A LIMNOLOGICAL STUDY OF LAKE WORTH

APPROVED:

[Signatures]

Major Professor

Minor Professor

Director of the Department of Biology

Chairman of the Graduate Council
A LIMNOLOGICAL STUDY OF LAKE WORTH

THESIS

Presented to the Graduate Council of the North
Texas State Teachers College in Partial
Fulfillment of the Requirements

For the Degree of

MASTER OF SCIENCE

By

William Barnette Johns, B. S.

Fort Worth, Texas

August, 1939
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*Figure 5 comprises the forty-four different figures found in the Appendix.*
CHAPTER I

PROBLEM AND METHODS

Introduction

The limnological study of Lake Worth was undertaken by the writer to determine the biological productivity of a reservoir lake that exceeded twenty years in age. Data from Lake Worth were collected over a period of three years, beginning in 1937 and continuing through June, 1939.

Thus far, most limnological work has been confined to natural lakes in the Northern United States and in Europe. The first publication from the Southwest dealing with aquatic studies was written by Major John B. Hawley.¹ Lee S. Roach (1933) worked on some of the reservoirs in Ohio.² A. H. Wiebe (unpublished papers) worked on Texas reservoirs while he was associated with the Texas State Game, Fish and Oyster Commission, during which time he made several preliminary limnological investigations. With the exception of Major Hawley's excellent accounts, reservoir lakes of the Southwest have been scientifically neglected.

¹Major John B. Hawley, Microscopic Life in Texas Waters, American Society for Municipal Improvements, 1926.

Methods

Physical.—In order to assure a complete knowledge of the actual limnological conditions in Lake Worth, samples and data were collected from several locations on the lake. The stations or locations were altered from time to time, but at least three different points, widely separated, were always studied. Samples from various depths and locations of Lake Worth were taken to the laboratory and the turbidity determined by the use of the Jackson Turbidimeter. This method employs a long graduated tube which fits into a special brass holder attached to a substantial tripod. Underneath is a candle placed in a special spring candle-holder which is kept burning at a constant rate and distance from the bottom of the tube. Water is poured into the tube until the image of the flame is no longer visible on looking down the tube. The reading is taken from the graduations on the tube where turbidity is marked in parts per million (p. p. m.).

The temperature was determined at the surface and at each meter of depth to the bottom of the lake. During the first part of this study a Negretti and Zambra reversing thermometer was employed for these determinations. (Figure 1) This instrument was corrected for pressures of three tons and sealed in an outer glass tube. Attached to the thermometer was a graduated cord, so that the instrument might be lowered to any desired depth. In taking the reading, the thermometer was placed in the water for two minutes, a signal was dropped
which tripped a special arrangement, and the thermometer was reversed. After the instrument reversed, it was permitted
to stay one minute before it was raised and the reading recorded. During the latter half of the work, a H-B thermometer
mounted in a similar case was used in the same manner as described above.

Chemical.—Samples for chemical determinations were collected by means of a two-liter Juday sampler attached to a calibrated rope. (Figure 2) At the bottom of the sampler there was a special valve to which was attached a quarter-inch rubber hose, twelve inches in length, to facilitate the filling of glass stoppered eight-ounce bottles. The bottles were rinsed and flooded about twice their volume by letting the water run into the bottles near the bottom through the rubber hose. These were placed in a box designed to protect them. (Figure 2)

In the determination for oxygen, carbon dioxide, and
bicarbonates, the methods were followed as described in
Standard Methods for Examinations of Water and Sewage\textsuperscript{3} and
Laboratory Manual for Chemical and Bacterial Analysis of
Water and Sewage\textsuperscript{4}.

Fig. 2.---Two- and three-liter Juday samplers and sample
and chemical boxes.

As soon as the oxygen samples were collected, in each
case .7 milliliter of concentrated sulphuric acid and one
milliliter of potassium permanganate were added by means of
pipettes. Then the stopper was inserted and the contents
mixed by inverting the bottle several times. The sample was
permitted to stand for a period of twenty minutes, and, in
case the color disappeared, a similar amount of the potassium
permanganate was added. Then one milliliter of potassium

\textsuperscript{3}American Public Health Association, Standard Methods
for Examinations of Water and Sewage (8th edition), 1936,
pp. I-xiv; I-309.

\textsuperscript{4}Frank R. Theraux, Edward F. Eldridge, and W. LeRoy
Mallman, Laboratory Manual for Chemical and Bacterial Analysis
of Water and Sewage, 1936, pp. v-x; 3-228.
oxalate was added, a stopper inserted, and the contents were mixed as before. The precipitate formed at this step was allowed to settle half way and was again mixed and allowed to settle as before. One milliliter of concentrated sulphuric acid was then added, a stopper inserted immediately, and the contents mixed. Care was used not to allow the bottle to stand open after the addition of the acid. This procedure fixed the oxygen until work could be completed on the test, which, in many instances, was one or two days later. One hundred milliliters of the solution was withdrawn rapidly from the bottle and put into an Erlenmeyer flask and titrated with .025 normal sodium thiosulphate drop by drop from a burette until the yellow color almost disappeared. Then one milliliter of starch solution was added and the titration continued until the blue color just disappeared. The amount of sodium thiosulphate was noted and the number of milliliters used multiplied by two, which gave the amount of dissolved oxygen present in parts per million.

The dissolved carbon dioxide was determined in the field. A one hundred-milliliter Nessler tube was filled to the mark with the freshly taken sample and ten drops of phenolphthalein indicator added. This was immediately titrated with one forty-fourth normal sodium hydroxide from a burette until a slight permanent pink color appeared. The milliliters of sodium hydroxide used were multiplied by ten in order to determine the parts per million of carbon dioxide.
The determination for the hydrogen-ion concentration was made in the field by means of the LaMotte colorimeter and frequently checked in the laboratory by means of a quinhydrone potentiometer. In the field, phenol red was used, and the sample was filled to the designated mark (ten milliliters) and five tenths of phenol red added. The standard tubes were used to match the sample, and the nearest was read as the hydrogen-ion concentration.

The determination of the alkalinity was done in the laboratory. By alkalinity is meant the amount of bicarbonate present that is equivalent to parts per million of calcium carbonate as determined by titration with .02 normal sulphuric acid. One hundred milliliters of the sample was pipetted into an Erlenmeyer flask and the same quantity of distilled water into another. To each was added four drops of phenolphthalein indicator. The sample did not become pink in any instance of the writer's experience, which indicated that the water had no carbonates. Then two drops of methyl-orange were added to each flask, and the sample turned yellow. It was then titrated with .02 normal sulphuric acid until the first difference in color was noted that compared with the distilled water control. The milliliters of sulphuric acid required, multiplied by ten, indicated the bicarbonate content in terms of calcium carbonate.

The mineral determinations were made for nitrates, nitrites, chlorides, phosphates, silicon, aluminum, total iron, calcium,
sodium, potassium, magnesium, bicarbonates, sulphates, and manganoses. These data were secured from chemistry students in research, and the writer will refer to the various findings as the need arises.

**Biological.**—All plankton were collected by means of a three-liter Juday sampler which was attached to a calibrated rope. (Figure 2) The water was strained through a standard plankton net modeled after that used by Juday. (Figure 3) The net was made by fashioning two circles from three-sixteenth-inch brass wire to form a rigid construction at the top of the net. Between the two hoops was attached a special water-proof piece of canvas twelve inches in depth and of the same inside diameter as the outside diameter of the hoops. The net was suspended from the top hoop by attaching three pieces of brass wire one-thirty-second by six inches at intervals, so as to form a pyramid to which was attached a long piece of cord for tying the net to the boat while the work

![Fig. 3.—Standard plankton net](image)
was in progress. From the bottom hoop was attached a cone-shaped net of No. 25 mesh silk bolting cloth which had a depth of twenty inches, terminating with a two-inch opening. A detachable Juday plankton bucket was attached to the bottom of the net.

The plankton samples were secured at the surface and at each two-meter interval to the bottom. Thirty liters of water composed a sample which was sieved through the net. The net was attached to the boat so that the bottom of the water-proof canvas was just beneath the surface of the water. This permitted the water to flow through without washing the organisms through or injuring them in any way. The net was raised and the water permitted to drain down to approximately fifty milliliters. The water was then transferred to a plankton bottle that contained five milliliters of formaldehyde by detaching the plankton bucket and removing the plunger. The plankton bucket was then washed with ten milliliters of distilled water which was added to the concentrate.

Counting the plankton.—The plankton was counted by means of a calibrated microscope into the ocular of which had been inserted a Whipple Micrometer. Each side of the micrometer was measured accurately by observing a stage micrometer and then the results squared. This gave the square surface of the field observed. This was multiplied by the average depth of the counting cell, which gave the unit volume of the field of the scope under lower power. During the first part of the
work a counting cell modeled after the Sedgwick-Rafter was used, which consisted of a brass frame one millimeter deep, twenty millimeters wide, and fifty millimeters long. It was attached by balsam to a glass slide. By using a caliper micrometer, the average depth was ascertained. During the latter half of the work, a regular Sedgwick-Rafter counting cell was used. It was designed to hold exactly one cubic centimeter. By counting ten fields on three separate cells of the concentrate, using the calibrated microscope, the number of organisms per liter was determined. The formula used was:

\[
\text{Number of organisms} = \frac{\text{organisms found}}{\text{unit}} \times \frac{\text{concentrate}}{\text{liters of sample}} \times 1000
\]
CHAPTER II

MORPHOMETRY

Lake Worth is located about six and one-half miles west of the court house of Tarrant County, longitude 97° 27' and latitude 32° 47', in the Walnut formation of the Fredericksburg group. It was formed by impounding the waters of the west fork of Trinity River with the dam 3,500 feet long with a maximum height of sixty feet. At present the west fork of the Trinity River and its tributaries are impounded by Lake Bridgeport and drained into Eagle Mountain Lake, which in turn is connected to Lake Worth by a short conduit. In addition, this lake is fed by Cottonwood, Mill, Silver, and Live Oak Creeks, which form a large part of the ninety-two square miles of immediate drainage area. Its total water area is approximately 3,800 acres with a volume of 19,000 acre-feet. Its shoreline is approximately thirty miles in length.

The maximum length of the lake is approximately ten miles; the breadth is two miles; and the maximum depth is thirty-nine feet. The major axis runs NW-SE.

The general terrain is predominately of limestone formation, and, being improperly cultivated, it furnishes a great amount of silt to the lake, which produces a high amount of bicarbonates in addition to raising the turbidity and filling in the lake. (+ organics + nutrients)
Fig. 4.—Map of Lake Worth.

Lake Worth
Traced from Fisherman's Guide
0' 1400' 11,200'
Approximate scale
in the lake. It also furnishes plenty of organic matter and dissolved mineral which are necessary for the flourishing of aquatic biota.
CHAPTER III

PHYSICAL-CHEMICAL FEATURES

Physical

Turbidity.—The turbidity of Lake Worth varies with the seasons from fifteen parts to eighty-five parts per million.

The average annual turbidity at the surface is approximately thirty-three parts per million, while at the bottom it increases to forty-six parts per million. Usually as the temperature lowers, the turbidity increases. This may be due in part to the release of the silt by the top water, or to the fact that cooler/water retains more suspended material. In August of 1937 it was found that the turbidity increased twenty-seven parts per million in the tenth meter over that in the ninth meter, and the temperature drop was only two tenths of a degree centigrade.

The effect of turbidity on productivity in shallow lakes has not been determined. It seems plausible that the higher the turbidity, the more sunlight would be excluded from the water, and the flora would have to make a vertical adjustment to obtain sufficient light to carry on photosynthesis. However, it was found in the rise in turbidity described above that the majority of organisms in the tenth meter were phytoplankton, while in the ninth meter the majority were zooplankton. It is possible that the phytoplankton obtain enough
subdued light to carry on life activities at this depth in
the lake until the turbid conditions become less, since the
turbidity varies from day to day, depending upon the amount
of rainfall and the velocity and direction of the wind. High
winds have been known to increase turbidity in a very short
time.

Temperature.--The time of stratification is governed by
the atmospheric temperature, rainfall, and wind action. Since
the major axis of the lake is NW-SE direction, it is expected
that high winds will disturb the surface of the water to such
an extent that stratification may be delayed or upset. In
the experience of the writer, the minimum temperature of 6.20
Centigrade was found in January. (Table 1) With the advent
of spring, the surface water warms and thermal stratification
may soon follow. In late spring conditions are favorable, and
the lake stratifies between the second and third or the third
and fourth meters. This condition may change over night be-
cause of wind action or heavy rains. Usually by June the
water that is ten meters deep is stratified, except when there
are occasional torrential rains.

If a rain of sufficient magnitude to cause a heavy influx
of water has occurred any place on the watershed, the incom-
ing current tends to seek a level in the lake of the same
temperature. Since the feed waters are ordinarily heavily
laden with silt, thermal relations alone will not account for
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the distribution of new water. If it happens that the lake is not stratified at such a time and is comparatively cool throughout, an inflow of warm water after a heavy spring rain may in a short time induce stratification. On the other hand, the cold summer rain accompanied by hail often gives rise to torrents of cold waters which spread over the lake, sinking from the surface to the bottom and creating convection currents that completely upset both chemical and thermal stratification.

Chemical

**Dissolved oxygen.**—Dissolved oxygen is higher in the lake during the winter than at any other season. (Table 2) A gradual reduction in the dissolved oxygen at the surface occurs with the approach of warm weather and drops from the winter maximum of fourteen parts per million to the summer minimum of six and two tenths parts per million. In May, 1939, the reduction of oxygen began on the bottom and continued to decrease each month until a complete absence was noted by the latter part of June. This condition remained until the upset of stratification in September. Cooler weather, heavy fall rains, and high winds lower the temperature of the surface waters below that of the underlying layers. The cooler water, being heavier, sinks, resulting in a turnover of the lake water. Chemical and thermal stratification disappear simultaneously, leaving the oxygen content equal in vertical distribution.
TABLE 2

READINGS OF CARBON DIOXIDE, OXYGEN AND pH FOR THE YEAR OF 1937

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*Expressed in parts per million (p. p. m.)
## LAKE WORTH - '39

**TABLE 2—Continued**

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</table>
Under normal conditions, during the late fall, winter, and spring months, the lake has an equal vertical distribution of dissolved oxygen. However, this condition may be disturbed by an excessive inflow of silt which settles to the bottom, increasing the rate of decomposition followed by a reduction of oxygen.

Free carbon dioxide.—Free carbon dioxide, constantly present in Lake Worth water, varied in content from one to nineteen parts per million, depending upon the depth in the lake and the season of the year. (Table 2) During the late winter and early spring months the carbon dioxide was found to be evenly distributed from the surface to the bottom, ranging from two to six parts per million. As summer approaches, the carbon dioxide content at the surface falls to a minimum of two parts per million, while on the bottom it increases to a maximum of nineteen parts per million. In the fall the carbon dioxide usually begins adjusting itself toward a more even vertical distribution, ranging from four to six parts per million. Frequently, however, there is one part per million more on the bottom than on the surface, due largely to the decomposition of organic matter. It is noted that with the diminution of oxygen there is an increase of carbon dioxide which usually takes place in the late spring and through the summer; however, in April, 1939, there was a "bloom" of algae, and the carbon dioxide ranged from four parts per million at the surface to five parts per million at the bottom.
The first of April, two weeks before the "bloom," the carbon dioxide was nine parts per million at the surface and eleven parts per million at the bottom. On May 7, two weeks after the "bloom," the carbon dioxide ranged from four parts per million at the surface to ten parts per million at the bottom. In all instances the oxygen remained almost constant from surface to the bottom.

**Hydrogen-ion concentration.**--The formation of the surrounding drainage area and the basin is of an alkaline nature, leading to a rather constant basic condition. The hydrogen-ion content in Lake Worth ranges from seven and three tenths to eight and two tenths. (Table 2) With the exception of mid-summer months, the hydrogen-ion range is equal in vertical distribution. With the onset of thermal stratification, the hydrogen-ion altered more toward the acid in the bottom water, the minimum for three years being seven and three-tenths increase.
CHAPTER IV

BIOLOGICAL FEATURES

Higher Vegetation

Since the establishment of Lake Worth, various plants have appeared, and as expected, the older a basin becomes, the greater variety and number of plants it will support.

Approximately fifty-six species of plants have been found. The portion of the lake area covered by vegetation amounts possibly to eight or nine per cent, depending upon the time of the year and the water level. The encroachment of aquatic vegetation does not appear to have been sufficient to cause a noticeable reduction in shoreline. Sufficient open areas are found in the lake, and much of the region covered by vegetation has either a sandy or a gravel bottom. If vegetation should be as useful as is often indicated, the lake appears to possess an optimum for the production of plankton.

Qualitative Plankton

Lake Worth has a large variety of biota that is planktonic. In the quantitative counts, the phytoplankton were most numerous, but in the number of genera, the zooplankton predominate. The

\[1\] North Texas State Teachers College Herbarium; Albert Ruth Herbarium, Fort Worth Botanic Garden; Private herbarium of William L. McCart (matched specimens from National Herbarium).
### TABLE 3

**ANNOTATED LIST OF LAKE WORTH VEGETATION**

<table>
<thead>
<tr>
<th>Plant Name</th>
<th>Scientific Name</th>
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<tr>
<td>Nitella sp.</td>
<td>Azolla caroliniana Willd.</td>
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<tr>
<td>Nasturtium officinale</td>
<td>Equisetum hyemale L.</td>
</tr>
<tr>
<td></td>
<td>var. robustum(A. Br.) A. A. Eaton</td>
</tr>
<tr>
<td></td>
<td>(Equisetum praealtum Raf.)</td>
</tr>
<tr>
<td>Potamogeton americanum Cham &amp; Schlecht. (Potamogeton lorchites Tucker.)</td>
<td></td>
</tr>
<tr>
<td>Potamogeton natans L.</td>
<td>Potamogeton pectinatus L.</td>
</tr>
<tr>
<td>Alisma subcordatum Raf.</td>
<td>Echinodorus cordifolius (L.) Griseb.</td>
</tr>
<tr>
<td>Sagittaria graminea Michx.</td>
<td>Sagittaria arifolia Nutt</td>
</tr>
<tr>
<td>Paspalum floridanum Michx.</td>
<td>Paspalum pubiflorum Rupr.</td>
</tr>
<tr>
<td>Paspalum stramineum Nash.</td>
<td>Zizaniopsis miliacea (Michx.) D &amp; H.</td>
</tr>
<tr>
<td>Carex Blanda Dewey</td>
<td>Carex crus-corvi Shuttlew.</td>
</tr>
<tr>
<td>Carex Davissii Schwein &amp; Torr. Carex emoryi Dewey</td>
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</tr>
<tr>
<td>Carex microdonata (Torr &amp; Hook) Carex vulpinoidea Michx. var. latifolia Bailey</td>
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</tr>
<tr>
<td>Cyperus erythrorhizos Muhl.</td>
<td>Cyperus rotundus L.</td>
</tr>
<tr>
<td>Fimbristylis autumnalis (L.) R &amp; S.</td>
<td></td>
</tr>
<tr>
<td>Seirpus validus Vail.</td>
<td>Seirpus lacustris L.</td>
</tr>
<tr>
<td>Fuirena simplex Vail.</td>
<td>Fuirena hispida Ell.</td>
</tr>
<tr>
<td>Eleocharis caribaea (Rottb.) Blake</td>
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</tr>
<tr>
<td>Lemna minor L.</td>
<td>Heteranthera limosa (SW.) Willd.</td>
</tr>
<tr>
<td>Juncus bufonius L.</td>
<td>Juncus diffusissimus Buckl.</td>
</tr>
<tr>
<td>Juncus effusus L.</td>
<td>Juncus setaceus Rostk.</td>
</tr>
<tr>
<td>Juncus marginatus Rostk.</td>
<td></td>
</tr>
<tr>
<td>var. setosus Coville</td>
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<tr>
<td>(Juncus setosus (Coville) Small.)</td>
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TABLE 3 --Continued

<table>
<thead>
<tr>
<th>Juncus texanus (Englem.) Coville</th>
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<tr>
<td>Juncus tenuis Willd.</td>
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<tr>
<td>Salix nigra L.</td>
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<tr>
<td>Polygonum incarnatum Ell.</td>
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<td>Polygonum lapathifolium L.</td>
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<td>Polygonum pennsylvanica L.</td>
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<tr>
<td>Nelumbo lutea (Willd.) Pers.</td>
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<tr>
<td>Nasturtium officinale R. Br.</td>
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<tr>
<td><em>Rorippa nasturtium-aquaticum</em> (L.) Schinz &amp; Thell.</td>
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<tr>
<td>Rorippa pedicellata</td>
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<tr>
<td>Hibiscus trionum L.</td>
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<td>Hibiscus militaris Cav.</td>
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<tr>
<td>Bergia texana (Hook) Seubert.</td>
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<tr>
<td>Ammannia coccinea Rottb.</td>
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<td>Ammannia auriculata Willd.</td>
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<tr>
<td>Hydrocotyle verticillata Thumb.</td>
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<td>(Hydrocotyle cuneata C &amp; R.)</td>
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<tr>
<td>Lippia lanceolata (Michx.) Greene.</td>
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<tr>
<td><em>var.</em> recognita Fern &amp; Grisc.</td>
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<tr>
<td>Lippia incisa (Small Tidestrom.)</td>
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<tr>
<td>Mentha spicata L.</td>
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<tr>
<td>Monniera rotundifolia Michx.</td>
</tr>
<tr>
<td>Utricularia gibba L.</td>
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</table>
classification followed was that given by Smith\textsuperscript{2} for the phytoplankton and that given by Ward and Whipple\textsuperscript{3} for the zooplankton. It will be noted that each author includes a classification of the flagellates.

The variety of genera, as may be observed from the following list, represents the majority of planktonic organisms found in Lake Worth. These were observed to be more prevalent at certain seasons of the year than at others. The most predominating phytoplankton organisms were *Aphanizomenon flos-aqua* and *Melosira cremulata*.

The other species in the list, though more prevalent during the winter and spring than in the summer, were never present in sufficient quantities to produce a "bloom." Of the zooplankton the *Rotatoria* were the predominate organisms. (Table 4)

Quantitative Plankton

**Vertical Distribution.**—In the summer months during stratification there is a noticeable reduction in the number of plankton below the thermocline; however, when there is no stratification, the vertical distribution ordinarily is more regular from surface to bottom. (Table 5) In general, the annual cycle of organisms is about the same from year to year. The

\textsuperscript{2}Gilbert M. Smith, *The Fresh Water Algae of the United States*, 1933.

\textsuperscript{3}Henry B. Ward and George C. Whipple, *Fresh Water Biology*. 
# TABLE 4

ANNOTATED LIST OF PLANKTON IDENTIFIED IN LAKE WORTH

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<td>Myxophyceae</td>
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<td>Hormogonales</td>
<td>Oscillatoriaceae</td>
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<td>Bacillariaceae</td>
<td>Centrales</td>
<td>Coscinodiscaceae</td>
<td><em>Cyclotella; Melosira granulata;</em> M. cremulata;* M. ambigu*</td>
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<td>Pennales</td>
<td>Tabellariaceae</td>
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<td>Fragilariaceae</td>
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<td>Cylindrocladaceae</td>
<td><em>Cylindroclada geminella</em></td>
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*Species verified by H. C. Bold, Vanderbilt University, Nashville, Tennessee.*
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*Listed as phytoplankton by Smith and as zooplankton by Ward and Whipple.*
<table>
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<th>Class</th>
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<th>Genera</th>
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<td>Anapus</td>
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number cited in the above tables are averages for a two and one-half year period.

In January the surface had approximately 32,500 organisms per liter, while at the bottom they increased to 62,000 organisms per liter. The oxygen content was approximately fourteen parts per million at the bottom, and the temperature was 7.3° Centigrade; at the surface the water was .2° Centigrade warmer and contained .4 parts per million more oxygen. The majority of these plankton were produced by a "bloom" of Melosira orenulata and a "semi-bloom" of Aphanizomenon flos-aqua. The reason for the greater number of organisms at the bottom was the fact that samples were secured at the end of the "bloom" which was sinking. In February, although the physical and chemical conditions remain practically the same, there was a sharp drop in plankton, there being approximately 21,000 per liter at the surface and 13,800 at the bottom. In March the plankton at the surface were further reduced to approximately 12,000, while the temperature increased to 16.4° Centigrade with a slight decrease of oxygen and carbon dioxide. At the sixth and seventh meters there was a sharp increase to approximately 28,000, but the other conditions remained constant with the exception of the temperature, which was lowered approximately two degrees Centigrade.

A "bloom" of Aphanizomenon flos-aqua in April increased the surface organisms to approximately 52,000 per liter. The temperature was approximately 15.6° Centigrade, and the
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chemical conditions were approximately the same from surface to the bottom; however, at the second meter the number of organisms increased to 63,000 to the liter, dropping to 52,987 at the fourth meter with a slight rise at the sixth meter to 57,600. Then there was a decline to 39,600 at the bottom. By May the organisms had decreased to 4,500 at the surface and had increased slightly at the bottom. The chemical conditions showed no change from surface to bottom, but the temperature varied between the fourth and the fifth meters. In June the organisms showed a slight raise at the surface to 7,371. The carbon dioxide increased from two parts per million at the surface to ten parts per million at the fourth meter and to thirteen parts per million at the bottom. The oxygen remained constant at seven parts per million through the second meter, but it began to decrease rapidly at the third and fourth meters, and there was a complete reduction of it at the bottom. The hydrogen-ion at the surface was 8, while at the bottom it was 7.3. There was also a noticeable increase in the bicarbonates at the bottom. There was a temperature variation between the surface and the bottom of approximately 10° Centigrade. The temperature at the surface was 29.5°, which gradually decreased to 26° Centigrade at the eighth meter. There was a drop of 2.7° Centigrade between the eighth and the ninth meters and a drop of 3.8° Centigrade between the tenth and eleventh meters. (In June, 1939, eleven meters was found at Station III, and a sharp drop in temperature
noted above was recorded.) The organisms at the second meter increased to 9,148, and at the fourth meter they decreased to 5,959. Even though the carbon dioxide increased and the oxygen decreased, there was a rise of plankton to 8,659 at the sixth meter and 6,950 at the eighth meter. At the bottom where the carbon dioxide was highest and the test showed no oxygen, there were 9,000 organisms per liter, most of which were phytoplankton, Melosira cremulata and Aphanizomenon flos-aqua.

In July the plankton at the surface was approximately 4,500 organisms per liter with a gradual decrease to 1,200 at the bottom. The chemical conditions were about the same as those for June. The highest temperature of the year, 32.3° Centigrade, was recorded at the surface, and 27.1° was recorded at the bottom. The scarcity of plankton prevailed in August. At the surface there were about 2,500 organisms per liter with a decrease to 900 at the eighth meter and a slight increase at the tenth meter. With the exception of oxygen, which at the surface was 6.2 parts per million and .2 parts per million at the bottom, the chemical conditions remained about the same as they were in July. The temperature ranged from 30° Centigrade at the surface to 27.6° Centigrade at the bottom, with stratification between the sixth and seventh meters.

The plankton in September decreased to 1,981 at the surface and rose to 3,537 at the fourth meter, then dropped to
750 organisms per liter at the eighth meter. The carbon dioxide increased to one part per million at the surface and to five parts per million at the bottom, while the oxygen increased to 8.65 parts per million at the surface and 5.9 parts per million at the bottom. The temperature rose from 31.4°F Centigrade at the surface and dropped at the second meter to 27.8°F Centigrade. Although thermal stratification was present, there was no chemical stratification. This would account for the sharp rise of plankton as noted at the second and fourth meter. (Table 6)

In October the plankton at the surface was approximately 6,000 per liter and gradually increased to 10,700 at the bottom. The carbon dioxide was six parts per million at the surface and seven parts per million at the bottom, and the oxygen varied from 7.6 parts per million at the surface to 7.2 parts per million at the bottom. Thermal stratification was between the fourth and fifth meters.

By November the temperature ranged from 9.3°F Centigrade at the surface to 9.1°F Centigrade at the bottom, and there was an increase of oxygen to 9.8 parts per million at the surface and 9.8 parts per million at the bottom. The carbon dioxide remained constant at five parts per million from the surface to the bottom. The plankton at the surface was 13,500 with a gradual increase to 26,500 at the bottom.

In December the carbon dioxide decreased to two parts per million. Oxygen increased to 11.5 parts per million with a
TABLE 6
MONTHLY AND SEASONAL DISTRIBUTION OF PLANKTON EXPRESSED
IN THOUSANDS OF ORGANISMS PER LITER

|--------|------|------|------|------|------|-----|------|------|------|-------|------|------|

[Graph showing the distribution of plankton across different months and seasons with specific values on the x-axis ranging from 0 to 60.]
decrease in temperature to approximately 70° Centigrade. There was a "bloom" of plankton composed of Melosira crenulata and Aphanizomenon flos-aquae, which increased the plankton to 62,160 organisms per liter at the surface. The greatest number of organisms was found at the sixth meter, which estimate totaled 113,100 organisms per liter with a slight decrease at the bottom.

Seasonal Distribution

As might be expected, Lake Worth has a usual seasonal distribution of plankton which is shown in Table 6. In mid-winter the number of organisms per liter averages approximately 40,000. In early spring there is a decrease of organisms to less than 20,000 per liter with a "bloom" following in late spring, at which time the organisms increase to 51,000. Throughout the summer there was comparatively little productivity, which reached the minimum in August. In the fall there was an increase which reached approximately the same number as the early spring. In the winter the organisms increased above 40,000 per liter.
CHAPTER VI

CONCLUSIONS

Relative Productivity

As indicated by Raymond,\(^1\) it would appear that the greater amount of aquatic vegetation would be conducive to the growth of plankton, which is apparently true. In Lake Worth there are more plants found than in any younger lake in this section. The number of plankton is also greater. The greater amount of silting which accompanies the aging of the lake is, no doubt, of great importance in determining favorable or unfavorable conditions. Ellis (1936)\(^2\) and Moore (1937)\(^3\) indicate that aquatic habitats may be greatly altered by this fact. Eakin (1938)\(^4\) showed that Lake Worth has a great amount of silting, although it is obvious that the vegetation has not been greatly hampered, and one would expect to find a large number of plankton. The deeper part of the lake apparently has been filled in by silting, thus removing the profundal


zone and making the entire basin littoral and sub-littoral. Since the feederstreams have basins composed almost entirely of alluvial soils, this rich material, if deposited in shoal regions, would greatly enhance the growth of aquatic vegetation necessary to biological productivity. Due to the large water shed, much of the silting is produced by animal and plant remains rather than by clay and sand. It would seem that this material, if not in too great abundance, might add to the productivity of the lake. Naturally, such materials can not be called silt, but rather should be referred to as "fill-in" substances, since most of them undergo either putrefaction or decay and ultimately give up the space they occupy in the basin.

Since turbidity in the water is more or less an index to the rate of silting or "fill-in," it would appear that the more constantly turbid waters would smother all life and carry much useful material to the bottom that would not be recovered. Certain workers have voiced this opinion, and scattered references in literature allude to turbidity in water as a very destructive factor. It would seem that the more turbid waters would contain more organic matter than the less turbid waters over a long period of time, thereby furnishing plenty of material necessary to life of plankton. No doubt an excess turbidity over a long period of time would be detrimental. The writer found Lake Worth to be as productive during high turbidity as during the low. Perhaps the high turbidity was due
to the organisms that were produced.

As far as data from the present investigation can be interpreted, it would appear that aging in years is not coincident with "aging geologically."

Summary

From the foregoing information it would be noted that as the temperature of the water decreases, the amount of dissolved oxygen increases, the amount of dissolved carbon dioxide decreases, and under normal conditions the water will be more turbid.

The greatest productivity occurred during the time when the temperature was low, the carbon dioxide near the minimum, and the oxygen near the maximum. This takes place in the spring and winter. In the summer, during the time of high temperature, low oxygen content, and high carbon dioxide content, the productivity is at a minimum; however, on the average Lake Worth apparently is more productive of plankton at this time than at any time during its history.
APPENDIX

Fig. 5.--Microphotographs of plankton from Lake Worth (reproductions from preserved plankton).

Fig. 1.--Aphanizomenon X250
Fig. 2.--Merismopedia X225

Fig. 3.--Oscillatoria X360
Fig. 4.--Anabaenopsis X110

Fig. 5.--Nodularia X150
Pediasstrum X150

Fig. 6.--Nodularia X200
Pediasstrum X200
Fig. 7.—Pediastrum X100
Tabellaria X100

Fig. 8.—Spirogyra X100

Fig. 9.—Pediastrum X150

Fig. 10.—Closterium X100

Fig. 11.—Closterium X73

Fig. 12.—Staurastrum X115
Melosira X115
Fig. 13. -- Fragellaria X250
Fig. 14. -- Frustulia X525
        Melosira X525

Fig. 15. -- Gomphonema X250
Fig. 16. -- Gomphonema X250

Fig. 17. -- Gyrosigma X274
Fig. 18. -- Melosira X125
        Navicula X125
Fig. 25.---*Euglena* X200

Fig. 26.---*Ceratium* X100
*Diurella* X100
*Polyarthra* X100

Fig. 27.---*Anapus* X300

Fig. 28.---*Anuracea* X350
*(Keratella cochlearis)*

Fig. 29.---*Conochilus* X115
*Nauclus* X115
*Ceratium* X115

Fig. 30.---*Notholca* X136
Fig. 31. -- Pedalion X250
Fig. 32. -- Polyarthra X454

Fig. 33. -- Pterodina X86
Fig. 34. -- Rattulus X225

Fig. 35. -- Tetramastix X315
Fig. 36. -- Triarthra X85
Fig. 37.--Bosmina X140

Fig. 38.--Cyclops X40

Fig. 39.--Daphnia X144

Fig. 40.--Daphnia X44

Fig. 41.--Diaptomus X43
Fig. 42.---Nauplius X60

Fig. 43.---Entomostraca eggs X 106

Fig. 44.---Ostracod X160
BIBLIOGRAPHY


Hawley, Major John B., Microscopic Life in Texas Waters, American Society for Municipal Improvements, 1928.


