 25 cc. of the sample, consisting of the debris and the organisms, which had been held back by the silk net were placed in a flat glass dish and a little fresh lake water poured over it. This was closely inspected, frequently stirred and worked over and the organisms picked out with forceps and either identified immediately and tabulated or put aside in vials, marked and later identified. No attempt was made to isolate and identify the plankton crustaceans, such as ostracods and cladocerans, some of which were often found in the samples. *Hyalella*, however, was counted as it is a much larger form. Only a few mematodes were taken from the fresh samples, although they undoubtedly occur in great numbers in the mud of the lake bottom. From the size of those found now and then in the samples, it is likely that the great majority went through the meshes of the net. It is also true that these forms are almost at the edge of visibility with the naked eye and for this reason most of them would be missed, particularly in the preserved material. In many samples Bryozoan statoblasts were observed in large numbers. No attempt, however, was made to keep a record of them as they float in the lake water at the season the samples were taken and many of them no doubt came from the water used in washing the sample and not from the sample itself.

The Data.—A tabular summary of the organisms collected in the 246 samples has been made and together with a map of the lake showing the exact location of each station, is on file at the office of the Division

TABLE VIII

SUMMARY OF BOTTOM ORGANISMS. THE TOTAL NUMBER OF ORGANISMS COLLECTED AT VARIOUS STATIONS FOR EACH MONTH IS SHOWN. THE GRAND TOTAL FOR THE SURVEY AND THE PERCENTAGE OF THE TOTAL FOR THE MORE IMPORTANT ORGANISMS ARE ALSO GIVEN

	July	August	September	Total	Per Cent Total
Diptera					
Palpomyia	15	52	13	80	0.77
Corethra	45	266	133	444	4.26
Tanypus	1623	2444	959	5026	48.29
Chironomus	928	1111	516	2555	24.74
Coleoptera					
Donacia	3	0	0	3	.....
Cybister	0	0	1	1	.....
Hemiptera					
Corixa	0	1	9	10	.....
Ephemerida					
Hexagenia	0	0	2	2	.....
Caenis	1	0	4	5	.....
Odonata					
Didymops	0	0	3	3	.....
Nehallenia	2	0	9	11	.....
Trichoptera					
Leptocerus	1	0	0	1	.....
Hydroptilidae	13	3	7	23	.....
Neuroptera					
Sielis	87	53	16	156	1.5
Crustacea					
Hyalella	71	114	137	332	3.09
Arachnida					
Hydracerina	3	60	55	118	1.13
Mollusca					
Musculium	63	21	1	83	0.81
Oligochaeta					
Nais	0	0	5	5	.....
Branchiura sowerbyi	2	9	4	15	.....
Limnodrilus	743	233	511	1487	14.89
Hirudinea					
Herpobdella	2	2	1	5	.....
Glossophionidae	1	0	0	1	.....
Nematoda	0	0	16	16	.....

of Conservation at Columbus. In Table VIII is given a list of the organisms collected and identified with the total numbers secured in each month, the total collected during the summer and the per cent of the total of some of the more abundant forms. The samples were all taken at depths of between 0.2 and 3.7 meters so that depth plays an insignificant part in the distribution of these organisms in Buckeye Lake. In other deeper lakes a regular zonation correlated with depth has been observed. This was shown very nicely in a recent paper by Townes (1938) on the bottom organisms in Chautauqua Lake, where small chironomids were found in shallower sandy parts, while in the deeper water, where muck bottom prevailed, *Limnodrilus*, *Chaoborus*, *Tanypus* and larger species of *Chironomus* were found.

An inspection of the summary in Table VIII shows that almost all the forms belong either to the chironomid larvae or to the tubificid worms. Of the total of 10,408 organisms recorded, there are 2,575 or about 25 per cent *Chironomus*, 5,026 or nearly 50 per cent *Tanypus*, 444 or over 4 per cent *Chaoborus* and 1,487 or 14 per cent *Limnodrilus* or closely related genera of tubificids. Thus over 75 per cent by number of the forms are chironomids and less than 10 per cent of the forms come from groups other than chironomids and tubificids. With the abundance of chironomids it may be noted that there are practically no mayfly larvae. Buckeye can certainly be classed as a chironomid lake.

Certain of the facts noted can best be discussed by taking up the major groups of organisms collected individually.

Diptera.—As the chironomids formed by far the most abundant organisms from the bottom samples, a representative lot were weighed, live, dry and ashed. The following data were obtained:

Name	No. of Individuals	Wt. of Empty Dish	Live Wt. With Dish	Dry Wt. With Dish	Ash Wt. With Dish
Chironomus.....	84	17.4063	19.4285	17.5565	17.4371
Tanypus........	139	19.1496	19.4385	19.1795	19.1536

If the individuals taken represent a fair sample of the total collected, then the organic matter of the total *Chironomus* larvae collected (2,555) would amount to 3.630 grams and that of the total *Tanypus* collected (5,026) would be 0.936 grams. It is obvious that while *Tanypus* is more abundant, the *Chironomus* larvae represent a much larger amount of food material by weight. Records were not kept of the variation in size of *Chironomus* and *Tanypus* from month to month as it seemed that the investigators were dealing with several different species, the identification of which was too difficult to make a study of growth feasible. It may be stated, however, that large numbers of extremely small *Chironomus* and *Tanypus* were found in the September counts. These must have been recently hatched individuals. This would agree with the observations on the swarming of adults around the lake in late August and the opening days of September.

It seems likely that *Chaoborus* occurs relatively more abundantly than recorded. Many individuals were doubtless lost in the formalin samples owing to the extremely fragile nature of this larva. This form certainly cannot, however, be of the importance of the other two genera as food for young fishes in Buckeye Lake.

Neuroptera.—156 *Sialis*, 1.5 per cent of the total organisms found were recorded. On the basis of the amount of organic matter in four individuals, which was determined, the total amount of organic matter in the 156 *Sialis* collected was estimated to be 0.876 grams, a figure comparable with that obtained for the total *Tanypus* catch. While the numbers were small, it would seem that this form was relatively less abundant in September than in July, which probably indicates that the adults were emerging at this time of year.

Trichoptera, Odonata, Ephemerida, Hemiptera, Coleoptera.—These forms of insect life seem to occur only sporadically. The bottom of the lake being mostly mud, it seems likely that many micro-mayflies may have been overlooked in the samples. It is also probable that many more of the above orders would be found if the animal life on and around submerged water plants were studied. In any estimate of the total food material available to young fishes in a lake such as Buckeye, it would seem that that part of the fauna living on submerged vegetation should be taken into consideration. This very abundant animal life is accounted for neither in bottom nor plankton studies. Chandler (1937) has shown recently that a large part of the plankton of a lake is lost, when the water leaves the lake by way of stream, by being caught up by the detritus on the outside of submerged vegetation. The same thing very probably is true of plankton in weedy areas of a lake and very likely is an important factor in accounting for the increased transparency of the water in the weeded areas at the eastern end of the lake.

Arachnida and *Crustacea.*—Water mites were found rather abundantly in certain samples. The distribution of *Hyalella* was found to be sporadic, 112 of the 322 recorded specimens coming from one sample. This form is probably better considered with the plankton than with the bottom fauna.

Annelida.—Only five leeches were found. Small tubificid worms occurred widely distributed and abundant at many stations. A number of these were examined and from their external anatomy, setae, etc., they were placed in the genus *Limnodrilus.* Some of these may, perhaps have been *Tubifex,* as a careful examination of the individual specimen is necessary to separate these genera. *Nais* was likely present much more often than the counts indicate but it lies on the border of visibility with the naked eye and would often be overlooked.

From the zoologist's viewpoint, by far the most interesting item turned up during the summer's work was the finding of fifteen specimens of the gilled annelid, *Branchiura sowerbyi.* A more detailed description of this interesting worm is given in another paper (Spencer, 1932). This is the first record of this rather rare species from the western continent. It has formerly been recorded from the Royal Botanical Society's gardens, Regents Park, London, the Botanical Gardens of Hamburg and of Göttingen, from several canals and ponds in France, from India and Japan. The worm is a tubificid with a series of some sixty pairs of gill-like respiratory processes, one pair to a segment on the posterior third of the worm. The gills extend at right angles to the long body axis, in the mid-dorsal and mid-ventral lines. They diminish in length anteriorly becoming mere knobs and finally disappearing entirely. Several of these worms were kept alive and under observation in the laboratory for several days and a careful study was made of their behavior, external anatomy and setae. *Branchiura sowerbyi* was taken at six different stations, which indicates that the worm is fairly well distributed in the central part of the lake. If it is an introduced species, it must have been established for several years to have gained its present distribution in the lake. Where it has been found in other regions it has not been taken in large numbers. Stephenson (1912) bases his description on seven specimens taken in India and Beddard's original paper (Beddard, 1892) is based on about the same number of individuals.

Nematoda, Gordiacea.—Nematodes are probably abundant but too small to be observed readily without the use of a microscope and are often washed through the net. Very few Gordiacea were found.

Mollusca, Bryozoa.—Half a dozen or so small specimens of snails, classified as *Physa, Planorbis* and *Limnaea* were taken but were not tabulated. A small bivalve occurred in some numbers. It was tentatively classified as *Musculum*, although this may not be correct. One bivalve about five centimeters long and unidentified was taken at station 185.

A bryozoan colony was found in the sample from station 167. As already stated many bryozoan statoblasts were seen but were not recorded.

SUMMARY

1. During the summer of 1930, from June 25, to September 10, an extensive study of Buckeye Lake was carried out under the auspices of the Division of Conservation of Ohio. Buckeye Lake is a long, narrow lake located about thirty miles east of Columbus, Ohio, which has a maximum depth of about seven meters and a mean depth of around two and one half meters.

2. The temperature reached an observed maximum of 29.0° C. at the surface. The transparency varied between 0.3 and 0.7 meters, low figures being due to the great abundance of plankton material and the shallowness of the lake. The color is low, about 25 on the platinum-cobalt scale.

3. Dissolved oxygen was present in abundance at all depths, except at five meters and below in the deep hole, due to the decomposition on the bottom. Free carbon dioxide was present later in the summer than in most lakes due to the decomposition of the bottom materials and to the lake's shallowness. Methyl orange alkalinity reached a maximum of 96.0 p.p.m., showing the waters to be hard. The pH varied between 7.3 and 8.9 in the limnetic regions. Chlorides were found in minute traces only. Soluble phosphorus was low during the summer; dissolved silica was not very abundant. Nitrates were fairly low due to their consumption by algae. Free ammonia declined to a low point by the end of the summer.

4. Rotifers were the most abundant zooplankton organisms.

5. The Cladocera were never present in great numbers in the limnetic region.

6. Of the copepods, *Cyclops viridis americanus* was the most abundant species.

7. The lake reached a maximum of activity during the first week in August. At this time there was more oxygen, more plankton and the temperature was the highest; organic matter was also at a maximum.

8. The zooplankton organisms were found to be unevenly distributed over the limnetic area of the lake and occurred in patches or swarms here and there.

9. The Chlorophyceae was the dominant group for the lake during the period covered by the survey and reached a peak in June and another in September. Most abundant genera were *Scenedesmus* and *Pediastrum*.

10. The Diatomeae varied in abundance from a maximum in June, gradually decreasing to a minimum in early September. The dominant diatom was *Synedra*, followed not closely by *Melosira* and *Navicula*.

11. The Myxophyceae varied from a low minimum in June, gradually increasing to a maximum in late August and early September. The most abundant blue-green alga was *Microcystis*.

12. The Dinophyceae, represented by *Peridinium* and *Ceratium*, reached a first maximum in June with a second in late August. The decline in early September was very marked.

13. The Euglenophyceae, as shown by the presence of *Euglena*, reached a maximum in early August preceded by a lesser maximum in late June and early July. *Phacus*, though present in small numbers throughout the survey, showed no definite periodicity.

14. The Chrysophyceae was an unimportant group of the algal plankton of the lake. *Dinobryon* occurred in June and July and *Synura* in late July only.

15. Studies of the diurnal changes over a 24 hour period showed considerable fluctuation both in chemical determinations and in migrations of plankton.

16. The particulate organic matter was extremely high (maximum of 18,000 mgs/m^3. Dry residue reached a maximum of 228,400 mgs/m^3. Buckeye Lake is therefore an extremely productive lake of the eutrophic type.

17. The bottom of Buckeye Lake was sampled for bottom organisms; 246 samples were taken with an Eckman dredge, 20 cm. by 20 cm.

18. The chironomid larvae formed over 75% by number of the bottom organisms recorded. *Limnodrilus* formed about 15%.

19. There was almost a complete absence of mayfly larvae.

20. *Branchiura sowerbyi*, a gilled tubificid worm, was found at six stations in the central part of the lake. 15 specimens were taken in the bottom samples. This is the first record of this form in the western hemisphere.

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