A LIMNOLOGICAL INVESTIGATION OF A (CHRISTIAN COUNTY) KENTUCKY FARM POND

RONALD DALE HARNED

A LIMNOLOGICAL INVESTIGATION OF A (CHRISTIAN COUNTY) KENTUCKY FARM POND

An Abstract

Presented to

the Graduate Council of

Austin Peay State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

---

by

Ronald Dale Harned

December 1976

ABSTRACT

A limnological study of a pond in Christian County, Kentucky, was conducted from August, 1974 through December, 1974. Selected morphological, physical, chemical and biological parameters were measured at four stations on a weekly basis. The three major objectives of this investigation were: determining selected physical and chemical properties, enumerating and identifying the phytoplankton and identifying and explaining the interrelations that existed between the major phytoplankton groups and the various chemical and physical properties analyzed.

Variations were observed in all of the parameters examined. Dissolved oxygen, pH and temperature generally demonstrated a direct relation with the phytoplankton populations. Secchi disc visibility, orthophosphate, ammonium nitrogen and nitrate nitrogen concentrations exemplified a general inverse relationship with the phytoplankton concentrations.

The Vovocales and the Euglenales encompassed the majority of the phytoplankton examined. Large numbers of Volvox species were found during the warm month of August with corresponding low nitrate and ammonium nitrogen values and low orthophosphate concentrations. The Euglenales were found during periods of high phosphate and low dissolved oxygen.

The high nitrate and ammonium nitrogen values, with low Secchi disc readings and abundant numbers of Euglenales suggested the presence of organic pollution.

A LIMNOLOGICAL INVESTIGATION OF A (CHRISTIAN COUNTY) KENTUCKY FARM POND

A Thesis

Presented to

the Graduate Council of

Austin Peay State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

---

by

Ronald Dale Harned

December 1976

To the Graduate Council:

I am submitting herewith a Thesis written by Ronald Dale Harned entitled "A Limnological Investigation of a (Christian County) Kentucky Farm Pond." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Biology.

Major Professor

We have read this thesis and recommend its acceptance:

Second Committee Member

Third Committee Member

Accepted for the Council:

Dean of the Graduate School

ACKNOWLEDGEMENTS

The assistance and advice of a number of people made the completion of this project possible. I wish to express my thanks to all of them.

Appreciation is extended to the Biology Department, Austin Peay State University, for furnishing the equipment and facilities required in this study. To Dr. Davis Findley, my major professor, I give special thanks for his advice, guidance and encouragement. Appreciation is extended to Dr. Diane Findley and Dr. Floyd Ford for their advice throughout the study, and their careful editing of the manuscript.

Gratitude is expressed to the United States Department of Agriculture for their valuable information. Also to the United States Weather Station, Army Air Field, Fort Campbell, Kentucky, for the important climatic data.

Appreciation is given to Tom Swor, Fisheries Biologist (T.V.A.), for his help and encouragement.

I am grateful to Rev. Paul Moody and Erin Baptist Church for the use of their equipment in typing portions of this manuscript.

A special thanks is also due to Mr. and Mrs. Jesse O. Fleming, owners of the farm pond, for their many hours of assistance in the field and in use of their pond and equipment.

I am most grateful to my wife, June, for her invaluable help in the field and in typing portions of this manuscript. Above all her encouragement and support during my graduate career is most appreciated.

TABLE OF CONTENTS

LIST OF FIGURES

FIGURE PAGE

FIGURE PAGE

LIST OF TABLES

TABLE PAGE

TABLE PAGE

TABLE PAGE

TABLE		PAGE

CHAPTER I

INTRODUCTION

The seasonal succession and development of phytoplankton have attracted the attention of limnologists for over three quarters of a century. Some of the early workers, such as Ward and Whipple (1918), noted that the seasonal succession and amount of phytoplankton may be determined by a deficiency of one substance. Many of the modern investigators have regarded nitrogen and phosphorous to be critical to phytoplankton succession and development (Hutchinson, 1967). Another recent view, as reported by Vanlandingham (1964), is that in recent years workers have abandoned the theory that any single factor or related factors are always controlling phytoplankton growth. Throughout these many years of investigation, it is still not clear as to what actually controls the growth and succession of phytoplankton (Fogg, 1965). It is a matter of some difficulty to decide in any given instance whether a particular nutrient is limiting phytoplankton growth or not.

Objectives of the Study

This paper presents a survey conducted on a farm pond in Christian County, Kentucky, from 6 August 1974 to 28 December 1974 to determine the following:

(1) ascertain selected morphological and hydrographic characteristics of the pond and the watershed.

(2) determine certain chemical and physical parameters that are known to be required for phytoplankton growth,

(3) describe the observed relationships that exist between the chemical and physical parameters analyzed,

(4) enumerate and identify the phytoplankton sampled,

(5) explain the observed relationships between the major phytoplankton taxon and the chemical and physical properties examined, and

(6) interpret and describe the observed relation between the major phytoplankton taxon.

The physical parameters examined included temperature, dissolved oxygen, and Secchi disc visibility. The chemical properties investigated were total hardness ($CaCO_3$), orthophosphate (PO_4), orthosilicate silicon (SiO_2), nitrate nitrogen (NO_3), ammonium nitrogen (NH_4^+), pH and specific conductance. Also, certain selected morphological and hydrographic features of the pond and watershed were measured.

Description of the Study Area

The farm pond is located approximately 16.09 kilometers south of Hopkinsville, Kentucky, at an elevation of five hundred and eighty feet above sea level, longitude 87°35', latitude 36°41' (U. S.

Defense Mapping Agency, 1972). The pond was excavated under the direction of the U. S. Department of Agriculture and Soil Conservation Service in 1963. It was principally designed for livestock watering. During the investigation the number of livestock having direct utilization of the pond varied from twenty-five to thirty head of cattle.

The pond is centered in the Robertsville, silt loam, which is a typically level, poorly drained, acid soil (U. S. Department of Agriculture, 1975).

Immediately surrounding the pond on the western side is a rolling deciduous woodland and all other sides are rolling to gentle pasture and cropland. Polygonum coccineum was observed around the shoreline in August and September. In October Lemna minor was very dense around the shoreline.

The pond has a surface area of 840.125 square meters (m) with a mean width of 16.8 m, a maximum length of 50 m, and a mean depth of 1.905 m. The volume of the pond is 1600.649 (m^3) with a shoreline development of 1.696. A hydrographic map is provided in Figure 1.

Four sampling sites were established within the pond. Station I and II were centered in the deepest area of the pond. Station I was located on the surface and station II directly below in the bottom waters. Both stations III and IV were established in the surface

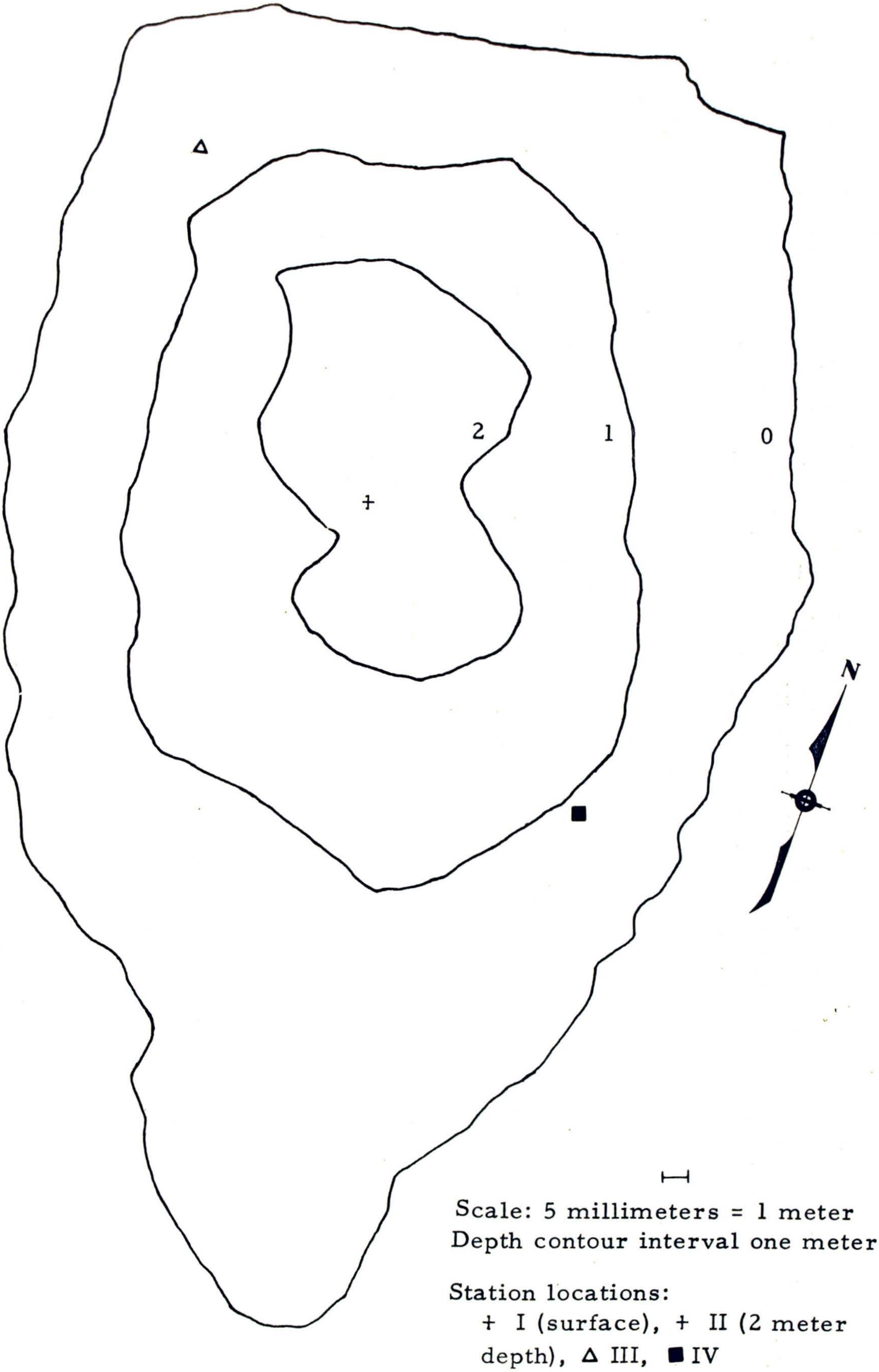


Figure 1. Hydrographic map of a Kentucky farm pond surveyed in March 1975, Christian County, Kentucky.

waters with station III in the northwestern sector and station IV in the southeastern sector.

The watershed is predominantly woodland and pasture. The basin is drained by only one small wet weather stream into which the pond drains during periods of extremely heavy rainfall.

The watershed is located in the Mississippian geological age and is underlaid by Saint Genevieve limestone (U. S. Department of Interior, 1963).

The watershed contains approximately 95.48 hectares with an average moderate land slope of 2.6 per cent and a computed peak discharge of 4.53 cubic meters per second within a 10 year frequency (U. S. Department of Agriculture, 1976).

The seven soil types of the basin are listed below:

(1) Robertsville silt loam,

(2) Lawrence silt loam,

(3) Bedford silt loam, 2 to 6 per cent slopes,

(4) Crider silt loam, 2 to 6 per cent slopes,

(5) Pembroke silt loam, 2 to 6 per cent slopes,

(6) Crider silt loam, 0 to 2 per cent slopes, and

(7) Baxter-Mountview complex, 6 to 12 per cent slopes, eroded (U. S. Department of Agriculture, 1975).

Climatic Factors

The coldest month of the year is January with an average daily temperature of 2.2° centigrade (°C), a mean daily minimum temperature of -3.3°C, and a mean daily maximum temperature of 23.8°C. The warmest month of the year is July with an average daily temperature of 25.5°C, a mean daily minimum temperature of 20°C, and a mean daily maximum temperature of 31.1°C. The mean number of days in which the temperature reached a minimum of less than 0°C is 85 days per year.

The mean total rainfall was the greatest in March with 132.32 millimeters (mm). The mean total rainfall was the lowest in October with 55.98 mm of rainfall.

All climatic data was obtained from the Fort Campbell Weather Station (1974). The location of the station is approximately eight kilometers from the study area.

CHAPTER II

METHODS AND MATERIALS

Sampling was conducted on a weekly basis from 6 August 1974 to 28 December 1974, with the exceptions of 1 November 1974 and 1 December 1974. All field investigations were begun as near 1300 hours as possible. A john boat was utilized in traveling to and from the individual stations.

Temperature, dissolved oxygen, pH, specific conductivity and Secchi disc visibility were measured at the sampling site. A Yellow Springs Instrument (YSI) Model 54 was used to obtain the atmospheric temperature and a vertical profile of dissolved oxygen and temperature at stations I and II. Dissolved oxygen and temperature were both measured at 30.48 centimeter (cm) intervals from the top to the bottom of the water column. Dissolved oxygen was expressed as milligrams per litre and temperature as degrees centigrade. Dissolved oxygen measurements were corrected for temperature and altitude in accordance with instructions furnished by the YSI Company. One-hundred percent oxygen saturation was determined according to the method of (Reid, 1961). A YSI Model 33-S-C-T meter was used to measure specific conductance at station I as micro-ohms per centimeter. Secchi disc visibility was determined at stations I, III, and IV by the methods of Tyler (1968), with a 20.5 cm diameter Secchi disc. All Secchi disc readings, except for 6 August 1974, were averaged from the three stations to obtain one value (only one reading was taken at station I on 6 August 1974). Temperature, dissolved oxygen and specific conductance were periodically checked at stations III and IV and consistently agreed with that recorded at station I. All samples were taken with a vertical 4.5 litre van Dorn sampler attached to a graduated line (Lind, 1974). Samples for chemical analysis were placed in polyethylene bottles and prepared as described by Lind (1974), before being transported to the laboratory. All the samples, except for total hardness, were examined in duplicate on the day of collection. Total hardness was determined by EDTA titration (Hach, 1973). Ammonium nitrogen was determined by the Nesslerization method (Hach, 1975). The ammonium nitrogen readings were made with a Bausch and Lomb Spectronic 20 calorimeter. All other analysis values were accomplished by direct readings from a Hach DR-EL-DC calorimeter and performed in accordance with the Methods Manual furnished by the Hach Chemical Company (Hach, 1973). All chemical results were expressed as milligrams per litre. There was no significant difference observed in the water chemistry of the four stations sampled, therefore, all four stations were averaged to obtain one value for each sampling period. Standard deviations were computed for all average values from each sampling period and presented graphically for comparison.

Phytoplankton samples were also collected at all four stations with the van Dorn sampler. A modified method of Wollitz (1972) was used to collect and prepare the phytoplankton samples. The enumeration and identification were accomplished with a Carl Zeiss Standard W L Research Microscope, using a modified method of Lund, Kipling, and Le Cren (1958). Diatoms were prepared and mounted for identification in accordance with the U. S. Environmental Protection Agency (1973).

The phytoplankton was identified to the species level when possible using the following taxonomic keys: Bloomquist and Oosting (1959), Cocke (1967), Gojdics (1953), Hansmann (1973), Patrick and Reimer (1966), Prescott (1962 and 1970), Smith (1950), Tilden (1970), Weber (1971) and Whitford and Schumacker (1969). The taxa were expressed as cells per litre and an average value was computed for each from the individual stations for each sampling period. The average values were then converted to a log and presented graphically for comparison. Per cent composition for each taxa were also computed and presented in tabular form for comparison.

All morphological features of the pond were determined by the methods of Welch (1948).

CHAPTER III

RESULTS AND DISCUSSION

Temperature

The greatest source of heat is solar radiation (Hutchinson, 1957). It was found that the water temperature and the air temperature showed a parallel decline as shown in Figure 2. Macon and Maudsley (1966) and McCombie (1959) pointed out that the average air and water temperature are related and tended to move in the same direction. It is apparent in this investigation that the water temperature had less of an amplitude of change than did the air temperature. McCombie (1959) found that the water temperature had less year to year variation than the air temperature. Macon and Maudsley (1966) also pointed out that the relationship existing between the air temperature and the water temperature varies according to the sunshine and wind strength. Martin (1972), in a study of lowland ponds, regarded the most important external factor affecting the summer water temperature to be the hours of sunshine per day. He further explained that the most important factor affecting the water temperature in the winter to be the air temperature. It can only be speculated that this may have been a controlling factor in this study. To definitely establish a relationship would have required measuring the time and duration of cloud cover.

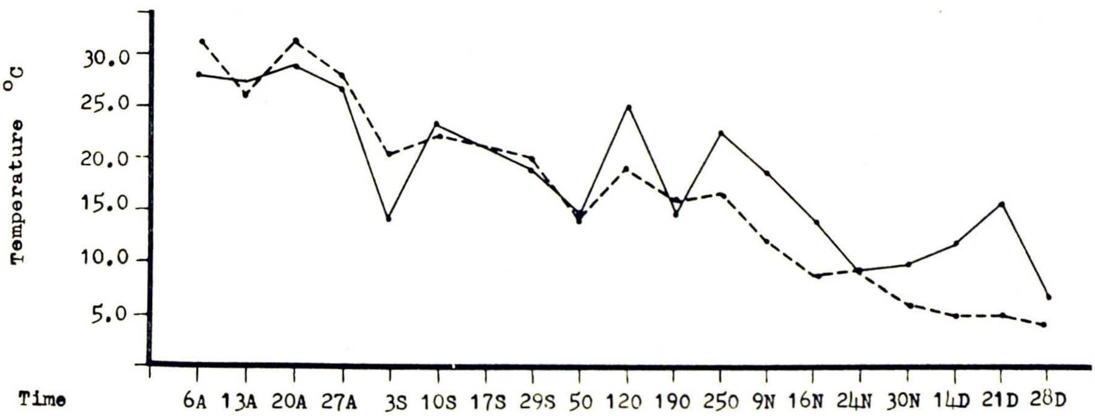


Figure 2. Surface water and atmospheric temperature of a Kentucky farm pond plotted against time from 6 August 1974 through 28 December 1974. Temperature is expressed as °C and months are represented by the first letter. Surface water (---) and atmospheric (—) temperatures are as indicated.

In the winter the sun has little warming power and a rise in temperature is often associated with rain (Macon and Maudsley, 1966). The steady decline in atmospheric and surface water temperature was interrupted by a gradual increase in surface water temperature on 24 November 1974. This may be attributed to the heavy amount of rainfall received at that time. The periods of peak rainfall coincide with sharp drops in both atmospheric and surface water temperatures in August, September, and October, 1974.

Lakes that are only a few meters in depth do not stratify (Moss, 1969) and (Hutchinson, 1957). Hutchinson (1957) suggested that the wind is important in preventing consistent stratification in shallow lakes. Figures 3 through 7 provide the weekly temperature profiles taken at station I. The water column showed a moderate to slight direct stratification; however, it was not consistent. The inconsistent stratification may be attributed to the protection from the wind by the woodland on the immediate western and southwestern sides of the pond. Moss (1969) in a study of Abbot's Pond, Somerset, noted that it was thermally stratified on a seasonal basis. He attributed this to the absence of wind disturbance of the water column; the pond was sheltered by a large woodland. The complete circulation, as observed on 3 September 1974, may be related to several factors. The sudden drop in atmospheric temperature coupled with the cooling effect of the heavy rains may have created convection currents that cooled the

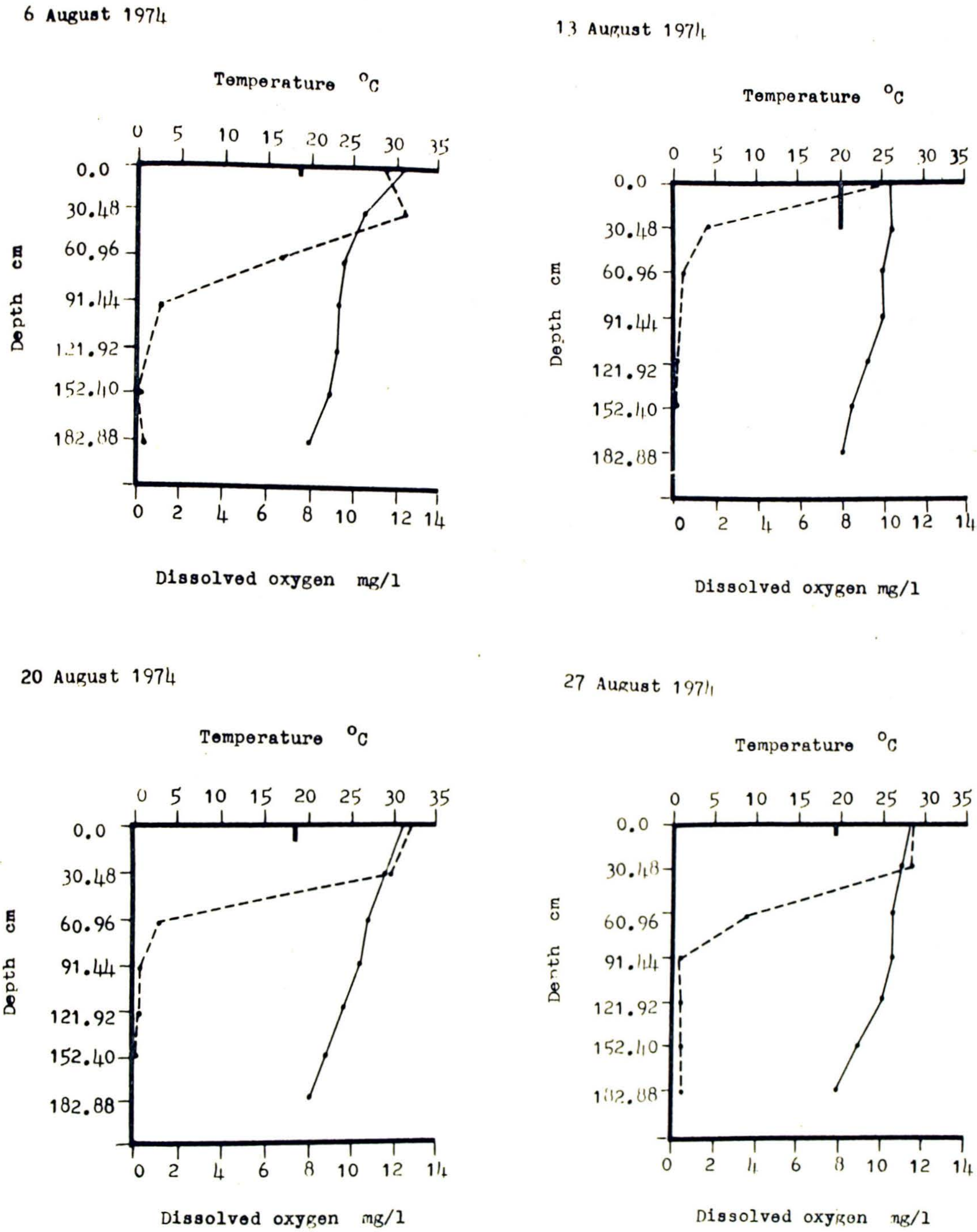


Figure 3. Dissolved oxygen and temperature of a Kentucky farm pond plotted against depth from 6 August 1974 through 27 August 1974. Depth is expressed as cm, temperature (——) is expressed as °C, and dissolved oxygen (---) as mg/l. The heavy dark line corresponds to the dissolved oxygen concentration within 3 mg/l of 100 per cent saturation.

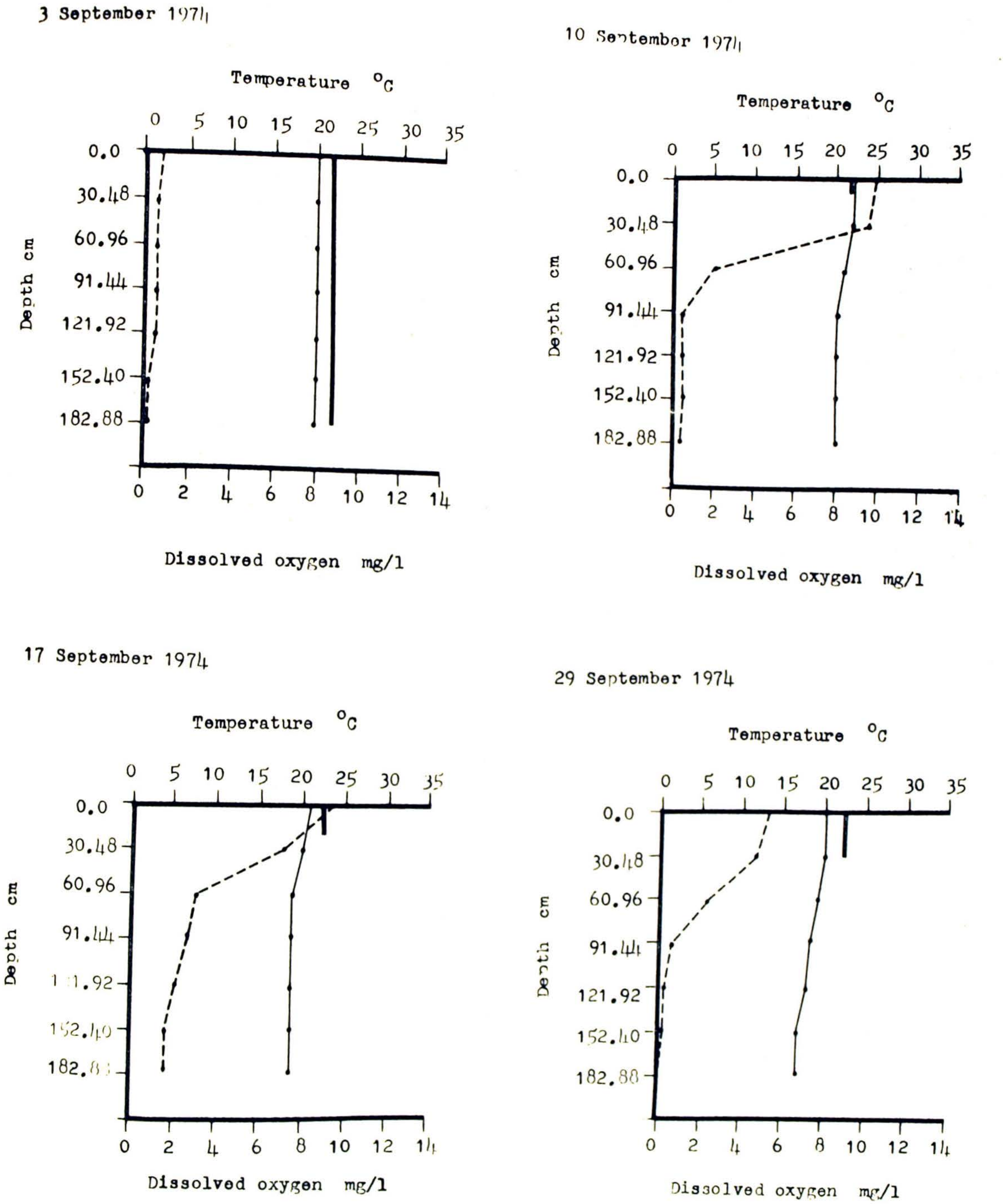


Figure 4. Dissolved oxygen and temperature of a Kentucky farm pond plotted against depth from 3 September 1974 through 29 September 1974. Depth is expressed as cm, temperature (——) is expressed as °C, and dissolved oxygen (---) as mg/l. The heavy dark line corresponds to the dissolved oxygen concentration within 3 mg/l of 100 per cent saturation.

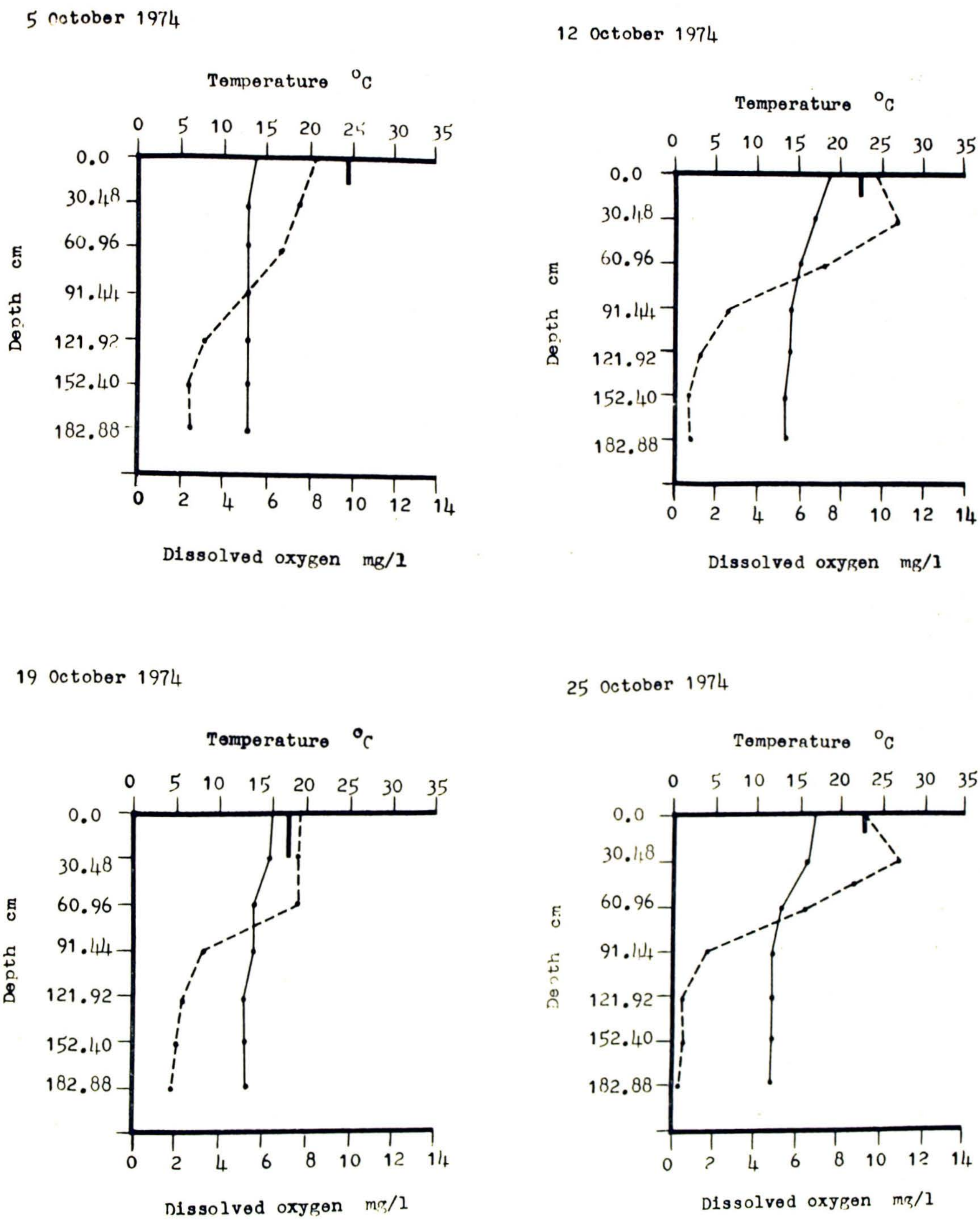


Figure 5. Dissolved oxygen and temperature of a Kentucky farm pond plotted against depth from 5 October 1974 through 25 October 1974. Depth is expressed as cm, temperature (——) is expressed as °C, and dissolved oxygen (---) as mg/l. The heavy dark line corresponds to the dissolved oxygen concentration within 3 mg/l of 100 per cent saturation.

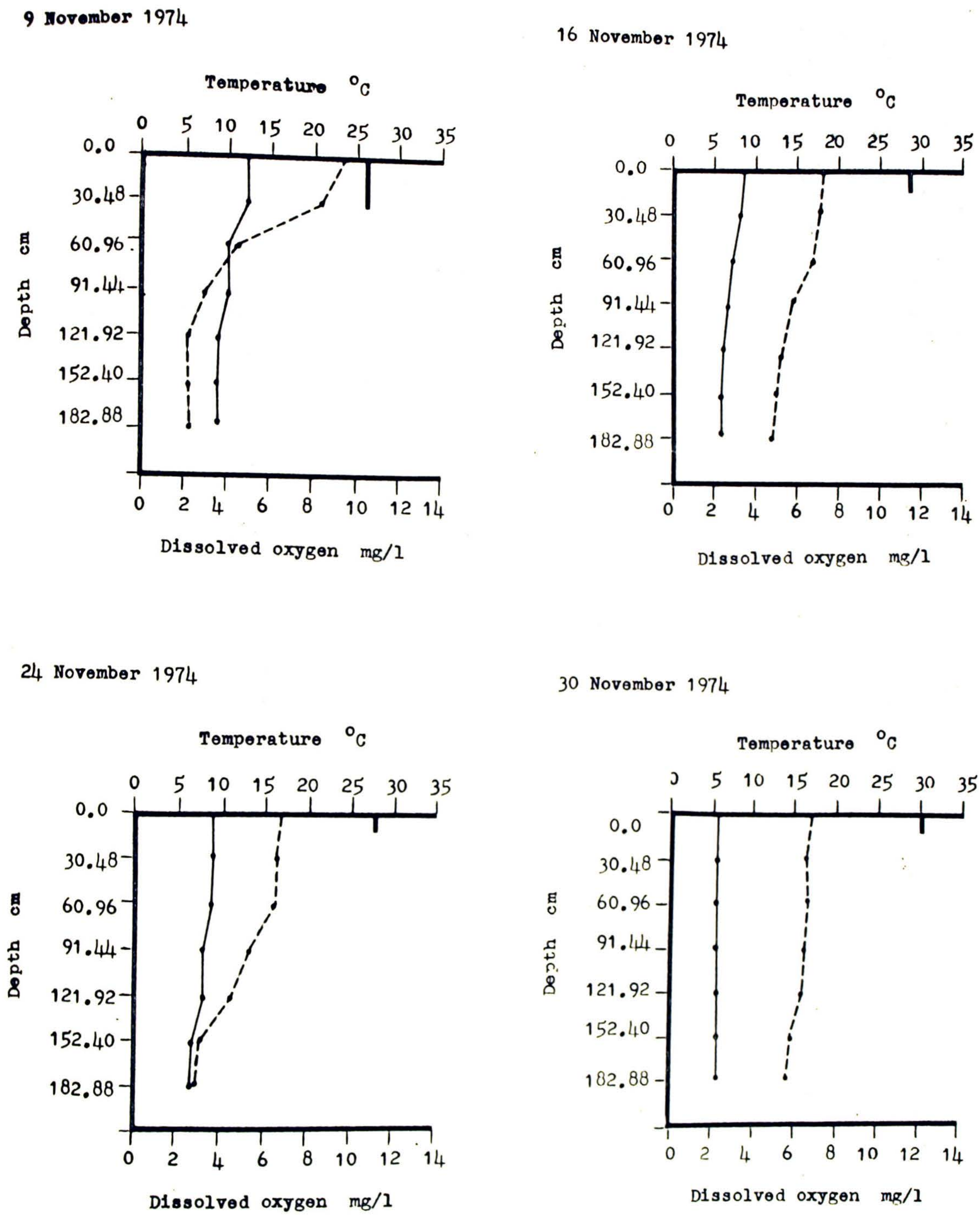
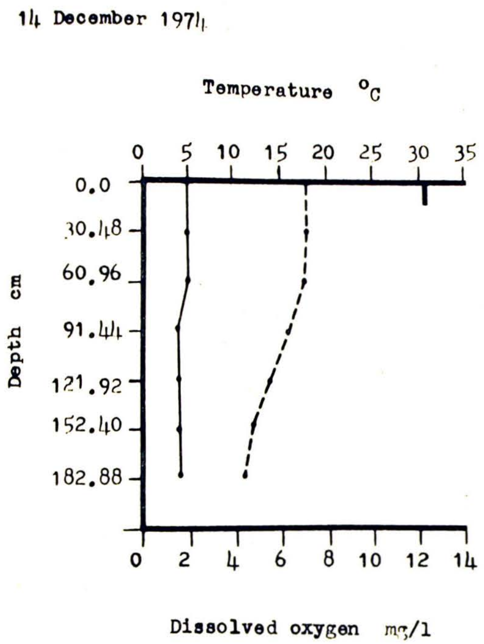
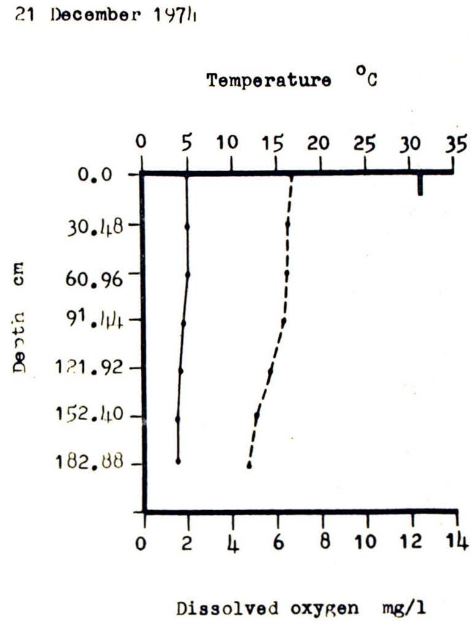


Figure 6. Dissolved oxygen and temperature of a Kentucky farm pond plotted against depth from 9 November 1974 through 30 November 1974. Depth is expressed as cm, temperature (——) is expressed as °C, and dissolved oxygen (---) as mg/l. The heavy dark line corresponds to the dissolved oxygen concentration within 3 mg/l of 100 per cent saturation.





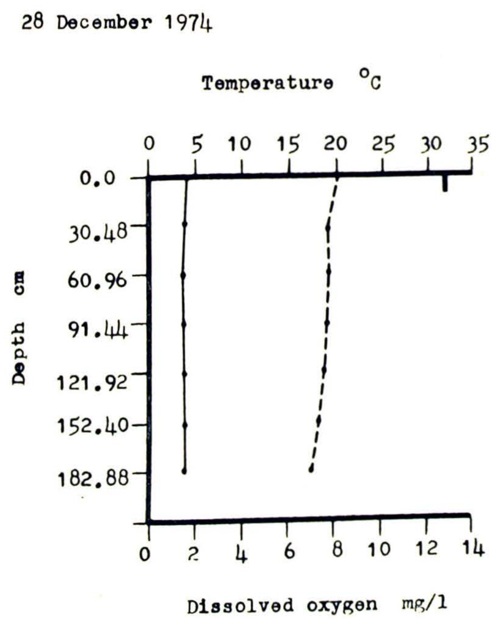


Figure 7. Dissolved oxygen and temperature of a Kentucky farm pond plotted against depth from 14 December 1974 through 28 December 1974. Depth is expressed as cm, temperature (——) is expressed as °C, and dissolved oxygen (---) as mg/l. The heavy dark line corresponds to the dissolved oxygen concentration within 3 mg/l of 100 per cent saturation.

entire water column (Welch, 1952). The close relationship observed between the surface water temperatures and air temperatures is a major factor in controlling the behavior of the water column. Cooling by evaporation was probably only of minor importance. This may be attributed to the warmer air above the cooler water.

Riley (1940) found that the decrease in the plankton was dependent largely on low temperature and light intensity. Throughout the investigation the phytoplankton demonstrated a gradual decline in concentration. This may be correlated with the complementary decline in the water and in the air temperature observed.

Dissolved Oxygen

Dissolved oxygen is considered to be one of the most important indicators of lake types. A skillful limnologist can probably learn more about the nature of a lake from a series of oxygen determinations than from any other kind of chemical data (Hutchinson, 1957).

Oxygen conditions in a lake vary during the year, due to physical factors and the biological activity within the water (Happey, 1970a). Prescott (1962) points out that oxygen is one of the primary limiting and determining factors in phytoplankton ecology. He further explains that by increasing or decreasing the oxygen content algae act as agents in determining the quantity and kinds of animal life which a body of water may support.

Figures 3 through 7 show the dissolved oxygen profiles taken at station I. The dissolved oxygen concentration was observed to be greater in the surface waters than in the bottom waters on all sampling occasions. The dissolved oxygen in the surface waters was observed to be supersaturated on nine occasions. Happey (1970a), in a study of Abbot's Pool, Somerset, found that algae production maintains high levels of dissolved oxygen in the surface layers. Algae have the ability to yield oxygen at a rate of about 1.6 pounds per pound of algae grown (Bartsch, 1961). The maximum dissolved oxygen concentration observed on 27 August 1974 may be attributed to a longer photosynthetic period. Munawar (1970a), in a study of ponds in India, observed that the longer duration of photosynthetic activities of plants in the summer may produce larger quantities of oxygen. Schultz (1952), in an investigation of an Ohio farm pond, observed that the dissolved oxygen peaks were accompanied by maximum phytoplankton populations. This trend was not observed in this study.

On 3 September 1974 a minimum dissolved oxygen concentration of 0.70 milligrams litre (mg/l) was observed in the surface waters. This may be related to the complete circulation of the waters causing large quantities of oxygen to be removed from the water by the absorption by the mud. Happey (1970a) observed that the oxygen uptake at the mud-water interface produced significant levels of oxygen depletion. She also noted that the degree of oxygen depletion depends upon the turbulence of the water and molecular diffusion.

The dissolved oxygen concentration in the bottom waters fell below 1 mg/l during 9 of the 19 weeks sampled. The apparent dissolved oxygen deficit in the bottom waters was possibly related to both physical and biological factors. During the warmer months of August and September 1974 the dissolved oxygen deficit was observed to be greater than in the cooler months of November and December 1974. This may be related to the higher temperatures causing the rate of oxidation of the organic matter to increase; thus, large quantities of oxygen were used in the process. As mentioned earlier, the oxygen uptake at the mud-water interface may have contributed to the dissolved oxygen deficit in the bottom waters. It is this investigator's opinion that the addition of exogenous materials, such as dead leaves, was important in producing the dissolved oxygen deficit of the bottom waters. Hutchinson (1957) explained that exogenous organic materials, such as dead leaves, are important in the deoxygenation of deep waters. Copeland and Whitworth (1964), in a study of four Oklahoma farm ponds, found that high respiration values occurred after a heavy leaf fall and was undoubtedly caused by their decay. Welch (1968) observed, in an investigation of an enriched estuary, that the minimum dissolved oxygen concentrations of the bottom waters are related to the maximum phytoplankton activity. This same trend was demonstrated in this investigation; however, the amount of phytoplankton organic matter that was contributed to the total oxygen demand was not known. As explained by Welch (1968), to definitely establish the degree of oxygen deplicition caused by the phytoplankton organic matter, an examination of the total seston would be required.

The bottom waters showed a gradual increase in dissolved oxygen content throughout the investigation. Again this may have been related to both physical and biological activities in the water. One of the major factors is the cooling of the bottom waters thus increasing the solubility of oxygen at lower temperatures (Reid, 1961). Another explanation may have been that a lower rate of oxidation and decomposition by microorganisms takes place at lower temperatures placing less demand on the dissolved oxygen. Mills and Alexander (1974) in an in vitro study found that decomposition of the algae decreased as the temperature was lowered. A third possible explanation may have been the decline in the total phytoplankton population causing a decreased phytoplankton contribution to the organic matter in the bottom waters.

An inverse relationship was observed between the rainfall and the dissolved oxygen content. Rain may cause the runoff of oxygen consuming compounds to enter the pond and thus lower the dissolved oxygen concentration (Munawar, 1970a).

Secchi Disc Visibility

The importance of light as an environmental factor can not be overemphasized since it is the basis for almost all biological activity in the water (Beeton, 1957). Hutchinson (1957) noted that the Secchi disc reading represents the depth at which five per cent of solar radiation is transmitted. Secchi disc visibility is not an actual measure of light penetration but may provide a relative index when used under standard conditions.

Surface runoff from rainfall normally brings large quantities of suspended particles into the water causing the water to become very turbid. Micheal (1969), in an investigation of fishponds, noted silt being washed in by heavy rains was the greatest cause for the reduction in transparency. Secchi disc readings during this study showed an increase in visibility during the period of low rainfall, from 17 September to 25 October 1974, and a decrease in visibility during the period of heavy rainfall, from 6 August to 10 September 1974. This suggested that surface runoff may have occurred. The mean Secchi disc values are portrayed in Figure 8. Kielhorn (1952) suggested phytoplankton content and detritus control the water transparency.

Beeton (1957) has observed that the distribution and production of phytoplankton are directly related to the quantity of radiant energy penetrating the water. In this investigation the maximum Secchi disc

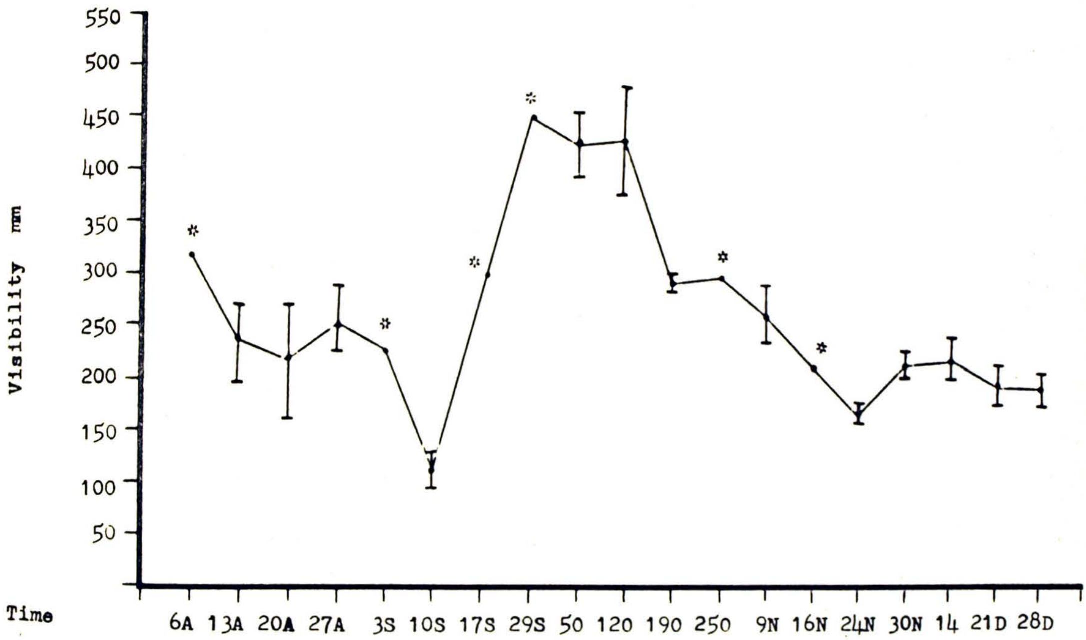


Figure 8. Mean Secchi disc values and standard deviations of a Kentucky farm pond plotted against time from 6 August 1974 through 28 December 1974. Values from stations I, III and IV were lumped to determine the mean. Secchi disc values are expressed as mm of visibility. Abbreviations are the same as in Figure 2. * Indicates the absence of a deviation.

readings corresponded to the minimum phytoplankton concentrations. The maximum phytoplankton concentration also occurred during a time of low Secchi disc values. However, a definite relationship can not be established between the Secchi disc values and the phytoplankton concentrations because the total seston was not measured. Chandler (1944) reported that increased turbidity decreased phytoplankton production by reducing the amount of light that becomes available for photosynthesis.

The low Secchi disc values pictured in Table I may be an indication that the pond is rich in organic matter. Harris and Silvey (1940) related that writers have found more turbid waters to contain more organic matter than less turbid waters over a long period of time.

Total Hardness

Hardness is the total amount of alkaline earth present without regard to the particular anions to which they are bound (Ruttner, 1963).

Total hardness can be related to the productivity of the water, but the biological significance is reduced since it does not express the specific elements involved (Bell, 1973).

The total hardness of a small lake may show a decline for a short period of time when there is an increase in photosynthesis by aquatic vegetation (Tabor, 1966). This relation was not observed between the phytoplankton and the total hardness content in this investigation.

Table I. Secchi disc visibility values from stations I, III, and IV in a Kentucky farm pond from 6 August 1974 through 28 December 1974, Christian County, Kentucky.

Dates	Stations		
	I	III	IV
6 Aug.	*311.15	**. . .	. . .
13 Aug.	190.5	254.0	254.0
20 Aug.	228.6	254.0	152.4
27 Aug.	292.1	254.0	228.6
3 Sept.	228.6	228.6	228.6
10 Sept.	101.6	88.9	127.0
17 Sept.	304.8	304.8	304.8
29 Sept.	457.2	457.2	457.2
5 Oct.	431.8	381.0	457.2
12 Oct.	381.0	431.8	482.6
19 Oct.	304.8	279.4	304.8
25 Oct.	304.8	304.8	304.8
9 Nov.	279.4	241.3	279.4
16 Nov.	215.9	215.9	215.9
24 Nov.	165.1	177.8	165.1
30 Nov.	215.9	203.2	215.9
14 Dec.	203.2	241.3	215.9
21 Dec.	203.2	177.8	203.2
28 Dec.	190.5	203.2	177.8

* Secchi disc values are expressed as mm of visibility

** Periods signify no sample taken

Moderately hard water is sometimes defined as having a hardness between 60 and 120 mg/l (N.T.A.C.R., 1969). In this investigation the total hardness never exceeded 50 mg/l as shown in Figure 9. This indicates that the waters may be considered moderately soft to soft.

The total hardness concentration at all stations demonstrated a high degree of homogeneity over the entire investigation as shown in Table II.

Orthophosphate

Many fresh water biologists have viewed phosphorus as a limiting factor in the production of phytoplankton. Shapiro (1970) noted that phosphorus is usually present in freshwater in the least amount relative to need. Soluble phosphorus occurs in the trophogenic zone of lakes in two forms: in an inorganic form as orthophosphate and in a form that does not react with acidified molybdate called soluble organic phosphorus (Rigler, 1965). It is also known as an essential nutrient for plant growth (Kimmel and Lind, 1970).

The three major sources of phosphorus contribution to waters are organic matter in sewage, phosphorus containing detergents, and phosphorus in the runoff and drainage from farmlands (Verduin, 1967).

Phosphate contribution to the pond from surface runoff may have occurred. This is based upon the heavy use of phosphate containing fertilizers on the surrounding farm land in conjunction with the observed

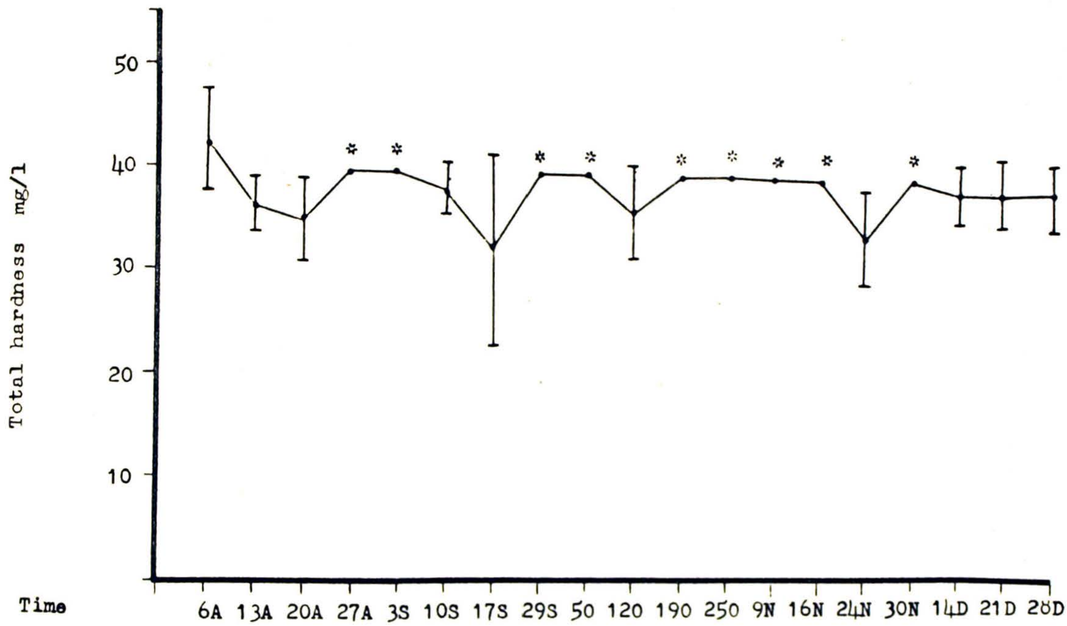


Figure 9. Mean total hardness values and standard deviations of a Kentucky farm pond plotted against time from 6 August 1974 through 28 December 1974. Values from the four stations were lumped to determine the mean. Total hardness is expressed as mg/l. Abbreviations are the same as in Figure 2. * Indicates the absence of a deviation.

Table II. Total hardness values from stations I through IV in a Kentucky farm pond from 6 August 1974 through 28 December 1974, Christian County, Kentucky.

	Stations			
Dates	I	II	III	IV
6 Aug.	*40	50	40	40
13 Aug.	40	35	35	35
20 Aug.	35	40	35	30
27 Aug.	40	40	40	40
3 Sept.	40	40	40	40
10 Sept.	35	40	40	40
17 Sept.	20	40	40	30
29 Sept.	40	40	40	40
5 Oct.	40	40	40	40
12 Oct.	30	40	35	40
19 Oct.	40	40	40	40
25 Oct.	40	40	40	40
9 Nov.	40	40	40	40
16 Nov.	40	40	40	40
24 Nov.	31	30	35	40
30 Nov.	40	40	40	40
14 Dec.	40	40	40	35
21 Dec.	35	40	40	40
28 Dec.	40	40	40	35

* Values are expressed as mg/l of calcium carbonate

relation between the Secchi disc values and the recorded rainfall as mentioned in an earlier section. However, orthophosphate concentrations did not appear to increase following periods of heavy rainfall. The addition of phosphates by agriculture drainage is not fully understood. Numann (1964) and Verduin (1967) pointed out that phosphates are tightly held by the soil and are not easily leached by rain water. A later view is that of McCarty (1967) who points out that agricultural lands can contribute up to 4 pounds of phosphate per acre.

The contribution of phosphates by detergents and organic matter in sewage was not considered as a major contributing source by this investigator because of the absence of an effluent.

Barica (1974) regarded the phosphorus cycle as being internal with released phosphorus being utilized by phytoplankton transformed into dissolved organic matter or particulate form, sedimented and released again to serve as nutrients for new phytoplankton cells. An opposing view is that muds do not provide readily available phosphorus (Fitzgerald, 1970). He points out that once lake muds are depleted of available nutrients by plant production, further production will depend upon nutrients from external sources such as wastewater effluents.

The availability of orthophosphate to the phytoplankton in this pond may be related to the internal cycle of the nutrient. It was observed that after a major decline in the total mean phytoplankton concentration, a sharp rise in the mean orthophosphate concentration was witnessed. The mean orthophosphate values are portrayed in Figure 10. Prescott (1962) in a study of Lake Erie found that soluble phosphorus decreased with the seasonal increase of phytoplankton and increased as the phytoplankton died and decayed. Rigler (1956) in a tracer study of phosphorus in lakes observed that 95 per cent of the phosphorus added may be removed immediately from solution and stored as cell components, especially by bacteria. Organic phosphorus compounds are released into solution from decaying organisms, taken up by bacteria, broken down, and inorganic phosphorus is released (Wyatt and Hayes, 1963).

In this investigation it was observed that during periods of peak orthophosphate concentrations there were also complementary declines in the dissolved oxygen concentrations. This may be related to the iron phosphate complex as described by Ruttner (1963). He noted when ferrous iron and phosphate occur together in the hypolimnion an insoluble ferric phosphate is precipitated when oxygen is present. When there is a lack of oxygen in the sediment the iron can be reduced from ferric to the ferrous form and phosphorus can be released into solution. This may be related to the maximum orthophosphate concentration observed on 24 November, 1974; however, it can not be substantiated. Table III provides the mean orthophosphate values recorded at each station during the investigation.

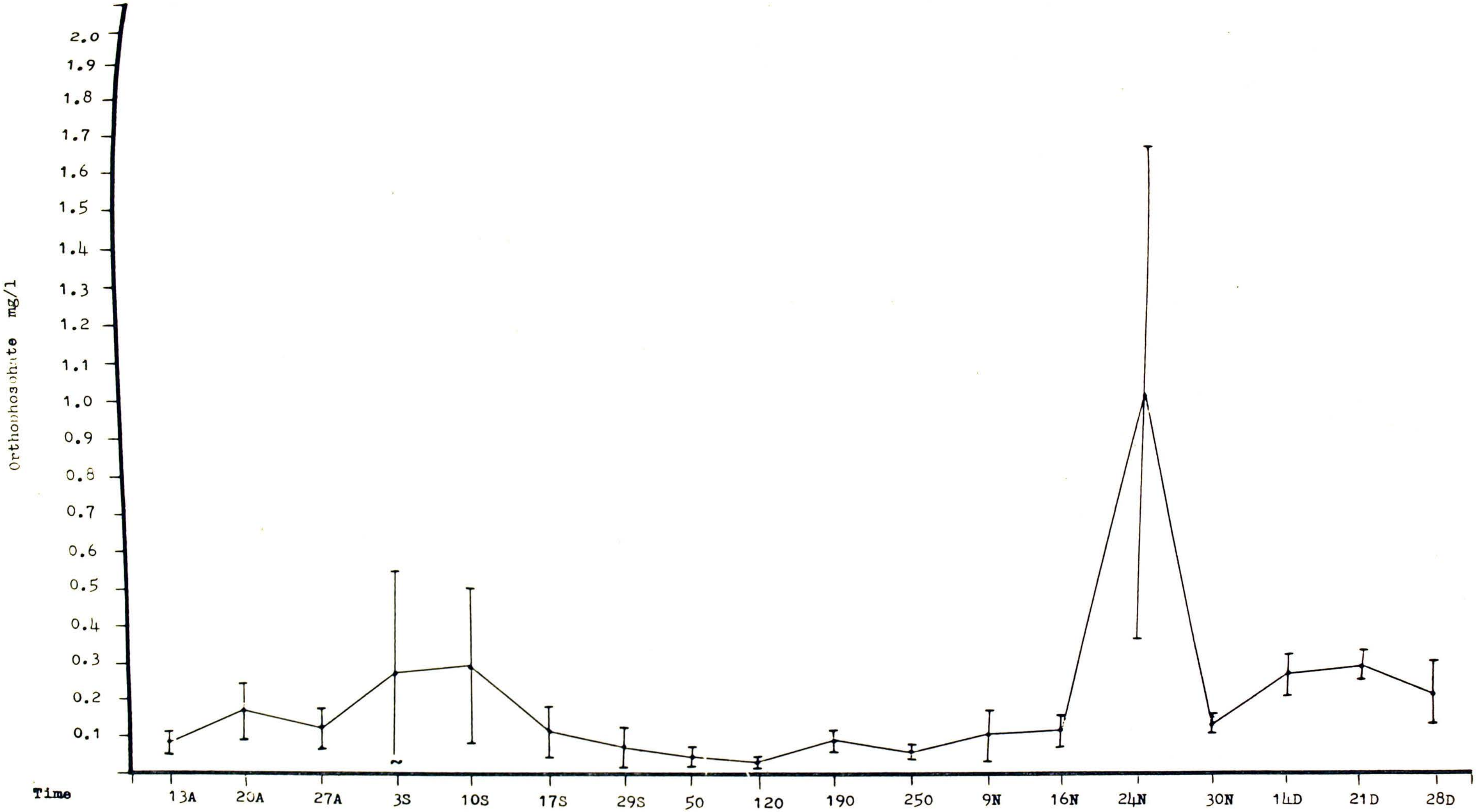


Figure 10. Mean orthophosphate values and standard deviations of a Kentucky farm pond, plotted against time from 13 August 1974 through 28 December 1974. Values were lumped from each of the four stations to determine the mean. Orthophosphate is expressed as mg/l. Abbreviations are the same as in Figure 2.

Table III. Average orthophosphate values from stations I through IV in a Kentucky farm pond from 6 August 1974 through 28 December 1974, Christian County, Kentucky.

	Stations			
Dates	I	II	III	IV
6 Aug.	**. . .	. . .	. . .	. . .
13 Aug.	*0.090	0.080	0.110	0.050
20 Aug.	0.150	0.225	0.250	0.090
27 Aug.	0.100	0.185	0.150	0.050
3 Sept.	0.260	0.085	0.050	0.700
10 Sept.	0.265	0.165	0.145	0.600
17 Sept.	0.115	0.065	0.225	0.060
29 Sept.	0.050	0.150	0.010	0.100
5 Oct.	0.050	0.050	0.035	0.050
12 Oct.	0.020	0.020	0.020	0.035
19 Oct.	0.050	0.100	0.120	0.050
25 Oct.	0.050	0.050	0.050	0.080
9 Nov.	0.150	0.130	0.010	0.125
16 Nov.	0.150	0.070	0.080	0.105
24 Nov.	0.125	1.700	1.100	1.150
30 Nov.	0.105	0.125	0.110	0.150
14 Dec.	0.230	0.335	0.200	0.295
21 Dec.	0.250	0.350	0.290	0.250
28 Dec.	0.150	0.150	0.350	0.190

* Values are expressed as mg/l orthophosphate

** Periods signify no sample taken

Orthosilicate Silicon

The chemistry of silicon compounds in water is not clear, but it appears that orthosilicate silicon is the form that is available for diatom utilization (Lund, 1965). The silicon available to diatoms will be referred to as silica since it is this crystalline form which forms the greater part of most diatom walls (Lund, 1965).

The major source of silica in lakes is from decomposition of aluminosilicate minerals in the drainage basin (Hutchinson, 1957). He subsequently explained that in the presence of water carbon dioxide reacts with silicates to produce carbonates and silica.

In this investigation the silica content was very inconsistent as displayed in Figure 11. Happey (1970b) in an investigation of Abbot's Pool, Somerset, found that the variation in the silica concentration in the epilimnion was considerable and that replacement was from the hypolimnion.

During each month of this investigation an inverse relationship between the silica concentration and the diatom population was observed. Happey (1970c) observed large silica depletions in the surface waters during the year and on each occasion in association with a diatom peak in the phytoplankton. She also found that mineralization from large diatom populations could provide large amounts of silica in the sediment; thus allowing silica to be cycled in the water.

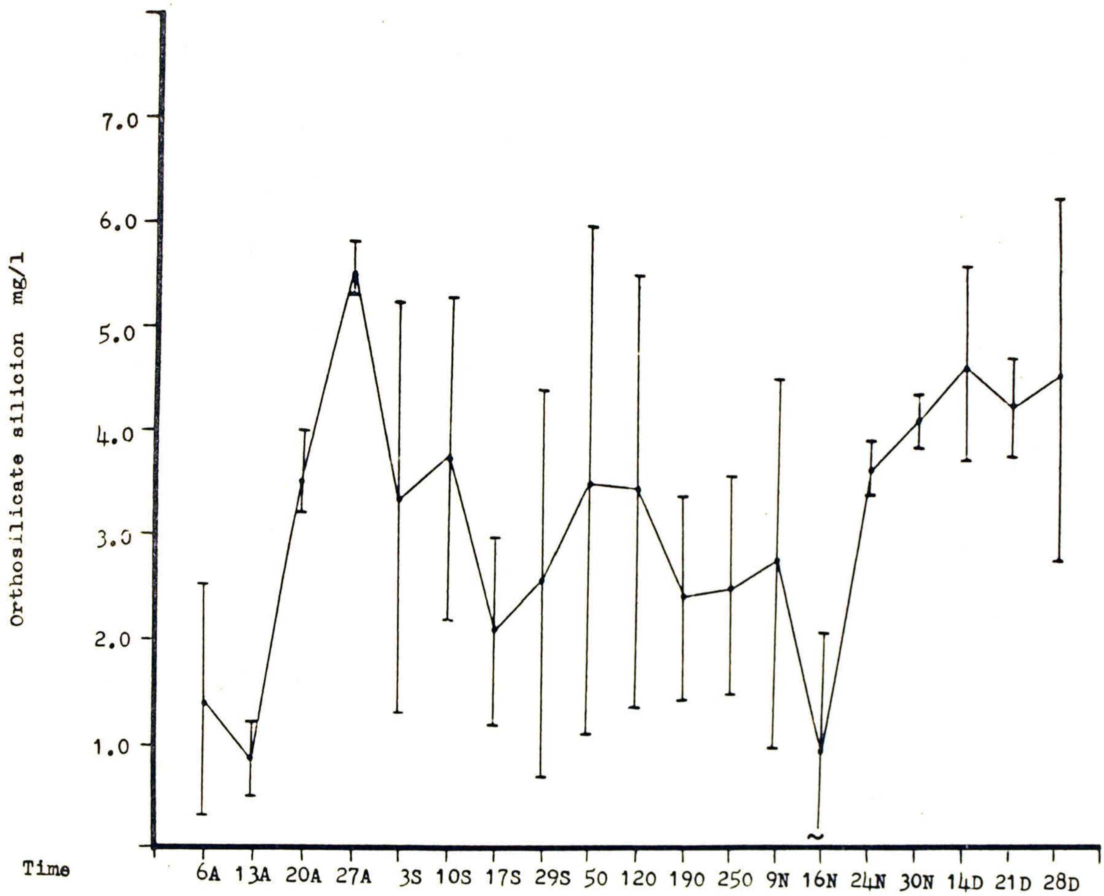


Figure 11. Mean orthosilicate silicon values and standard deviations of a Kentucky farm pond plotted against time from 6 August 1974 through 28 December 1974. Values from the four stations were lumped to determine the mean. Orthosilicate silicon is expressed as mg/l. Abbreviations are the same as in Figure 2.

In this investigation the bottom waters (during the month of August) contained more silica than the surface waters as shown in Table IV. This may suggest the following: (1) mineralization of the diatom frustules, (2) release of silica from the sediment, and (3) diatoms are the major mechanics by which silica is cycled throughout the pond.

Mortimer (1942), in his experimental mudwater tanks from Windermere, found the silica concentration increased more under anaerobic conditions than aerobic conditions. In this investigation the maximum silica concentration occurred in association with de-oxygenated conditions in August 1974.

Nitrate and Ammonium Nitrogen

Nitrogen is a substance that is required by aquatic organisms and usually occurs in small quantities in unpolluted waters (Reid, 1961). Lund (1965) viewed nitrogen as a major component in the production and periodicity of phytoplankton and in determining the type of community present. He also related that nitrogen is not considered as a major nutritional factor as it once was. Algae can use either inorganic or organic nitrogen, but the inorganic nitrogen is preferred (Keeney, 1973).

In this investigation two important forms of inorganic nitrogen were considered nitrate and ammonium. The dominant form of ammonia nitrogen present in water is ammonium nitrogen (Keeney,

Table IV. Average orthosilicate silicon values from stations I through IV in a Kentucky farm pond from 6 August 1974 through 28 December 1974, Christian County, Kentucky.

Dates	Stations I	II	III	IV
6 Aug.	*1.200	3.000	0.300	1.400
13 Aug.	0.600	1.400	0.750	0.600
20 Aug.	3.400	4.200	3.400	3.400
27 Aug.	5.600	6.000	5.500	5.500
3 Sept.	3.000	1.750	6.250	2.370
10 Sept.	5.750	2.500	2.500	4.500
17 Sept.	0.750	2.250	2.875	2.537
29 Sept.	4.750	3.250	0.185	2.380
5 Oct.	7.000	3.000	3.625	0.750
12 Oct.	0.937	2.687	5.000	5.500
19 Oct.	1.125	2.500	3.625	2.700
25 Oct.	2.000	2.250	1.797	4.187
9 Nov.	2.500	0.450	3.925	4.500
16 Nov.	0.275	0.275	0.325	2.750
24 Nov.	3.750	3.875	4.000	3.437
30 Nov.	4.062	4.125	4.125	4.625
14 Dec.	3.625	4.437	5.625	5.500
21 Dec.	4.750	4.187	4.687	3.625
28 Dec.	3.750	4.500	4.250	6.250

* Values are expressed as mg/l orthosilicate silicon

1973). Chu (1943) found all the phytoplankton he investigated could use nitrate nitrogen as the sole source of nitrogen.

Hutchinson (1957) indicated that there are three possible sources of nitrogen compounds. They are (1) influents to the lake, including groundwater, (2) precipitation on the lake surface, and (3) fixation in the lake and its sediments.

Surface runoff from the surrounding croplands may have contributed certain amounts of nitrogen to the pond. This can only be speculated since surface runoff was not measured. The U. S. Department of Agriculture (1976) does not include the cropland in the watershed and consequently they do not consider runoff from the cropland as a nutrient contributing source to the pond. Hill and McCague (1974) near Alliston, Ontario, found the nitrate nitrogen concentrations in a stream near a fertilized grain field increased above those recorded upstream. Lind (1938), in a study of Beauchief ponds Sheffield, indicated rainfall to be responsible for increasing the amount of nitrates in the water. In the temperate zone ammonia is more abundant than nitrate in the rain (Hutchinson, 1957). In this investigation minimum nitrate and ammonium nitrogen concentrations coincide with minimum periods of rainfall. However, the period of maximum rainfall in August does not parallel the maximum nitrate nitrogen concentration. This may be related to the maximum total mean phytoplankton concentration observed at this time.

Neilson and Lewis (1974) observed a general inverse correlation between the amounts of nitrates and phytoplankton. From this they inferred that nitrogenous materials serve as nutrients for phytoplankton and that their profuse growth had reduced the nitrogenous values accordingly.

Nicholas (1965) in a review of nitrates regarded the atmosphere as the major source of nitrogen. Reid (1961) explained the solubility of gases increases as the temperature decreases and nitrogen concentrations increase as temperature decreases. The nitrate and ammonium nitrogen concentration appeared to exhibit an inverse relationship to the surface water temperature during the colder weeks of the investigation. This may have been related to the decreased rate of denitrification during the colder period of the investigation. To definitely prove this would have required measuring the rate of denitrification. Chandler and Weeks (1945) in a study of Lake Erie observed decreased rates of denitrification in association with lower temperatures and increased nitrates during the winter.

The accepted opinion is that the blue-green algae are the dominant nitrogen fixers in surface waters and that bacteria are the dominant nitrogen fixers in oxygen depleted waters and the sediment (Keeney, 1973). Dugdale and Dugdale (1962), have measured the rates of nitrogen fixation by plankton in Sanctuary Lake, Pennsylvania. They found the mean rate to be one per cent of the total nitrogen content.

Findley, Findley, and Stein (1973) in a study of surface nitrogen in Skaha Lake, British Columbia, correlated Gloeotrichia echinulata (J. E. Smith) P. Richter with an increase in nitrogen fixation. However, during this investigation a relationship was not observed between the Cyanophyta population and the nitrogen concentrations. Table V provides the average nitrate nitrogen values recorded at each station during the course of the investigation.

The sharp rise in the nitrate nitrogen content in this investigation was paralleled by a corresponding rise in ammonium nitrogen concentration as pictured in Figures 12 and 13. Both the ammonium and nitrate nitrogen maximums were preceeded by a decline in the total mean phytoplankton concentration. This may suggest increased organic breakdown on sedimentation of the dead cells by nitrifying bacteria (Happey, 1970b). The maximum nitrate nitrogen concentration occurred in conjunction with a sharp decline in ammonium nitrogen and a rise in dissolved oxygen in the bottom waters. Rutter (1963) noted that in the presence of oxygen, ammonia nitrogen is immediately transformed by nitrifying bacteria into nitrate nitrogen. This may account for the sudden decrease in ammonium nitrogen in association with the maximum nitrate nitrogen concentration. However, the ammonium nitrogen concentrations in the bottom waters were greater than in the surface water at this time, as shown in Table VI. This indicates nitrification may not have been the only factor involved in the increased nitrate nitrogen concentration.

Table V. Average nitrate nitrogen values from stations I through IV in a Kentucky farm pond from 6 August 1974 through 28 December 1974, Christian County, Kentucky.

Dates	Stations I	II	III	IV
6 Aug.	*0.660	0.924	0.440	0.264
13 Aug.	1.232	0.528	0.528	0.462
20 Aug.	0.528	0.792	0.484	0.374
27 Aug.	0.572	0.528	0.836	0.462
3 Sept.	0.418	0.396	0.409	0.484
10 Sept.	0.528	0.484	0.418	1.254
17 Sept.	0.506	0.418	0.418	0.396
29 Sept.	0.528	0.308	0.440	0.374
5 Oct.	0.484	0.374	0.396	0.352
12 Oct.	0.352	0.275	0.264	0.264
19 Oct.	0.352	0.352	0.264	0.440
25 Oct.	0.264	0.418	0.506	0.484
9 Nov.	0.308	0.352	0.440	0.264
16 Nov.	0.462	0.528	0.594	0.308
24 Nov.	0.451	0.616	0.704	0.660
30 Nov.	0.946	0.880	1.100	0.902
14 Dec.	1.848	1.870	2.046	1.980
21 Dec.	2.530	2.112	2.420	2.288
28 Dec.	2.860	2.915	2.750	2.750

* Values are expressed as mg/l nitrate nitrogen

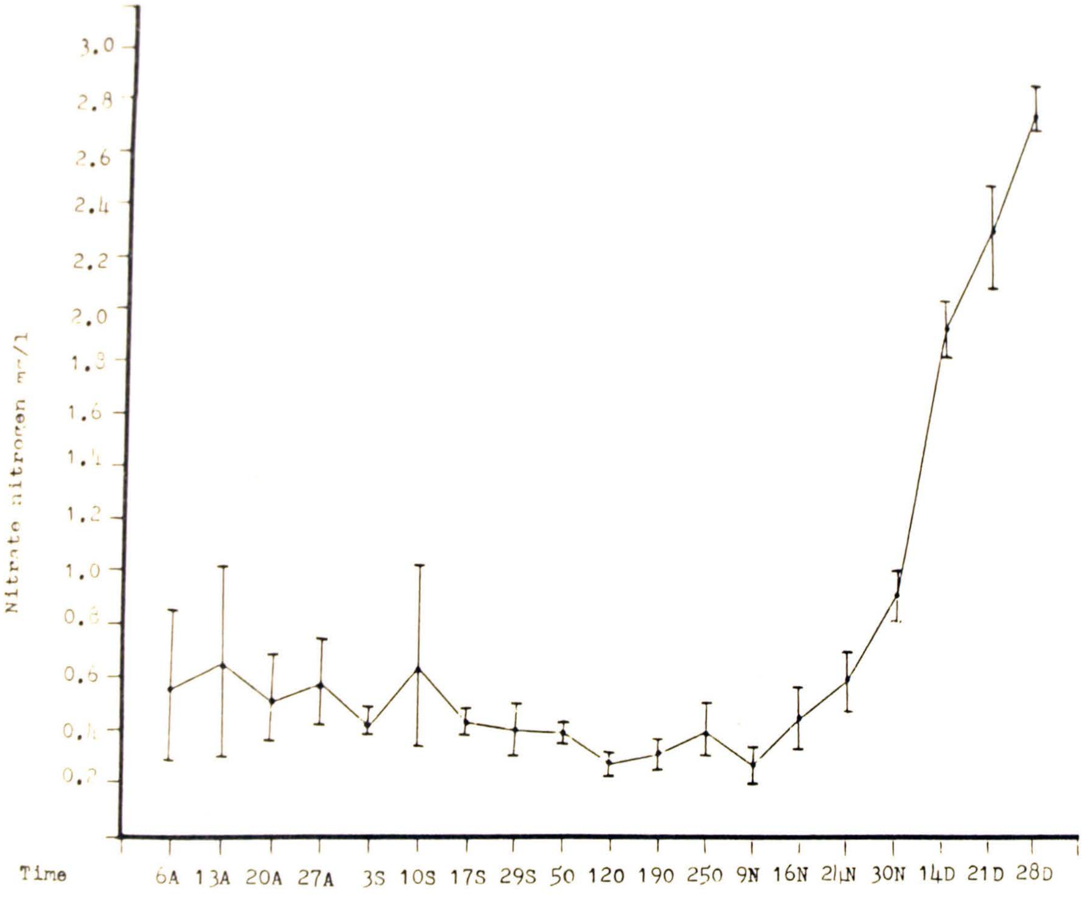


Figure 12. Mean nitrate nitrogen values and standard deviations of a Kentucky farm pond plotted against time from 6 August 1974 through 28 December 1974. Values from the four stations were lumped to determine the mean. Nitrate nitrogen is expressed as mg/l. Abbreviations are the same as in Figure 2.

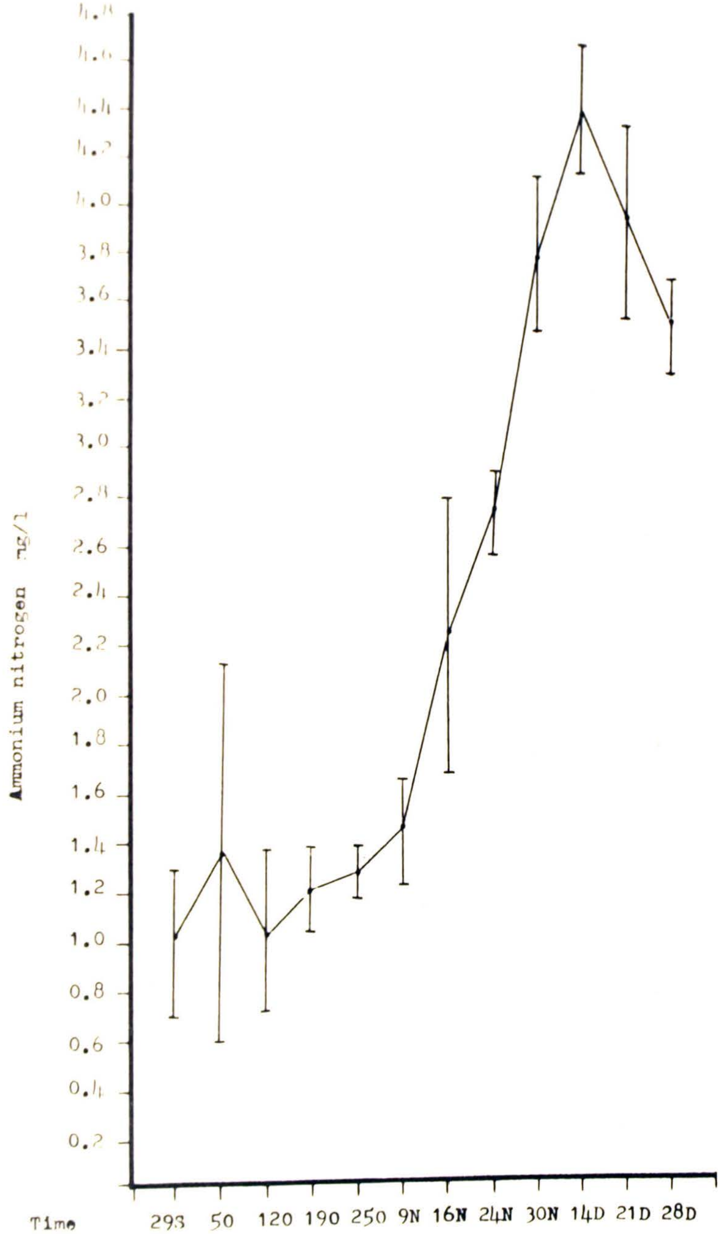


Figure 13. Mean ammonium nitrogen values and standard deviations of a Kentucky farm pond plotted against time from 29 September 1974 through 28 December 1974. Values from the four stations were lumped to determine the mean. Ammonium nitrogen is expressed as mg/l. Abbreviations are the same as in Figure 2.

Table VI. Average ammonium nitrogen values from stations I through IV in a Kentucky farm pond from 29 September 1974 through 28 December 1974, Christian County, Kentucky.

Dates	Stations I	II	III	IV
29 Sept.	*1.412	**. . .	1.032	0.877
5 Oct.	2.480	1.148	1.206	0.703
12 Oct.	0.599	1.341	1.070	1.264
19 Oct.	1.380	1.090	1.322	1.032
25 Oct.	1.283	1.322	1.148	1.393
9 Nov.	1.741	1.496	1.283	1.283
16 Nov.	1.909	1.960	3.083	2.115
24 Nov.	2.547	2.676	2.844	2.954
30 Nov.	3.431	4.024	4.179	3.676
14 Dec.	4.450	4.747	4.515	4.076
21 Dec.	3.680	4.515	3.870	3.870
28 Dec.	3.483	3.341	3.818	3.483

* Values are expressed as mg/l ammonium nitrogen
** Periods signify no sample taken

It seems apparent that one single factor is not responsible for the increased or decreased nitrate and ammonium nitrogen concentrations observed during the investigation.

A.P.H.A. (1971) regards the presence of ammonia nitrogen in raw surface waters as uncommon and indicates domestic pollution. The high concentrations of ammonium nitrogen may be related to the direct use of the pond by cattle.

The average nitrate nitrogen concentration exceeded 1.0 mg/l from 30 November through the end of the study. Patrick (1948) described eutrophic waters as having nitrogen concentrations of 1.0 to 2.0 mg/l. From Patrick's view point, the pond may be classified as eutrophic.

pH

Hydrogen-ion concentration (pH) has two important limnological values: (1) as a limiting factor and (2) as an index of general environmental conditions (Welch, 1952).

As represented in Figure 14, the pH generally showed a gradual decline throughout the investigation. Table VII provides the mean pH values recorded at each station.

Wade (1949) in an investigation of Michigan Lake remarked when phytoplankton populations are low, pH is also low due to the large amounts of carbon dioxide in the water; when phytoplankton

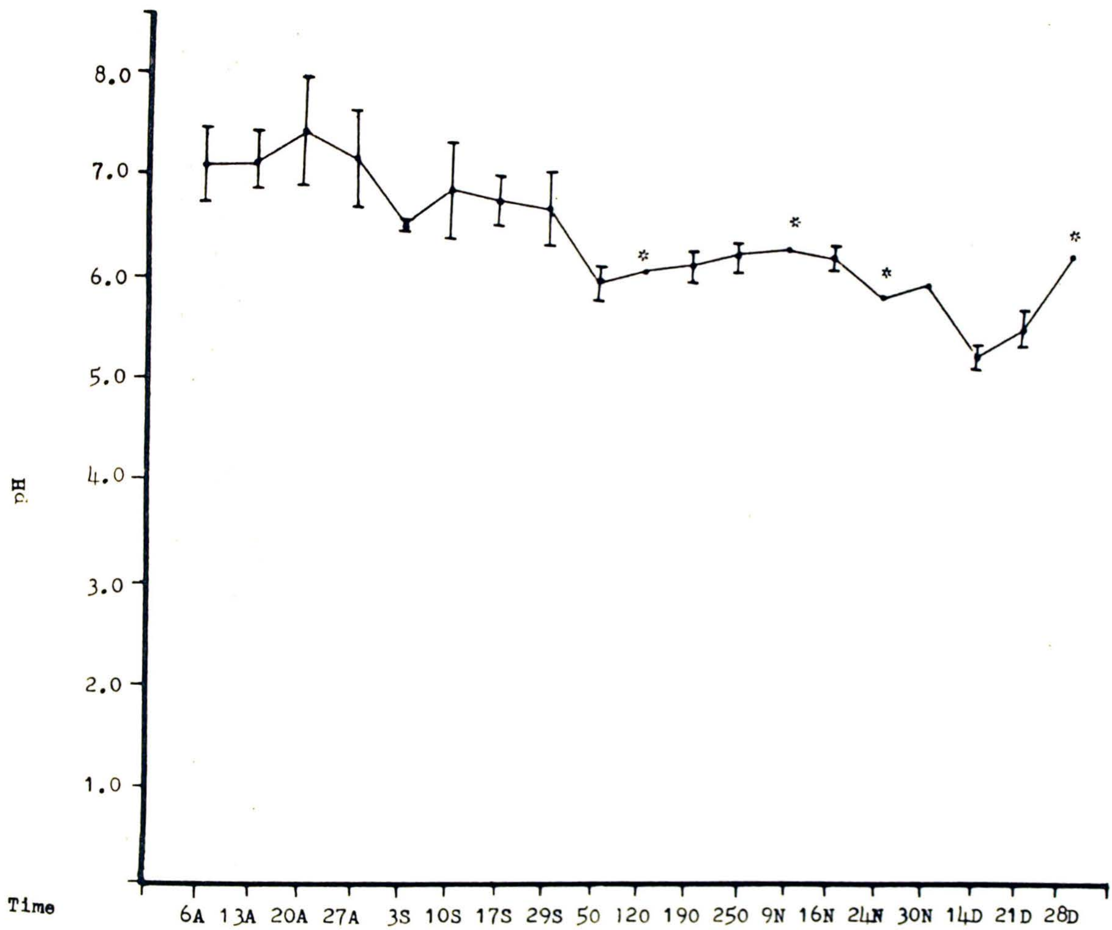


Figure 14. Mean pH values and standard deviations of a Kentucky farm pond plotted against time from 6 August 1974 through 28 December 1974. Values from each of the four stations were lumped to determine the mean. Abbreviations are the same as in Figure 2. * Indicates the absence of a deviation.

Table VII. pH values from stations I through IV in a Kentucky farm pond from 6 August 1974 through 28 December 1974, Christian County, Kentucky.

Dates	Stations I	II	III	IV
6 Aug.	7.3	6.6	7.3	7.2
13 Aug.	6.9	6.9	7.2	7.4
20 Aug.	7.0	6.9	7.8	8.1
27 Aug.	7.6	6.6	7.0	7.6
3 Sept.	6.6	6.6	6.5	6.5
10 Sept.	7.3	6.3	6.9	7.3
17 Sept.	6.8	6.6	6.6	7.2
29 Sept.	7.2	6.8	6.5	6.4
5 Oct.	6.1	5.8	6.1	6.1
12 Oct.	6.2	6.2	6.2	6.2
19 Oct.	6.3	6.2	6.3	6.4
25 Oct.	6.4	6.2	6.4	6.4
9 Nov.	6.4	6.4	6.4	6.5
16 Nov.	6.2	6.4	6.4	6.5
24 Nov.	5.9	5.9	6.0	6.0
30 Nov.	6.1	6.1	6.1	6.1
14 Dec.	5.3	5.3	5.5	5.4
21 Dec.	5.4	5.6	5.6	5.9
28 Dec.	6.4	6.4	6.4	6.4

populations increase, the pH rises with the precipitation of monocarbonates.

In this investigation the maximum and minimum mean pH values appear to be related to periods of high and low phytoplankton concentrations. Yongue and Cairs (1971) in a study of a micro-habitat postulated pH increases with temperature; the increase is associated with the appearance and subsequent growth of algae. In this investigation the maximum mean pH value coincided with the maximum surface temperature. This relationship could possibly be due to a high concentration of phytoplankton present at that time. Neilson and Lewis (1974) also observed a gradual increase in the pH as the phytoplankton increased.

Specific Conductance

Specific conductance is a measure of the waters capacity to conduct an electric current (Lind, 1974). He further related that the greatest value of specific conductance to the limnologist is the estimation of the total concentration of dissolved ionic matter in the water which is related to water fertility. Smith (1962) explained the relationship between the concentration of solutes and conductivity is not linear and varies for different electrolytes. He also noted that the conductance of electrolytes is directly associated with temperature. The specific conductance readings recorded at station I are portrayed in Figure 15. The specific conductance of the surface water appears to be related

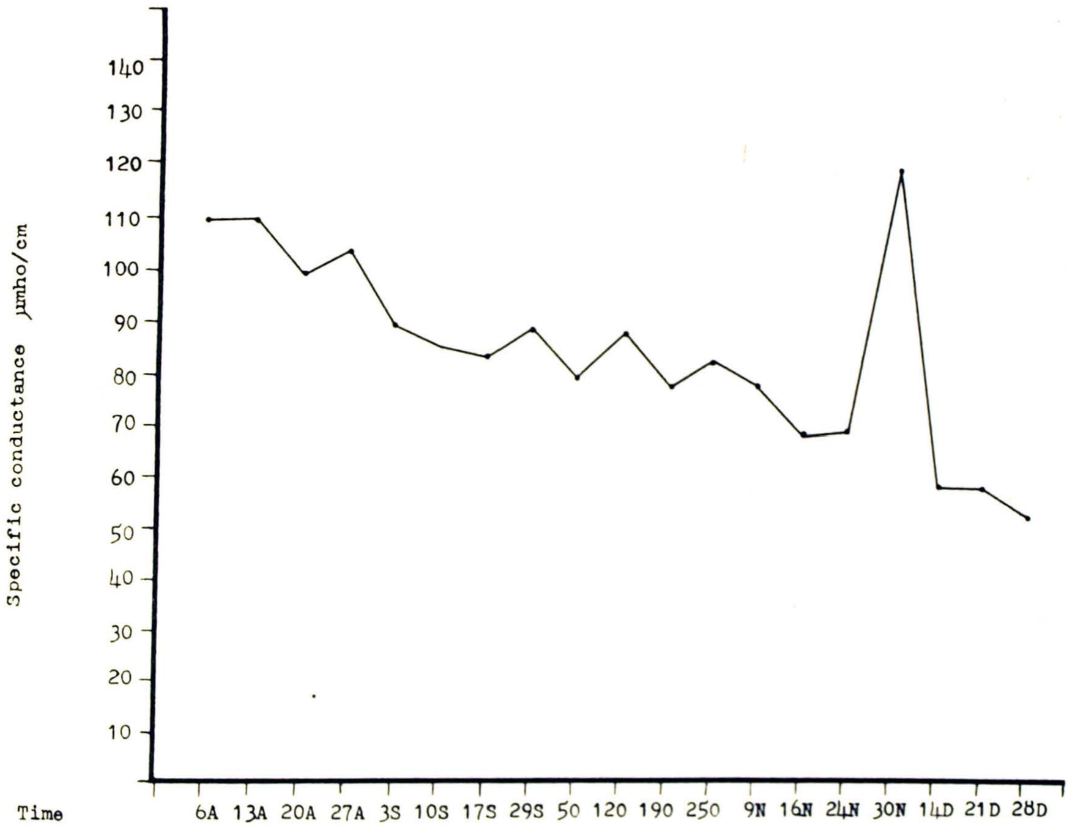


Figure 15. Specific conductance recorded at station I of a Kentucky farm pond plotted against time from 6 August 1974 through 28 December 1974. Specific conductance is expressed as µmho/cm. Abbreviations are the same as in Figure 2.

to the surface water temperatures; with the specific conductance readings paralleling the surface water temperatures. However, on 30 November 1974 there was a marked increase in the specific conductance in association with declining temperatures. This reading may have resulted from a decrease in the total mean phytoplankton concentration. Park and Curl (1965) observed an inverse relationship between photosynthetic activity and specific conductance due to transformation of bicarbonate ion to the carbonate ion and carbonate to bicarbonate by respiration.

Precipitation

The month of August received the most rainfall during the investigation with a total of 271.25 mm and a daily average of 8.73 mm of rainfall. The minimum amount of rainfall was recorded in October with a total of 36.64 mm and a daily average of 1.17 mm, as portrayed in Figure 16.

Phytoplankton

The total phytoplankton population observed was represented by five separate divisions during the investigation. The five divisions were represented by a total of seventy-eight taxa and four unidentifiable taxonomic forms.

The concentration of phytoplankton in lakes is extremely variable, but the algae can occur in the hundreds of thousands to tens

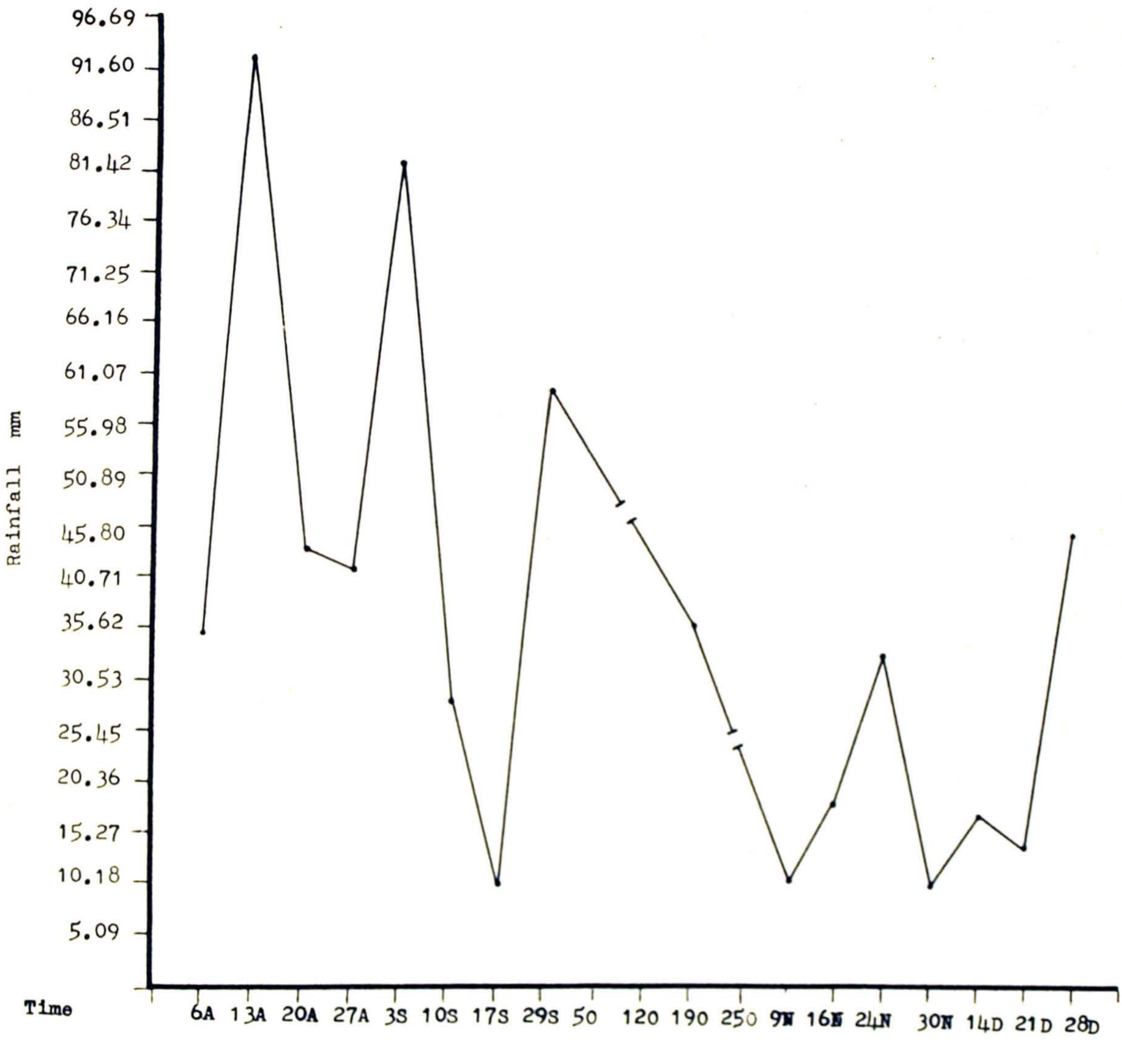


Figure 16. Total weekly rainfall of a Kentucky farm pond plotted against time from 6 August 1974 through 28 December 1974. Rainfall is expressed as mm. Abbreviations are the same as in Figure 2.

of millions of cells per litre (cells/l) (Pennak, 1946). In this investigation the maximum total mean phytoplankton concentration was observed on 27 August 1974 with 998, 137, 152 cells/l. A minimum total mean phytoplankton concentration of 20, 570 cells/l was observed on 19 October 1974.

The horizontal distribution of the phytoplankton was slight, with all the surface stations having approximately the same concentration. In small lakes the horizontal distribution of the phytoplankton is characteristically uniform (Round, 1965).

There was a noticable variation in the vertical distribution of the phytoplankton observed. The surface waters consistently demonstrated higher concentrations than the bottom waters during the peak phytoplankton concentrations. Round (1965) further pointed out that variations in the vertical plane are characteristic of all lakes. Moreover, cell numbers rise in the epilimnion, so long as other limiting factors do not interfere.

Chlorophyta

The Chlorophyta population revealed a general decline in concentration from 27 August through 30 November 1974 as evidenced in Figure 17. The division was represented by 23 taxa and 2 unidentifiable forms. The number of taxa representing the division at any one sampling time ranged from zero on 16 and 24 November to 12 taxa on 29 September 1974.

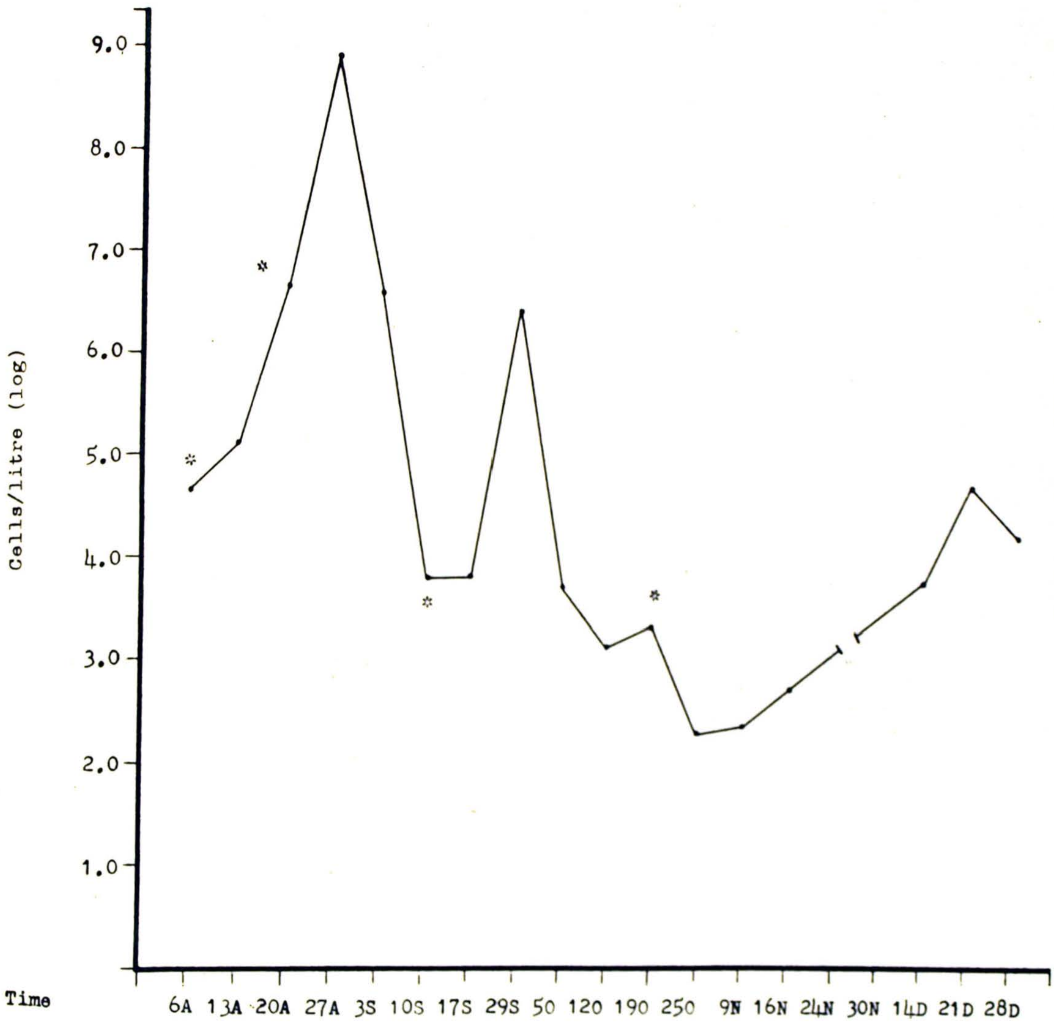


Figure 17. Mean phytoplankton counts of the division Chlorophyta from a Kentucky farm pond plotted against time from 6 August 1974 through 28 December 1974. Counts are expressed as cells/litre (log). Values were averaged from each of the four stations except where indicated (*). Abbreviations are the same as in Figure 2.

Table VIII provides the average per cent composition of phytoplankton of the division Chlorophyta. Volvox species (sp.) Linnaeus was the dominate taxon during the months of August and September. The large numbers of Volvox sp. may be related to mechanical injury during the counting process, causing the colony to fragment. Volvox tertius Meyer was the most persistent representative of the division. It was present in 14 of the 19 weeks sampled.

When the Chlorophyceae were in the greatest abundance the pH ranged from 6.0 to 7.4. Phillips and Whitford (1959) in an investigation of Boone Pond, North Carolina, observed that the Chlorophyceae were the most abundant when the pH ranged from 6.4 to 7.0. Gorham (1965) related the Chlorophyceae preference for a relatively low pH may be the manifestation of a high carbon dioxide demand.

According to Rawson (1956) the number of species of Chlorococcales may exceed the number of species of Desmideaceae in eutrophic waters. The only desmid observed was Netrium interruptum (Bresbission) Lutkemuller which occurred in only very small numbers on 19 October and 28 December 1974. Strom (1924, as reported by Staker, Hoshaw, and Everett, 1974) indicated the absence of desmids can be expected in contaminated waters as an indication of eutrophication.

The large Volvocine population may be an indication of a rise in organic matter as described by Munawar (1970b). During the zenith

Table VIII. Per cent composition of the division Chlorophyta from stations I through IV in a Kentucky farm pond from 6 August 1974 through 28 December 1974, Christian County, Kentucky.

	Sampling Period																		
Taxon	6/A	13/A	20/A	27/A	3/S	10/S	17/S	29/S	5/O	12/O	19/O	25/O	9/N	16/N	24/N	30/N	14/D	21/D	28/D
Ankistrodesmus (falcatus?) (Corda) Ralfs						*0.07													
Coelastrum microporum Naegeli								0.02											
Coelastrum sphaericum Naegeli	2.01	0.11						0.01											
Crucigenia quadrata Morren				0.0002				0.06	4.16										
Crucigenia rectangularis (Braun) Gay								0.76											
Kentrosphaera (gloeophila?) (Bohlin) Brunnthaler					0.02					1.80	1.44								
Kirchneriella sp. Schmidle											2.88								
Microspora sp. Thuret					0.01														

Table VIII. (continued)

Taxon	6/A	13/A	20/A	27/A	3/S	10/S	17/S	29/S	5/O	12/O	19/O	25/O	9/N	16/N	24/N	30/N	14/D	21/D	28/D
										Sampling Period									
Netrium interruptum (Brebission) Lutkemuller											1.15								0.04
Scenedesmus abundans var. brevicauda G. M. Smith								0.31											
Scenedesmus armatus (chodat) G. M. Smith	10.78		0.19					0.02											
Scenedesmus quadricauda Turpin								0.06											
Scenedesmus sp. Meyer		0.53				0.08		0.11											
Selenastrum minutum (Naegeli) Collins	1.16	0.13																0.30	
Selenastrum sp. Reinsch							0.16	0.30	1.66	2.65	5.77			0.06					
Spirogyra sp. Link							0.21										10.70	58.35	18.60
Tetraedron muticum (Braun) Hansgirg	0.95																		

Table VIII. (continued)

Taxon	Sampling Period 6/A	13/A	20/A	27/A	3/S	10/S	17/S	29/S	5/O	12/O	19/O	25/O	9/N	16/N	24/N	30/N	14/D	21/D	28/D
Tetraedron hastatum var. palatinum (Schmidle) Lemmerman					0.003														
Ulothrix tenerrima Kützing																			10.62
Undentifiable colony	3.30					0.60		2.96											
Unidentifiable single cell		0.86	0.03	0.0001			2.70												
Volvox sp. Linnaeus fragmented colony		45.85	92.24	99.94	96.64	0.15	1.67	92.87											
Volvox tertius Meyer	2.21	7.82	2.24	0.01	0.31	0.53	1.77				1.36	0.54	0.01	0.03			1.42	0.06	0.09
Volvox tertius Meyer daughter colony		10.28	4.79	0.03	0.41	0.87													
Zygnema sp. Agardh								0.004											
Total	20.91	65.58	99.49	99.98	97.39	2.30	6.51	97.48	5.82	4.45	12.60	0.54	0.01	0.09			12.12	58.71	29.35

* Represents the mean value of the four stations for each sampling period

of the Volvocine population in August, nitrate nitrogen and orthophosphate concentrations were characteristically low. Prescott (1962) viewed the Chlorophycean lake as having a minimum of nitrogen and phosphorus; furthermore, he related that they seldom, if ever, formed a bulky bloom.

O'Brien and De Noyelles (1974) in a nutrient enrichment study observed that large phytoplankton species are generally not grazed by zooplankton. The ungrazed species might be expected to exhibit large concentrations paralleling the nutrient concentration. This may explain why the Chlorococcales did not become abundant. Patrick and Strawbridge (1963) in a study of the predator-prey relationship observed that in a highly competitive system with many steps in the food chain the predator-prey relationship is more effective. This tends to prevent any species from becoming too numerous. The possible role played by the zooplankton in regulating the phytoplankton would only be conjecturable, since the zooplankton were not examined.

Spirogyra sp. Link was the only Conjugate to achieve dominance. On 21 December 1974 Spirogyra sp. represented 58.35 per cent of the total mean phytoplankton population of 137,210 cells/l. Prescott (1962) noted that some species of Spirogyra are found in shallow water rich in organic acids and where there are large amounts of decaying vegetation. The study pond had an abundance of leaf litter and possibly large amounts of organic acids making it a suitable habitat for Spirogyra sp.

Cyanophyta

The division Cyanophyta was sporadic in appearance and was only present in nine of the 19 weeks sampled as shown in Figure 18. The number of separate taxa present during any one sampling period ranged from zero on nine occasions to four taxa on 3 September 1974. The division was represented by 11 different taxa during the investigation.

The absence of large numbers of Cyanophyta and Chrysophyta may be related to the softness of the water. Prescott (1962) remarked that Cyanophyta and Chrysophyta are typically found in hard waters.

Vance (1965) explained that large numbers of Cyanophyta are present only in waters with high organic matter. The Cyanophyta only achieved dominance once during the investigation and that was during a period of low Euglenophyta growth on 5 October 1974. The dominant Cyanophyta taxa were *Anacystis* sp. Meneyhinie and *Anacystis marina* Drouet and Daily. Both taxa composed 66.38 per cent of 108,157 cells/l of the total mean phytoplankton population as shown in Table IX.

Vance (1965) also explained that certain species of *Euglena* may inhibit the growth of Cyanophyta. The Euglenophyta were abundant throughout the survey and may have been responsible for the low Cyanophyta population.

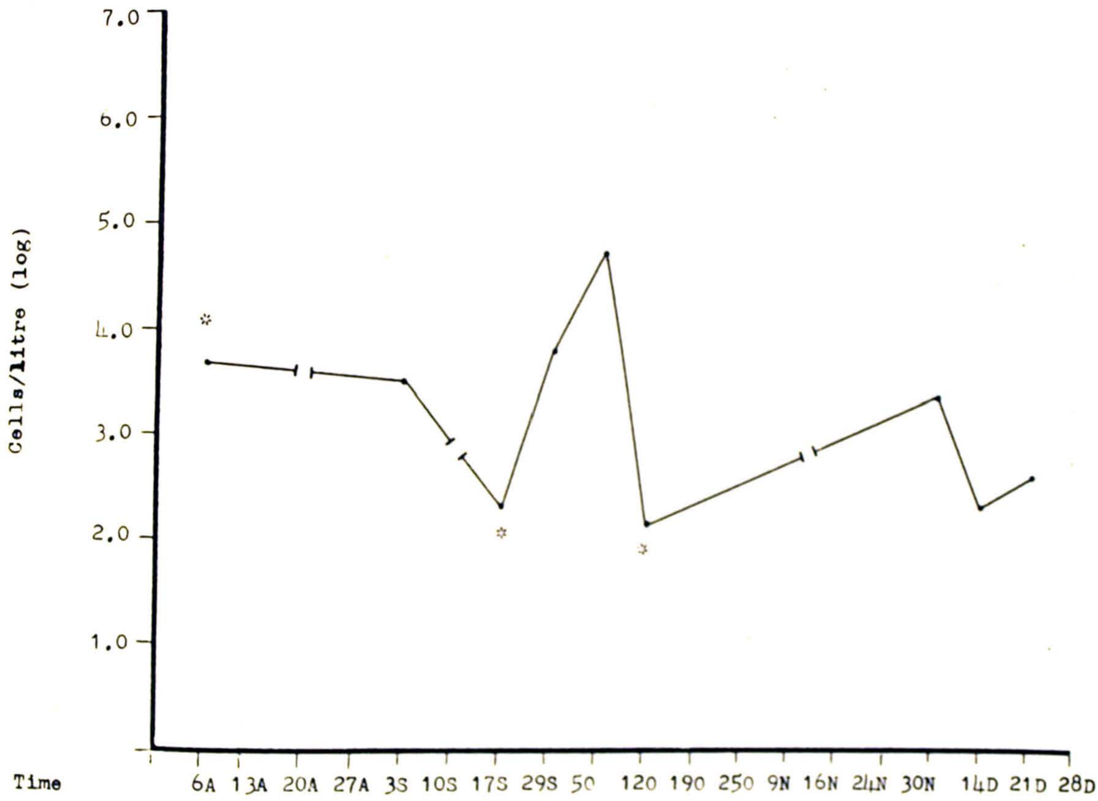


Figure 18. Mean phytoplankton counts of the division Cyanophyta from a Kentucky farm pond plotted against time from 6 August 1974 through 28 December 1974. Counts are expressed as cell/litre (log). Values were averaged from each of the four stations except where indicated (*). Abbreviations are the same as in Figure 2.

Table IX. Per cent composition of the division Cyanophyta from stations I through IV in a Kentucky farm pond from 6 August 1974 through 28 December 1974, Christian County, Kentucky.

	Sampling Period																	
Taxon	6/A	13/A	20/A	27/A	3/S	10/S	17/S	29/S	5/O	12/O	19/O	25/O	9/N	16/N	24/N	30/N	14/D	21/D	28/D
Anacystis cyanea Drouet and Daily	*1.90				0.01												0.12		
Anacystis incerta Drouet and Daily										0.44									
Anacystis marina Drouet and Daily									33.18										
Anacystis montana (Lightfoot) Drouet and Daily							0.21												
Anacystis thermalis (Meneghini) Drouet and Daily								0.20											
Anacystis sp. Meneghini					0.01				33.20										
Coccochloris sp. Sprengel					0.03														
Spirulina laxa G. M. Smith																0.12			

Table IX. (Continued)

Taxon	Sampling Period																		
	6/A	13/A	20/A	27/A	3/S	10/S	17/S	29/S	5/O	12/O	19/O	25/O	9/N	16/N	24/N	30/N	14/D	21/D	28/D
Spiralina princeps (West and West) G. S. West																	0.30	0.38	
Spiralina sp. Turpin					0.02														
Unidentifiable colony																1.25			
Total	1.90				0.07		0.21	0.20	66.38	0.44						1.37	0.42	0.38	

* Represents the mean value of the four stations for each sampling period

Euglenophyta

The Euglenophyta population was represented by six identifiable taxa. They and the order that includes the unidentifiable species is shown in Table X. The division was represented in all the samples examined and it was the dominant division of the total phytoplankton population in 10 of the 19 weeks sampled.

The maximum Euglenophyta population occurred on 9 November 1974 representing 99.59 per cent of the 1,944,057.5 cells/l of the total mean phytoplankton population.

Periods of maximum Euglenophyta development were associated with maximum orthophosphate concentrations and generally low dissolved oxygen concentrations. Figure 19 represents the mean Euglenophyta population throughout the investigation. Munawar (1970b) in a study of several ponds in India observed the Euglenales in association with the oxygen-iron-phosphate complex. The unidentifiable Euglenales were the most persistent in occurrence throughout the study.

In a study of Lake Louise, North Carolina, McCoy (1970) found a positive correlation between populations of Trachelomonas sp. and inorganic nitrogen. The above correlation was not observed during this investigation.

Vance (1965) pointed out that the presence of all essential elements may not result in the rapid growth of any of the algae. He suggested that organic substances play a role in the development of

Table X. Per cent composition of the division Euglenophyta from stations I through IV in a Kentucky farm pond from 6 August 1974 through 28 December 1974, Christian County, Kentucky.

Taxon	Sampling Period																		
	6/A	13/A	20/A	27/A	3/S	10/S	17/S	29/S	5/O	12/O	19/O	25/O	9/N	16/N	24/N	30/N	14/D	21/D	28/D
Euglena acus Ehrenberg	*1.43	1.12	0.05		0.04	1.51	0.74	0.01					0.03						
Euglena sp. Ehrenberg									11.19										
Phacus (helikorides ?) Pochmann					0.01														
Pacus orbicularis Huebner	0.57	0.86																	
Phacus sp. Dujardin	1.72		0.03			0.07	0.21	0.02		0.90									
Trachelomonas sp. Ehrenberg	56.78	6.78	0.10	0.01	1.88	88.0	85.75	1.15	1.13										
Unidentifiable Euglenales	15.34	22.98		0.001	0.39	6.18	0.47	0.86		15.36	61.04	84.18	99.56	99.58	72.48	96.98	76.38	11.61	15.49
Total	75.84	31.74	0.18	0.011	2.32	95.76	87.17	2.04	12.32	16.26	61.04	84.18	99.59	99.58	72.48	96.98	76.38	11.61	15.49

* Represents the mean value of the four stations for each sampling period

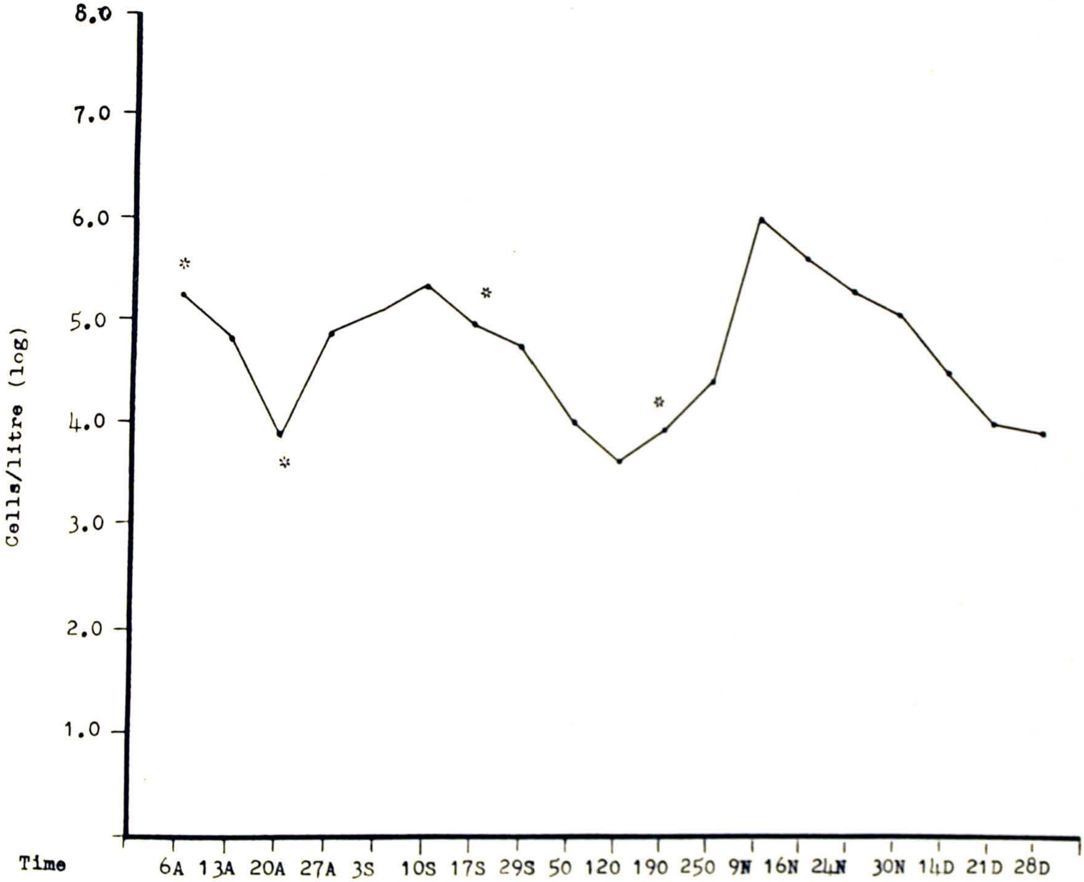


Figure 19. Mean phytoplankton counts of the division Euglenophyta from a Kentucky farm pond plotted against time from 6 August 1974 through 28 December 1974. Counts are expressed as cells/litre (log). Values were averaged from each of the four stations except where indicated (*). Abbreviations are the same as in Figure 2.

large populations. Graham and McCoy (1974) in a laboratory study of Trachelomonas hispida (Perty) Stein related that large numbers of Euglenales are associated with high dissolved organic content. The development of the Euglenales population as a result of organic content can only be suggested because organic production was not measured.

Chrysophyta

The Chrysophyta population was represented during the investigation by the Chrysomonadales and the Bacillariophyceae. The Bacillariophyceae were enumerated as either the Centrobacillariophyceae or the Pennatobacillariophyceae as shown in Table XI.

The Centrobacillariophyceae were represented by Cyclotella sp. Kutzing on nine occasions and by Melosira sp. Agardh on one occasion.

The Pennatobacillariophyceae were represented by 39 separate taxa. Synedra ulna (Nitzsch) Ehrenberg was the most persistent representative of the Chrysophyta population. It was represented in 16 of the 19 weeks sampled.

The Chrysomonadales were represented by Dinobryon sertularia Ehrenberg on 16 November and 24 November 1974.

The Chrysophyta population indicated a general increase in concentration throughout the investigation as shown in Figure 20. An inverse relationship was found to exist between the Chrysophyta population and the surface water temperature. Chandler (1944) in an

Table XI. Per cent composition of the division Chrysophyta from stations I through IV in a Kentucky farm pond from 6 August 1974 through 28 December 1974, Christian County, Kentucky.

Taxon	Sampling Period																		
	6/A	13/A	20/A	27/A	3/S	10/S	17/S	29/S	5/O	12/O	19/O	25/O	9/N	16/N	24/N	30/N	14/D	21/D	28/D
Bacillariophyceae																			
Centrobacillariophyceae						*0.13		0.004		3.50	0.71	1.29			0.30		3.73	0.73	2.06
Pennatobacillariophyceae	0.32	2.48	0.29	0.0003	0.15	1.33	5.45	0.26	11.30	69.10	24.19	11.66	0.37	0.67	20.70	1.65	7.35	28.56	53.10
Chrysomonadales																			
<u>Dinobryon sertularia</u> <u>Ehrenberg</u>														3.66	6.52				
Total	0.32	2.48	0.29	0.0003	0.15	1.46	5.45	0.264	11.30	72.60	24.90	12.95	0.37	4.33	27.52	1.65	11.08	29.29	55.16

* Represents the mean value of the four stations for each sampling period

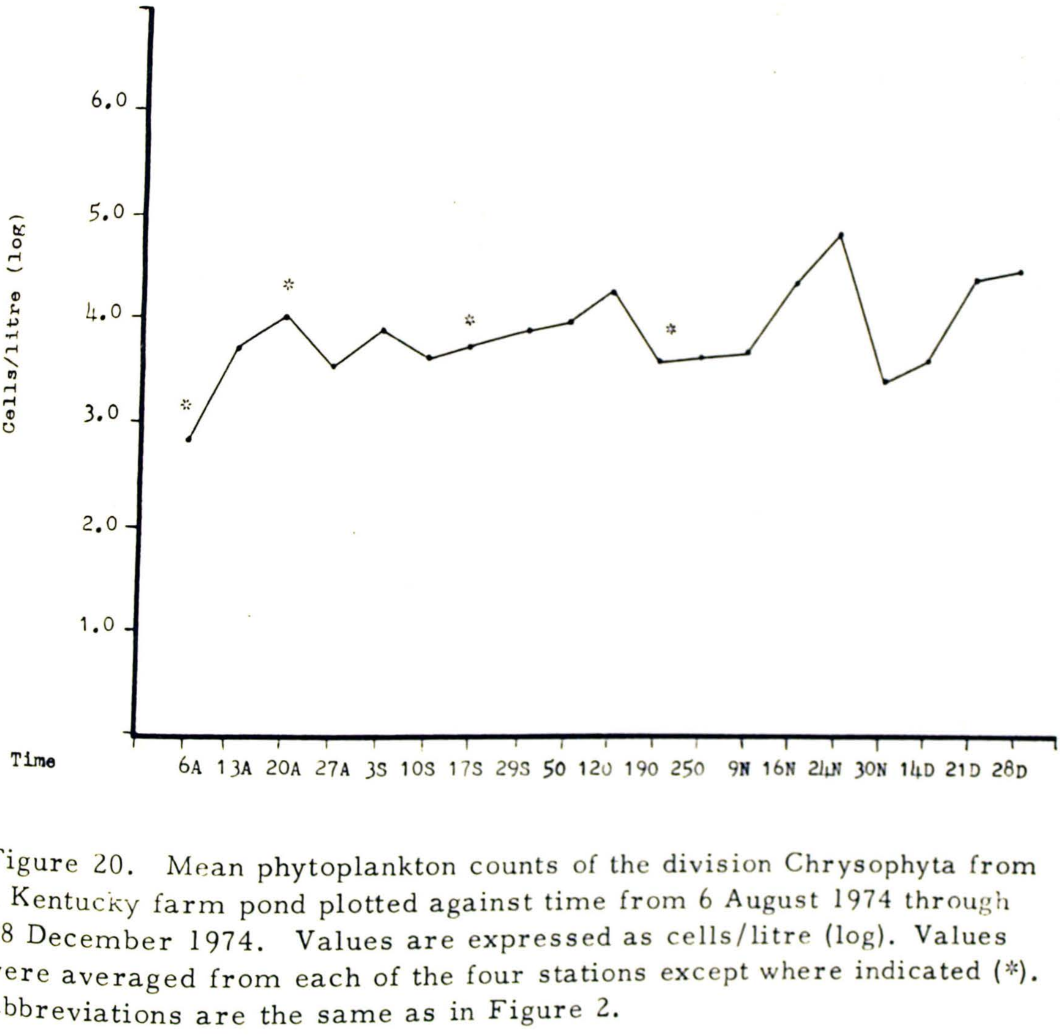


Figure 20. Mean phytoplankton counts of the division Chrysophyta from a Kentucky farm pond plotted against time from 6 August 1974 through 28 December 1974. Values are expressed as cells/litre (log). Values were averaged from each of the four stations except where indicated (*). Abbreviations are the same as in Figure 2.

investigation of western Lake Erie observed that as the water temperature decreased the Chrysophyta population increased. Patrick (1948) presented a different view. She remarks that Chrysophyta growth is directly related to temperature.

She further noted that it is the nitrate form of nitrogen which is preferred by the Chrysophyta. A correlation between the nitrate concentration and Chrysophyta population was not observed during the investigation.

The maximum Chrysophyta pulse occurred in conjunction with the peak orthophosphate concentration of 24 November 1974. Mackenthum, Keup, and Stewart (1968) in a study of Lake Sebasticook, Maine, observed a direct association between the soluble phosphorus and the phytoplankton activity.

Munawar (1970b) correlated the Chrysophyta population with organic content. He further pointed out *Synedra ulna* developed in large numbers in waters polluted from animal origin. This may explain the persistent occurrence of *Synedra ulna* throughout the investigation because the study pond has been directly utilized by cattle since it was excavated.

Pyrrhophyta

The division Pyrrhophyta was represented during the entire investigation by only *Ceratium hirundinella* (Mueller) Dujardin as shown in Table XII. *Ceratium hirundinella* was present for 13 weeks

Table XII. Per cent composition of the division Pyrrhophyta from stations I through IV in a Kentucky farm pond from 6 August 1974 through 28 December 1974, Christian County, Kentucky.

Taxon	Sampling Period 6/A	13/A	20/A	27/A	3/S	10/S	17/S	29/S	5/O	12/O	19/O	25/O	9/N	16/N	24/N	30/N	14/D	21/D	28/D
Ceratium hirundinella (Mueller) Dujardin*	1.04	0.22	0.05	0.0001	0.06	0.48	0.68	0.02	4.18	6.25	1.44	2.33	0.03						
Total	1.04	0.22	0.05	0.0001	0.06	0.48	0.68	0.02	4.18	6.25	1.44	2.33	0.03						

* Represents the mean value of the four stations for each sampling period

from 6 August 1974 to 9 November 1974 as shown in Figure 21. It never did become a dominant member of the observed phytoplankton community. This investigator could not find any relation between *Ceratium hirundinella* and the physical and chemical parameters examined in this investigation. Clear cut correlations between chemical conditions and the qualitative composition of the phytoplankton are not to be expected (Hutchinson, 1944).

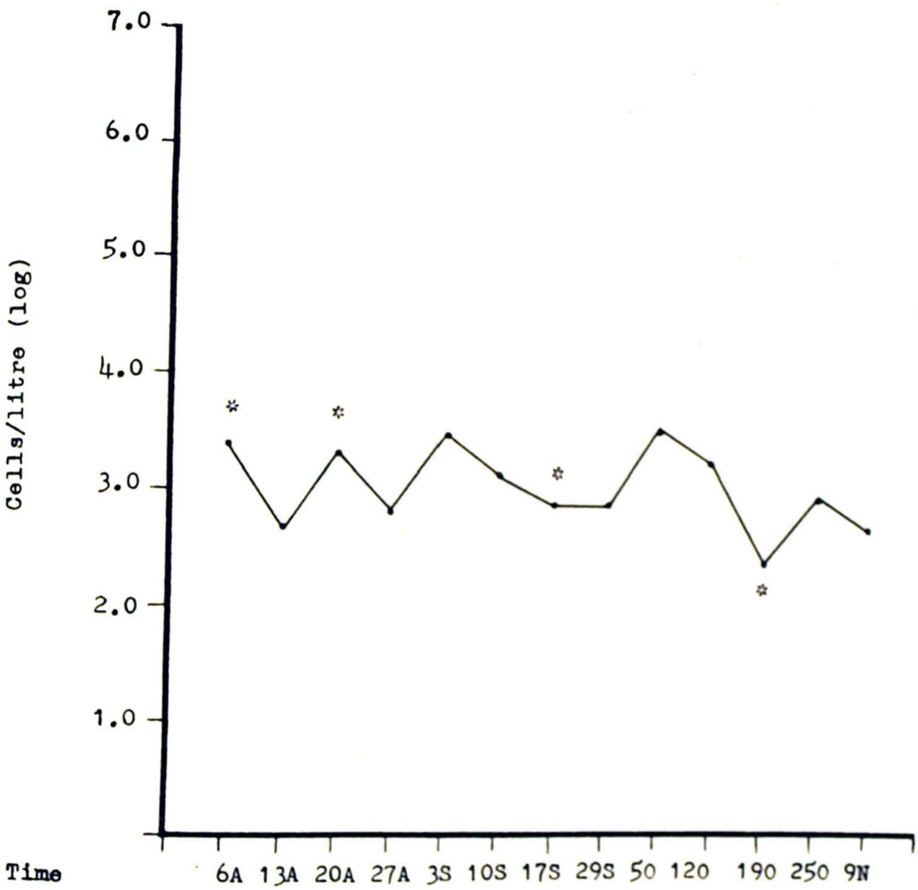


Figure 21. Mean phytoplankton counts of the division Pyrrhophyta from a Kentucky farm pond plotted against time from 6 August 1974 through 28 December 1974. Values are expressed as cells/litre (log). Values were averaged from each of the four stations except where indicated (*). Abbreviations are the same as in Figure 2.

CHAPTER IV

SUMMARY

A farm pond in Christian County, Kentucky, was sampled from 6 August 1974 through 28 December 1974. Variations in selected chemical, physical, and biological parameters were observed.

The watershed contains 95.48 hectares with seven soil types. The pond is located on the Robertsville, silt loam soil. It has a surface area of 840.125 square meters, a mean depth of 1.905 meters and a volume of 1600.649 (m^3).

Both atmospheric temperature and surface water temperature showed a gradual decline throughout the investigation. The gradual decline in the total mean phytoplankton concentration may be related to the gradual decline in temperature. The pond exhibited a moderate to slight stratification. It was observed that rainfall had a cooling effect upon the surface water temperature in August, September and October 1974 and a warming effect in November 1974. It appears that the wind was important in preventing persistent stratification of the water column.

Dissolved oxygen concentrations were greater in the surface waters than in the bottom waters. This may have been related to the photosynthetic activity in the surface waters and increased organic matter in the bottom waters. The bottom waters showed a gradual increase in dissolved oxygen throughout the investigation. This is possibly associated with declining temperatures and lower rates of oxidation and decomposition. Maximum dissolved oxygen concentrations and total mean phytoplankton peaks did not appear to be associated.

Secchi disc visibility demonstrated an inverse relation to rainfall. The maximum Secchi disc visibility corresponded with the minimum mean total phytoplankton concentration. Low Secchi disc values may be an indication that the pond is rich in organic matter.

Total hardness values indicated that the water was moderately soft to soft.

Maximum orthophosphate concentrations followed the major total mean phytoplankton concentrations. This suggests that the phytoplankton are important in the recycling of the phosphates. An inverse relationship was observed between the orthophosphate concentration and the dissolved oxygen concentration.

Silica concentrations showed a great deal of variation throughout the investigation. During each month of the investigation an inverse relationship between the silica concentration and the diatom population was observed. It is suggested by this investigator that diatoms are a major factor in the silica cycle.

Ammonium and nitrate nitrogen concentrations exhibited an inverse relationship to the surface water temperature during the colder weeks of the investigation. Minimum periods of rainfall coincided with minimum nitrate and ammonium nitrogen concentrations. The maximum nitrate nitrogen concentration occurred in conjunction with a decline in the ammonium nitrogen concentration suggesting nitrification. The high nitrate and ammonium nitrogen concentrations indicated organic pollution and eutrophication.

The pH generally showed a decline throughout the investigation. Maximum and minimum pH values were related to periods of high and low total mean phytoplankton concentrations. The maximum pH value was also related to the maximum temperature in August.

Specific conductance and surface water temperature exhibited a direct relation.

The variation in the horizontal distribution of the phytoplankton was slight. The vertical distribution indicated a greater concentration of phytoplankton in the surface waters than in the bottom waters.

The maximum Volvocine population in August may be related to organic content. The Chlorophyceae populations were in the greatest abundance when the pH ranged from 6.0 to 7.4. The small desmid population may have been an indication of eutrophication.

The absence of large numbers of Cyanophyta and Chrysophyta may have been related to the softness of the water.

The large Euglenophyta population may have inhibited the development of the Cyanophyta. The periods of maximum Euglenophyta development are associated with maximum orthophosphate concentrations and low dissolved oxygen concentrations. The large Euglenophyta population may have been an indication of high organic content.

The Chrysophyta population showed a general increase in concentration throughout the investigation. An inverse relationship was found between the Chrysophyta population and the surface water temperature. The maximum Chrysophyta population was associated with the maximum orthophosphate concentration. *Synedra ulna* was the most persistent Chrysophyta in occurrence.

The Pyrrhophyta population consisted of only *Ceratium hirundinella*. The growth and development of *Ceratium hirundinella* could not be correlated with the parameters examined.

That concise and clear cut explanations between the selected physical and chemical parameters as related to phytoplankton development are not evident.

LITERATURE CITED

A.P.H.A. Standard methods for the examination of water and wastewater, 13th ed. 1971. Washington, D. C. 874 pp.

Barica, J. 1974. Some observations on internal recycling, regeneration and oscillation of dissolved nitrogen and phosphorus in shallow self-contained lakes. Arch. Hydrobiol. 73: 334-360.

Bartsch, A. F. 1961. Algae as a source of oxygen in waste treatment. J.W.P.C.F. 33:239-249.

Beeton, A. M. 1957. Relationship between Secchi disc readings and light penetration in Lake Huron. American Fisheries Society 87:73-79.

Bell, M. C. 1973. Fisheries handbook of engineering requirements and biological criteria. Corps of Engineers, Portland.

Bloomquest, H. L., and H. J. Oosting. 1959. A guide to the spring and early summer flora of the Piedmont, North Carolina, 6th ed. H. L. Bloomquest and H. J. Oosting, Durham, 181 pp.

Chandler, D. C. 1944. Limnological studies of western Lake Erie. IV. Relation of limnological and climatic factors to phytoplankton of 1941. Trans. Amer. Micros. Soc., 63:203-236.

________. and O. B. Weeks. 1945. Limnological studies of western Lake Erie. V. Relation of limnological and meterorological conditions to the production of phytoplankton in 1942. Ecol. Monogr. 15:435-456.

Chu, S. P. 1943. The influence of the mineral composition of the medium on the growth of planktonic algae. II. The influence of the concentration of inorganic nitrogen and phosphate phosphorus. J. Ecology 31:109-148.

Cocke, E. C. 1967. The Myxophyceae of North Carolina. I. Edward Brothers, Inc., Ann Arbor. 206 pp.

Copeland, B. J. and W. R. Whitworth. 1964. Oxygen metabolism of four Oklahoma farm ponds. Publ. Institute of Marine Science 9:156-161.

Dugdale, V. A. and R. C. Dugdale. 1962. Nitrogen metabolism in lakes. II. Role of nitrogen fixation in Sanctuary Lake, Pennsylvania. Limnol. Oceanogr. 7:170-177.

Findley, D. L., D. I. Findley, and J. R. Stein. 1973. Surface nitrogen and plankton in Skaha Lake, British Columbia (Canada). Freshwat. Biol. 3:111-122.

Fitzgerald, G. P. 1970. Evaluations of the availability of sources of nitrogen and phosphorus for algae. J. Phycology 6:239-247.

Fogg, G. E. 1965. Algal cultures and phytoplankton ecology. The University of Wisconsin Press, Madison. 126 pp.

Gojdics, M. 1953. The genus Euglena. The University of Wisconsin Press, Madison. 268 pp.

Gorham, E. 1965. The influence of oxidizing and reducing conditions upon the distribution of some elements in lake sediments. Limnol. Oceanogr. 10:268-279.

Graham, T. P. and J. J. McCoy. 1974. The growth effects of varying concentrations of nitrate and phosphate on the Euglenoid Trachelomonas hispida. Bios. 45:74-79.

Hach Chemical Company. 1973. Methods manual, 9th ed. Ames. 119 pp.

________. 1975. Hach water wastewater analysis procedures manual. Ames. 2 109.

Hansmann, E. W. 1973. Diatoms of the streams of eastern Connecticut. Dept. of Environmental Protection, Bulletin 106. 119 pp.

Happey, C. M. 1970a. Some physico-chemical investigations of stratification in Abbot's Pool, Somerset: Studies in the dissolved oxygen content. J. Ecology 58:435-444.

________. 1970b. Some physico-chemical investigations of stratification in Abbot's Pool, Somerset: The distribution of some dissolved substances. J. Ecology 58:621-634.

________. 1970c. The effects of stratification on phytoplanktonic diatoms in a small body of water. J. Ecology 58:635-651.

Harris, B. B. and J. K. G. Silvey. 1940. Limnological investigation on Texas reservoir lakes. Ecol. Monogr., 10:111-143.

Hill, A. R. and W. P. McCague. 1974. Nitrate concentrations in streams near Alliston, Ontario as influenced by nitrogen fertilization of adjacent fields. J. Soil and Water Conservation 29:217-220.

Hutchinson, G. E. 1944. Limnological studies in Connecticut. VII. A critical examination of the supposed relationship between phytoplankton periodicity and chemical changes in lake waters. Ecology 25:3-29.

________. 1957. A treatise on limnology. I. Geography, physics, and chemistry. John Wiley and Sons, Inc., New York. 1015 pp.

________. 1967. A treatise on limnology. II. Introduction to lake biology and the limnoplankton. John Wiley and Sons, Inc., New York. 1115 pp.

Keeney, D. R. 1973. The nitrogen cycle in sediment-water systems. J. Environ. Quality 2:15-29.

Kielhorn, W. V. 1952. The biology of the surface zone zooplankton of a boreo-arctic Atlantic Ocean area. J. Fish. Res. Bd. Canada 9:223-264.

Kimmel, B. L. and O. T. Lind. 1970. Factors influencing orthophosphate concentration decline in the water of laboratory mud-water systems. Texas Journal of Science 21:439-445.

Lind, E. M. 1938. Studies in the periodicity of the algae in Beauchief Ponds, Sheffield. J. Ecology 26:257-274.

Lind, O. T. 1974. Handbook of common methods in limnology. C. V. Mosby Co., Saint Louis. 154 pp.

Lund, J. W. G. 1965. The ecology of the freshwater phytoplankton. Biol. Rev. 40:231-293.

Lund, J. W. G., C. Kipling, and E. D. LeCren. 1958. The inverted microscope method of estimating algal numbers and the statistical basis of estimates by counts. Hydrobiologia 11:143-170.

Mackenthum, K., L. E. Keup, and R. K. Stewart. 1968. Nutrients and algae in Lake Sebasticook, Maine. J.W.P.C.F. 40:R72-R81.

Macon, T. T. and R. Maudsley. 1966. The temperature of a moorland fishpond. Hydrobiologia 27:1-22.

Martin, N. H. 1972. Temperature fluctuations within English lowland ponds. Hydrobiologia 40:455-470.

McCarty, P. L. 1967. Sources of nitrogen and phosphorus in water supplies. J.A.W.W.A. 59:344-366.

McCombie, A. M. 1959. Some relations between air temperature and surface water temperature. Limnol. Oceanogr. 4:252-258.

McCoy, J. J. 1970. Population fluctuations in the genus Trachelomonas order Euglendia. The Journal of the Elisha Mitchell Scientific Sciety 86:198-202.

Micheal, G. R. 1969. Seasonal trends in physicochemical factors and plankton of a freshwater fish pond and their role in fish culture. Hydrobiologia 33:144-160.

Mills, A. L. and M. Alexander. 1974. Microbial decomposition of species of freshwater planktonic algae. J. Environmental Quality 4:423-428.

Mortimer, C. 1942. The exchange of dissolved substances between mud and water in lakes. J. Ecology 30:147-201.

Moss, B. 1969. Vertical heterogeneity in the water column of Abbot's Pond. I. The distribution of temperature and dissolve oxygen. J. Ecology 57:381-396.

Munawar, M. 1970a. Limnological studies on freshwater ponds of Hyderabad-India. I. The biotope. Hydrobiologia 35:127-158.

________. 1970b. Limnological studies on freshwater ponds of Hydrabad-India. II. The biocenose. Distribution of unicellular and colonial phytoplankton in polluted and unpolluted environments. Hydrobiologia 31:105-128.

Neilson, A. H. and R. A. Lewis. 1974. The uptake and utilization of organic carbon by algae: an essay in comparative biochemistry. Phycologia 13:227-264.

Nicholas, S. M. 1965. Nitrates in the environment. J.A.W.W.A. 57:1319-1327.

Numann. 1964. International association for theoretical and applied limnology: from Verdiun, 1967.

N.T.A.C.R. 1969. Raw-water quality criteria for public supplies. J.A.W.W.A. 61:133-138.

O'Brien, W. J. and F. DeNoyelles Jr. 1974. Relationship between nutrient concentration, phytoplankton density, and zooplankton density in nutrient enriched experimental ponds. Hydrobiologia 44:105-125.

Park, K. and H. C. Curl. 1965. Effect of photosynthesis and respiration on the electrical conductance of sea-water. Nature 205:274-275.

Patrick, R. 1948. Factors effecting the distribution of diatoms. Bot. Rev. 14:473-524.

________. and C. W. Reimer. 1966. The diatoms of the United States. I. Livingston Publishing Co., Philadelphia. 688 pp.

________. and D. Strawbridge. 1963. Variation in the structure of natural diatom communities. The American Naturalist 97:51-68.

Pennak, R. W. 1946. The dynamics of fresh-water plankton populations. Ecol. Monogr. 16:339-355.

Phillips, R. C. and L. A. Whitford. 1959. A quantitative study of the summer phytoplankton in four central N. Carolina ponds. Hydrobiologia 14:147-154.

Prescott, G. W. 1962. Algae of the western great lakes area. Reved. ed. W. C. Brown, Co., Dubuque. 977 pp.

________. 1970. The fresh-water algae, 2nd ed. W. C. Brown Co., Dubuque. 348 pp.

Rawson, D. S. 1956. Algal indicators of trophic lake types. Limnol. Oceanogr. 1:18-25.

Reid, G. K. 1961. Ecology of inland waters and estuaries. Reinhold Publishing Corp., New York. 375 pp.

Rigler, F. H. 1956. A tracer study of the phosphorus cycle in lake water. Ecology 37:550-562.

________. 1965. The phosphorus fractions and the turnover time of inorganic phosphorus in different types of lakes. Limnol. Oceanogr. 9:511-518.

Riley, G. A. 1940. Limnological studies in Connecticut. III. The plankton of Linsley Pond. Ecol. Monogr. 10:279-306.

Round, F. E. 1965. The biology of the algae. Edward Arnold LTD., London. 269 pp.

Ruttner, T. 1963. Fundamentals of limnology, 3rd ed. Transl. from German. University of Toronto Press, Canada. 375 pp.

Schultz, V. 1952. A limnological study of an Ohio farm pond. Ohio J. Sci. 52:267-285.

Shapiro, J. 1970. A statement on phosphorus. J.W.P.C.F. 42:772-774.

Smith, G. M. 1950. The fresh-water algae of the United States. McGraw-Hill Book Co., Inc., New York. 716 pp.

Smith, S. H. 1962. Temperature corrections in conductivity measurements. Limnol. Oceanogr. 7:330-334.

Staker, R. D., R. W. Hoshaw, and L. G. Everett. 1974. Phytoplankton distribution and water quality indices for Lake Meade (Colorado River). J. Phycology 10:323-331.

Strom, K. M. 1924. Studies in the ecology and geographical distribution of freshwater algae. Rev. Algol. 1:127-155. (from Staker, Hoshaw, and Everett, 1974).

Tabor, R. L. 1966. The effect of lake bloom on the total hardness content of Wasco Lake. J. Tenn. Acad. Sce. 41:132-134.

Tilden, J. 1970. The Myxophyceae of North America and adjacent regions. I. Of Minnesota algae. Wheldon and Wesley, LTD., New York. 328 pp.

Tyler, J. E. 1968. The Secchi disc. Limnol. Oceanogr. 13:1-6.

U.S. Army Weather Station, 1974. Personal communication. Fort Campbell, Kentucky.

U.S. Defense Mapping Agency Topographic Center. 1972. Washington, D.C.

U.S. Department of Agriculture. 1975. Soil descriptions. Unpublished. Hopkinsville, Kentucky.

________. 1976. Peak discharge computation for small watersheds. Unpublished. Hopkinsville, Kentucky.

U.S. Department of Interior. 1963. Kentucky geological survey and Department of Economic Affairs, U.S. Geological Survey. University of Kentucky.

U.S. Environmental Protection Agency. 1973. Biological field and laboratory methods for measuring the quality of surface waters and effluents. National Environmental Research Center, Cincinnati. 2 11-12.

Vance, B. D. 1965. Composition and succession of Cyanophycean water blooms. J. Phycology 1:81-86.

Vanlandingham, S. L. 1964. Some physical and generic aspects of flutuations in non-marine plankton diatom populations. Bot. Rev. 30:437-478.

Verduin, J. 1967. Eutrophication and agriculture in the United States. A.A.A.S. Symposium, agriculture and the quality of our environment. Nyle C. Brady Ed. 163-172 pp.

Wade, W. E. 1949. Some notes on the algal ecology of Michigan Lake. Hydrobiologia 2:109-117.

Ward, H. B. and G. C. Whipple. 1918. Fresh-water biology. Stanhope Press, Boston. 1111 pp.

Weber, C. I. 1971. A guide to the common diatoms at water pollution surveillance system stations, U S E P A U S Gov. Printing Office, Washington, D. C. 101 pp.

Welch, E. B. 1968. Phytoplankton and related water quality conditions in an enriched estuary. J. W. P. C. F. 40:1711-1727.

Welch, P. S. 1948. Limnological Methods. McGraw-Hill Book Company, Inc., New York. 381 pp.

________. 1952. Limnology, 2nd ed. McGraw-Hill Company, Inc., New York. 538 pp.

Whitford, L. A. and G. J. Schumacker. 1969. A manual of the fresh-water algae in North Carolina. The North Carolina Agricultural Experiment Station, Raleigh. 313 pp.

Wollitz, R. 1972. The effect of acid mine drainage on the limnology of a small impoundment in southwest Virginia. Pages 442-451 in proceedings of the Twenty-Sixth Annual Conference South-eastern Association of Game and Fish Commissioners. 1972.

Wyatt, W. D. and F. R. Hayes. 1963. Tracer study of the phosphorus cycle in sea water. Limnol. and Oceanogr. 8:276-285.

Yongue Jr., W. H. and J. Cairs Jr. 1971. Micro-habital pH differences from those of the surrounding water. Hydrobiologia 38:453-461.

APPENDIX I

Table XIII. Phytoplankton counts from stations I through IV in a Kentucky farm pond 6 August 1974, Christian County, Kentucky. Samples from each station were lumped to determine the mean number of cells.

Taxon	Stations I	II	III	**IV	$\bar{X}$
Chlorophyta					
Coelastrum sphaericum Naegeli		*13160.00	740.00		4633.33
Scenedesmus armatus (Chodat) G.M. Smith		65800	8880.00		24893.33
Selenastrum minutum (Naegeli) Collins		6580.00	1480.00		2686.66
Tetraedron muticum (Braun) Hansgirg		6580.00			2193.33
Unidentifiable colony		26320.00			8773.33
Volvox tertius Meyer	1980.00	11510.00	1850.00		5113.33
Total	1980.00	129950.00	12950.00		48293.33
Chrysophyta					
Pennate diatom			2220.00		740.00
Total			2220.00		740.00

Table XIII. (Continued)

Taxon	Stations I	II	III	**IV	X̄
Cyanophyta					
Anacystis sp. Meneghini		13160.00			4386.67
Total		13160.00			4386.67
Euglenophyta					
Euglena acus Ehrenberg	3950.00		5930.00		3293.33
Phacus orbicularis Huebner	3950.00				1316.67
P. sp. Dujardin		8220.00	3700.00		3973.33
Trachelomonas sp. Ehrenberg	144260.00	197380.00	51850.00		131163.33
Unidentifiable Euglenales	11860.00	82240.00	12220.00		35440.00
Total	164020.00	287840.00	73700.00		175186.67

Table XIII. (Continued)

Taxon	Stations I	II	III	**IV	$\bar{X}$
Pyrrhophyta					
<u>Ceratium hirundinella (Mueller) Dujardin</u>	3950.00	3290.00			2413.00
Total	3950.00	3290.00			2413.00
Total count	169950.00	434240.00	88870.00		231020.00

* Values are expressed in cells per litre
** Signifies sample was contaminated by fungus

Table XIV. Phytoplankton counts from stations I through IV in a Kentucky farm pond 13 August 1974, Christian County, Kentucky. Samples from each station were lumped to determine the mean number of cells.

	Stations				
Taxon	I	II	III	IV	$\bar{X}$
Chlorophyta					
Coelastrum sphaericum Naegeli		*890.00			222.50
Scenedesmus sp. Meyer	4440.00				1110.00
Selenastrum minutum (Naegeli) Collins		1110.00			277.50
Unidentifiable single cell	4440.00	2780.00			1805.00
Volvox tertius Meyer		1110.00	8890.00	55920.00	16480.00
V. tertius Meyer daughter colony			86660.00		21665.00
V. sp. Linnaeus fragmented cells			377740.00	8890.00	96657.50
Total	8880.00	5890.00	473290.00	64810.00	138217.50
Chrysophyta					
Pennate diatom	9440.00	1090.00	4440.00	5930.00	5225.00
Total	9440.00	1090.00	4440.00	5930.00	5225.00

Table XIV. (Continued)

Taxon	Stations I	II	III	IV	$\bar{X}$
Euglenophyta					
Euglena acus Ehrenberg	2220.00	1670.00	4440.00	1110.00	2360.00
Phacus orbicularis Huebner	3330.00	1670.00	2220.00		1805.00
Trachelomonas sp. Ehrenberg	12220.00	25000.00	4440.00	15550.00	14302.50
Unidentifiable Euglenales	7780.00	13050.00	169980.00	2960.00	48442.00
Total	25550.00	41390.00	181080.00	19620.00	66910.50
Pyrrhophyta					
Ceratium hirundinella (Mueller) Dujardin				1850.00	462.00
Total				1850.00	462.00
Total count	43870.00	48370.00	658810.00	92210.00	210815.00

* Values are expressed in cells per litre

Table XV. Phytoplankton counts from stations I through IV in a Kentucky farm pond 20 August 1974, Christian County, Kentucky. Samples from each station were lumped to determine the mean number of cells.

Taxon	Stations I	II	III	**IV	X̄
Chlorophyta					
Scenedesmus armatus (Chodat) G. M. Smith			*24400.00		8133.33
Unidentifiable single cell		3470.00			1156.66
Volvox tertius Meyer	11270.00	32220.00	239960.00		94483.33
V. tertius Meyer daughter colony	47670.00	327570.00	231720.00		202320.00
V. sp. Linnaeus fragmented cells	2981570.00	197580.00	8502140.00		3893763.33
Total	3040510.00	560840.00	8998220.00		4199856.66
Chrysophyta					
Pennate diatom		36400.00			12133.33
Total		36400.00			12133.33

Table XV. (Continued)

	Stations				
Taxon	I	II	III	**IV	$\bar{X}$
Euglenophyta					
Euglena acus Ehrenberg		3470.00	3050.00		2173.33
Phacus sp. Dujardin		3470.00			1156.67
Trachelomonas sp. Ehrenberg	2170.00	10400.00			4190.00
Total	2170.00	17340.00	3050.00		7520.00
Pyrrhophyta					
Ceratium hirundinella (Mueller) Dujardin			6100.00		2033.00
Total			6100.00		2033.00
Total count	3042680.00	614580.00	9007370.00		4221543.30

* Values are expressed in cells per litre
** Signifies sample was contaminated by fungus

Table XVI. Phytoplankton counts from stations I through IV in a Kentucky farm pond 27 August 1974, Christian County, Kentucky. Samples from each station were lumped to determine the mean number of cells.

Taxon	Stations I	II	III	IV	$\bar{X}$
Chlorophyta					
Crucigenia quadrata Morren				*8080.00	2020.00
Unidentifiable single cell		4550.00			1137.50
Volvox tertius Meyer	54680.00		15460.00	418540.00	122170.00
V. tertius Meyer daughter colony	430930.00	1520.00	33340.00	719520.00	296327.50
V. sp. Linnaeus fragmented cells	3848891900.00	62130.00	6891430.00	134647780.00	997623310.00
Total	3849377510.00	68200.00	6940230.00	135793920.00	993044965.00
Chrysophyta					
Pennate diatom		9090.00		4440.00	3382.00
Total		9090.00		4440.00	3382.00
Euglenophyta					
Phacus sp. Dujardin		1520.00			380.00

Table XVI. (Continued)

Taxon	Stations I	II	III	IV	$\bar{X}$
Trachelomonas sp. Ehrenberg	2030.00	309130.00	15150.00	4040.00	82587.50
Unidentifiable Euglenales	17280.00	3030.00			5077.50
Total	19310.00	313680.00	15150.00	4040.00	88045.00
Pyrrhophyta					
Ceratium hirundinella (Mueller) Dujardin	2030.00			1010.00	760.00
Total	2030.00			1010.00	760.00
Total count	3849398850.00	390970.00	6955380.00	135803410.00	998137152.50

* Values are expressed in cells per litre

Table XVII. Phytoplankton counts from stations I through IV in a Kentucky farm pond 3 September 1974, Christian County, Kentucky. Samples from each station were lumped to determine the mean number of cells.

Taxon	Stations I	II	III	IV	$\bar{X}$
Chlorophyta					
Kentrosphaera (*gloeophila*?) (Bohlin) Brunnthaler		*1210.00	2420.00		907.50
Microspora sp. Thuret			1210.00		302.50
Tetraedron hastatum var. *palatinum* (Schmidle) Lemmerman	610.00				152.50
Volvox tertius Meyer	5940.00	15630.00	27160.00	24350.00	18270.00
V. tertius Meyer daughter colony	6650.00	2420.00	10910.00	75990.00	23992.50
V. sp. Linnaeus fragmented cells Meyer	21732670.00	40000.00	55330.00	631050.00	5614762.00
Total	21745870.00	59260.00	97030.00	731390.00	5658387.50
Chrysophyta					
Pennate diatoms	1290.00	21210.00	1780.00	9950.00	8557.50
Total	1290.00	21210.00	1780.00	9950.00	8557.50

Table XVII. (Continued)

Taxon	Stations I	II	III	IV	$\bar{X}$
Cyanophyta					
Anacystis cyanea Drouet and Daily				1780.00	445.00
A. sp. Meneghini		1210.00			302.50
Coccochloris sp. Sprengel			7270.00		1817.50
Spirulina sp. Turpin			3640.00		910.00
Total		1210.00	10910.00	1780.00	3475.00
Euglenophyta					
Euglena acus Ehrenberg		2060.00	2670.00	5160.00	2472.50
Phacus (helikorides?) Pochmann				2670.00	667.50
Trachelomonas sp. Ehrenberg	56360.00	81080.00	141800.00	159900.00	109785.00
Unidentifiable Euglenales	12120.00	25450.00	38780.00	14220.00	22642.50
Total	68480.00	108590.00	183250.00	181950.00	135567.50
Pyrrhophyta					
Ceratium hirundinella (Mueller) Dujardin	300.00	910.00	2790.00	10750.00	3687.00

Table XVII. (Continued)

Taxon	Stations I	II	III	IV	$\bar{X}$
Total	300.00	910.00	2790.00	10750.00	3687.00
Total count	21815940.00	191180.00	295760.00	935820.00	5809675.00

* Values are expressed in cells per litre

Table XVIII. Phytoplankton counts from stations I through IV in a Kentucky farm pond 10 September 1974, Christian County, Kentucky. Samples from each station were lumped to determine the mean number of cells.

Taxon	Stations I	II	III	IV	$\bar{X}$
Chlorophyta					
Ankistrodesmus (*falcatus*?) (Corda) Ralfs	*890.00				222.50
Scenedesmus sp. Meyer			950.00		237.50
Unidentifiable colony			7600.00		1900.00
Volvox tertius Meyer	1780.00	830.00	380.00	3700.00	1672.50
V. tertius Meyer daughter colony	5330.00	1850.00	950.00	2890.00	2755.00
V. sp. Linnaeus fragmented cells			1890.00		472.50
Total	8000.00	2680.00	11770.00	6590.00	7260.00
Chrysophyta					
Centric diatom				1580.00	395.00
Pennate diatom	6670.00	1750.00	4440.00	3940.00	4200.00
Total	6670.00	1750.00	4440.00	5520.00	4595.00

Table XVIII. (Continued)

Taxon	Stations I	II	III	IV	$\bar{X}$
Euglenophyta					
Euglena acus Ehrenberg	4180.00	11200.00		3700.00	4770.00
Phacus sp. Dujardin		930.00			232.50
Trachelomonas sp. Ehrenberg	286550.00	295210.00	203110.00	326780.00	277912.50
Unidentifiable Euglenales		37040.00	29310.00	11780.00	19532.50
Total	290730.00	344380.00	232420.00	342260.00	302447.50
Pyrrhophyta					
Ceratium hirundinella (Mueller) Dujardin	890.00	3240.00		1930.00	1515.00
Total	890.00	3240.00		1930.00	1515.00
Total count	306290.00	352050.00	248630.00	356300.00	315817.50

* Values are expressed in cells per litre

Table XIX. Phytoplankton counts from stations I through IV in a Kentucky farm pond 17 September 1974, Christian County, Kentucky. Samples from each station were lumped to determine the mean number of cells.

Taxon	Stations I	II	III	**IV	$\bar{X}$
Chlorophyta					
Selenastrum sp. Reinsch			*560.00		186.67
Spirogyra sp. Reinsch		740.00			246.67
Unidentifiable single cell	6670.00	2960.00			3210.00
Volvox tertius Meyer	4370.00	810.00	1110.00		2096.67
V. sp. Linnaeus fragmented cell	5930.00				1976.67
Total	16970.00	4510.00	1670.00		7716.67
Chrysophyta					
Pennate diatom	5630.00	11110.00	2670.00		6470.00
Total	5630.00	11110.00	2670.00		6470.00
Cyanophyta					
Anacystis montana (Lightfoot) Drouet and Daily	740.00				246.67
Total	740.00				246.67

Table XIX. (Continued)

Taxon	Stations I	II	III	**IV	$\bar{X}$
Euglenophyta					
Euglena acus Ehrenberg		740.00	1890.00		876.67
Phacus sp. Dujardin	740.00				246.67
Trachelomonas sp. Ehrenberg	80730.00	103620.00	120990.00		556.67
Unidentifiable Euglenales			1670.00		556.67
Total	81470.00	104360.00	124550.00		103460.00
Pyrrhophyta					
Ceratium hirundinella (Mueller) Dujardin		740.00	1670.00		803.33
Total		740.00	1670.00		803.33
Total count	104810.00	120720.00	130560.00		118696.67

* Values are expressed in cells per litre
** Signifies sample was contaminated by fungus

Table XX. Phytoplankton counts from stations I through IV in a Kentucky farm pond 29 September 1974, Christian County, Kentucky. Samples from each station were lumped to determine the mean number of cells.

	Stations				
Taxon	I	**II	III	IV	X̄
Chlorophyta					
Coelastrum microporum Naegeli	*3330.00				832.50
C. sphaericum Naegeli		740.00			185.00
Crucigenia quadrata Morren	8880.00				2220.00
C. rectangularis (Braun) Gay	113280.00				28320.00
Scenedesmus abundans var. brevicauda G. M. Smith	46660.00				11665.00
S. armatus (Chodat) G. M. Smith				3040.00	760.00
S. quadricauda Turpin	8880.00				2220.00
S. sp. Meyer		10360.00		6040.00	4100.00
Selenastrum sp. Reinsch	23330.00	5560.00	6670.00	9070.00	11157.50
Unidentifiable colony	342160.00	94800.00		6040.00	110750.00
Volvox sp. Linnaeus fragmented cells	6999300.00	6492680.00	29440.00	388580.00	3477500.00
Zygnema sp. Agardh		740.00			185.00

Table XX. (Continued)

Taxon	Stations I	**II	III	IV	X̄
Total	7545820.00	6604880.00	36110.00	412770.00	3649895.00
Chrysophyta					
Centric diatom			560.00		140.00
Pennate diatom	7550.00	4440.00	14110.00	12300.00	9600.00
Total	7550.00	4440.00	14670.00	12300.00	9740.00
Cyanophyta					
Anacystis thermalis (Meneghini) Drouet and Daily	6680.00	23720.00			7600.00
Total	6680.00	23720.00			7600.00
Euglenophyta					
Euglena sp. Ehrenberg		740.00			185.00
Phacus sp. Dujardin			2220.00	760.00	745.00
Trachelomonas sp. Ehrenberg	76770.00	65920.00	19160.00	10430.00	43070.00
Unidentifiable Euglenales	34440.00	47770.00	38160.00	8320.00	32172.00
Total	111210.00	114430.00	59540.00	19510.00	76172.00

Table XX. (Continued)

Taxon	Stations I	**II	III	IV	$\bar{X}$
Pyrrhophyta					
Ceratium hirundinella (Mueller) Dujardin	2220.00		1390.00		902.50
Total	2220.00		1390.00		902.50
Total count	7673480.00	6747470.00	111710.00	444580.00	3744310.00

* Values are expressed in cells per litre
** Signifies sample was contaminated by fungus

Table XXI. Phytoplankton counts from stations I through IV in a Kentucky farm pond 5 October 1974, Christian County, Kentucky. Samples from each station were lumped to determine the mean number of cells.

	Stations				
Taxon	**I	**II	**III	**IV	$\bar{X}$
Chlorophyta					
Crucigenia quadrata Morren		*18000.00			4500.00
Selenastrum sp. Reinsch	2660.00	4500.00			1790.00
Total	2660.00	22500.00			6290.00
Chrysophyta					
Pennate diatom	27690.00		16270.00	4940.00	12225.00
Total	27690.00		16270.00	4940.00	12225.00
Cyanophyta					
Anacystis marina Drouet and Daily	10650.00	132880.00			35882.00
A. sp. Meneghini	31960.00	72080.00	39600.00		35910.00
Total	42610.00	204960.00	39600.00		71792.00
Euglenophyta					
Euglena sp. Ehrenberg	20770.00	15770.00	1980.00	9880.00	12100.00

Table XXI. (Continued)

Taxon	Stations				
	**I	**II	**III	**IV	$\bar{X}$
Trachelomonas sp. Ehrenberg	2660.00	2250.00			1227.00
Total	23430.00	18020.00	1980.00	9880.00	13327.50
Pyrrhophyta					
Ceratium hirundinella (Mueller) Dujardin		2250.00	15840.00		4522.50
Total		2250.00	15840.00		4522.50
Total count	96390.00	247730.00	73690.00	14820.00	108157.50

* Values are expressed in cells per litre
** Signifies sample was contaminated by fungus

Table XXII. Phytoplankton counts from stations I through IV in a Kentucky farm pond 12 October 1974, Christian County, Kentucky. Samples from each station were lumped to determine the mean number of cells.

Taxon	Stations				
	**I	**II	**III	**IV	$\bar{X}$
Chlorophyta					
Kentrosphaera (*gloeophila?*) (Bohlin) Brunnthaler		*2530.00			632.50
Selenastrum sp. Reinsch		1270.00		2470.00	935.00
Total		3800.00		2470.00	1567.50
Chrysophyta					
Centric diatom			4940.00		1235.00
Pennate diatom	1190.00	16580.00	17400.00	62220.00	24347.50
Total	1190.00	16580.00	22340.00	62220.00	25582.50
Cyanophyta					
Anacystis incerta Drouet and Daily			620.00		155.00
Total			620.00		155.00

Table XXII. (Continued)

Taxon	Stations **I	**II	**III	**IV	$\bar{X}$
Euglenophyta					
Phacus sp. Dujardin		1270.00			317.50
Unidentifiable Euglenales	2960.00	6960.00	11730.00		5412.50
Total	2960.00	8230.00	11730.00		5730.00
Pyrrhophyta					
Ceratium hirundinella (Mueller) Dujardin	990.00	1650.00	4940.00	1230.00	2202.50
Total	990.00	1650.00	4940.00	1230.00	2202.50
Total count	5140.00	30260.00	39630.00	65920.00	35237.50

* Values are expressed in cells per litre
** Signifies sample was contaminated by fungus

Table XXIII. Phytoplankton counts from stations I through IV in a Kentucky farm pond 19 October 1974, Christian County, Kentucky. Samples from each station were lumped to determine the mean number of cells.

Taxon	Stations **I	**II	**III	**IV	**$\bar{X}$
Chlorophyta					
Kentrosphaera (*gloeophila*?) (Bohlin) Brunnthaler				*890.00	296.67
Kirchneriella sp. Schmidle			1780.00		593.33
Netrium (*interruptum*?) (Brebission) Lutkemueller				710.00	236.67
Selenastrum sp. Reinsch	890.00		1780.00	890.00	1186.67
Volvox tertius Meyer			530.00	310.00	280.00
Total	890.00		4090.00	2800.00	2593.33
Chrysophyta					
Centric diatom			440.00		146.67
Pennate diatom	3560.00		3330.00	8040.00	4976.67
Total	3560.00		3770.00	8040.00	5123.33

Table XXIII. (Continued)

Taxon	Stations **I	**II	**III	**IV	**$\bar{X}$
Euglenophyta					
Unidentifiable Euglenales	7110.00		27000.00	3560.00	12556.00
Total	7110.00		27000.00	3560.00	12556.00
Pyrrhophyta					
Ceratium hirundinella _(Mueller) Dujardin_			890.00		296.67
Total			890.00		296.67
Total count	11560.00		34860.00	15290.00	20570.00

* Values are expressed in cells per litre
** Signifies sample was contaminated by fungus

Table XXIV. Phytoplankton counts from stations I through IV in a Kentucky farm pond 25 October 1974, Christian County, Kentucky. Samples from each station were lumped to determine the mean number of cells.

	Stations				
Taxon	**I	II	III	**IV	$\bar{X}$
Chlorophyta					
Volvox tertius Meyer	*590.00		400.00		247.50
Total	590.00		400.00		247.50
Chrysophyta					
Centric diatom		1480.00	880.00		590.00
Pennate diatom	6960.00	4070.00	3440.00	6810.00	5320.00
Total	6960.00	5550.00	4320.00	6810.00	5910.00
Euglenophyta					
Unidentifiable Euglenales	97840.00	10270.00	45520.00		38407.50
Total	97840.00	10270.00	45520.00		38407.50
Pyrrhophyta					
Ceratium hirundinella (Mueller) Dujardin	2220.00	990.00	1040.00		1062.50
Total	2220.00	990.00	1040.00		1062.50
Total count	107610.00	16810.00	51280.00	6810.00	45627.00

* Values are expressed in cells per litre
** Signifies sample was contaminated by fungus

Table XXV. Phytoplankton counts from stations I through IV in a Kentucky farm pond 9 November 1974, Christian County, Kentucky. Samples from each station were lumped to determine the mean number of cells.

Taxon	Stations I	II	III	IV	$\bar{X}$
Chlorophyta					
Volvox tertius Meyer			*1110.00		277.50
Total			1110.00		277.50
Chrysophyta					
Pennate diatom	8890.00	2220.00	1780.00	15780.00	7167.50
Total	8890.00	2220.00	1780.00	15780.00	7167.50
Euglenophyta					
Euglena acus Ehrenberg	2220.00				555.00
Unidentifiable Euglenales	1527400.00	382630.00	2507310.00	3324670.00	1935502.50
Total	1529620.00	382630.00	2507310.00	3324670.00	1936057.50
Pyrrhophyta					
Ceratium hirundinella (Mueller) Dujardin			2220.00		555.00
Total			2220.00		555.00
Total count	1538510.00	384850.00	2512420.00	3340450.00	1944057.50

* Values are expressed in cells per litre

Table XXVI. Phytoplankton counts from stations I through IV in a Kentucky farm pond 16 November 1974, Christian County, Kentucky. Samples from each station were lumped to determine the mean number of cells.

Taxon	Stations I	II	III	IV	$\bar{X}$
Chlorophyta					
Selenastrum sp. Reinsch				*1740.00	435.00
Volvox tertius Meyer		890.00			222.50
Total		890.00		1740.00	657.50
Chrysophyta					
Dinobryon sertularia Ehrenberg			25530.00	90217.50	28936.88
Pennate diatom	2960.00	4440.00	4440.00	9410.00	5312.50
Total	2960.00	4440.00	29970.00	99627.50	34249.38
Euglenophyta					
Unidentifiable Euglenales	730340.00	791080.00	743840.00	756910.00	755542.50
Total	730340.00	791080.00	743840.00	756910.00	755542.50
Total count	733300.00	796410.00	773810.00	858277.50	790449.38

* Values are expressed in cells per litre

Table XXVII. Phytoplankton counts from stations I through IV in a Kentucky farm pond 24 November 1974, Christian County, Kentucky. Samples from each station were lumped to determine the mean number of cells.

	Stations				
Taxon	I	II	III	IV	$\bar{X}$
Chrysophyta					
Centric diatom			*5300.00		1325.00
<u>Dinobryon sertularia</u> Ehrenberg			38295.00	76590.00	28721.25
Pennate diatom	5560.00	307750.00	30160.00	21330.00	91200.00
Total	5560.00	307750.00	73755.00	97920.00	121246.25
Euglenophyta					
Unidentifiable Euglenales	458980.00	151100.00	225760.00	441670.00	319377.00
Total	458980.00	151100.00	225760.00	441670.00	319377.00
Total count	464540.00	458850.00	299515.00	539590.00	440623.75

* Values are expressed in cells per litre

Table XXVIII. Phytoplankton counts from stations I through IV in a Kentucky farm pond 30 November 1974, Christian County, Kentucky. Samples from each station were lumped to determine the mean number of cells.

Taxon	Stations I	II	III	IV	$\bar{X}$
Chrysophyta					
Pennate diatom	*2210.00		6070.00	7410.00	3922.50
Total	2210.00		6070.00	7410.00	3922.50
Cyanophyta					
Spirulina laxa G. M. Smith	1100.00				275.00
Unidentifiable colony			11840.00		2960.00
Total	1100.00		11840.00		3235.00
Euglenophyta					
Unidentifiable Euglenales	126450.00	202940.00	267430.00	323290.00	230027.50
Total	126450.00	202940.00	267430.00	323290.00	230027.50
Total count	129760.00	202940.00	285340.00	330700.00	237185.00

* Values are expressed in cells per litre

Table XXIX. Phytoplankton counts from stations I through IV in a Kentucky farm pond 14 December 1974, Christian County, Kentucky. Samples from each station were lumped to determine the mean number of cells.

Taxon	Stations I	**II	III	IV	X̄
Chlorophyta					
Spirogyra sp. Link		*28700.00			7175.00
Volvox tertius Meyer	640.00	2010.00	360.00	800.00	952.00
Total	640.00	30710.00	360.00	800.00	8127.50
Chrysophyta					
Centric diatom	320.00	6020.00	400.00	3250.00	2497.50
Pennate diatom	3250.00	5108.00	4000.00	7360.00	4929.50
Total	3470.00	11128.00	4400.00	10610.00	7427.00
Cyanophyta					
Anacystis cyanea Drouet and Daily	320.00				80.00
Spirulina princeps (West and West) G. S. West			800.00		200.00
Total	320.00		800.00		280.00
Euglenophyta					
Unidentifiable Euglenales	36770.00	68580.00	23060.00	76270.00	51195.00
Total	36770.00	68580.00	23060.00	76270.00	51195.00
Total count	41300.00	110518.00	28620.00	87680.00	67029.50

* Values are expressed in cells per litre
** Signifies sample was contaminated by fungus

Table XXX. Phytoplankton sampled from stations I through IV in a Kentucky farm pond 21 December 1974, Christian County, Kentucky. Samples from each station were lumped to determine the mean number of cells.

Taxon	Stations I	II	III	IV	$\bar{X}$
Chlorophyta					
<u>Selenastrum minutum</u> (Naegeli) Collins		*180.00		1480.00	415.00
<u>Spirogyra</u> sp. Link	2840.00	8180.00		309230.00	80062.50
<u>Volvox tertius</u> Meyer	180.00	40.00	120.00		85.00
Total	3020.00	8400.00	120.00	310710.00	80562.50
Chrysophyta					
Centric diatom	1820.00	720.00	1480.00		1005.00
Pennate diatom	2630.00	1280.00	7230.00	145620.00	39190.00
Total	4450.00	2000.00	8710.00	145620.00	40195.00
Cyanophyta					
<u>Spirulina princeps</u> (West and West) G. S. West			590.00	1480.00	517.50
Total			590.00	1480.00	517.50
Euglenophyta					
Unidentifiable Euglenales	7460.00	6070.00	43540.00	6670.00	15935.00
Total	7460.00	6070.00	43540.00	6670.00	15935.00
Total count	14930.00	16470.00	52960.00	464480.00	137210.00

* Values are expressed in cells per litre

Table XXXI. Phytoplankton counts from stations I through IV in a Kentucky farm pond 28 December 1974, Christian County, Kentucky. Samples from each station were lumped to determine the mean number of cells.

Taxon	Stations **I	II	III	IV	$\bar{X}$
Chlorophyta					
Netrium interruptum (Brebission) Lutkemuller				*150.00	37.50
Spirogyra sp. Link	29470.00	10890.00	11200.00	16550.00	17027.50
Ulothrix tenerrima Kutzing	11110.00		27768.00		9719.50
Volvox tertius Meyer				330.00	82.50
Total	40580.00	10890.00	38968.00	17030.00	26867.00
Chrysophyta					
Centric diatom	2220.00		3470.00	1850.00	1885.00
Pennate diatom	43390.00	112620.00	16000.00	22410.00	48605.00
Total	45610.00	112620.00	19470.00	24260.00	50490.00
Euglenophyta					
Unidentifiable Euglenales	24210.00	5930.00	15110.00	11480.00	14182.50
Total	24210.00	5930.00	15110.00	11480.00	14182.50
Total count	110400.00	129440.00	73548.00	52770.00	91539.50

* Values are expressed in cells per litre
** Signifies sample was contaminated by fungus

APPENDIX II

Table XXXII. Qualitative list of the division Chrysophyta from stations I through IV in a Kentucky farm pond from 6 August 1974 through 28 December 1974, Christian County, Kentucky.

Taxon	Sampling Period																		
	6/A	13/A	20/A	27/A	3/S	10/S	17/S	29/S	5/O	12/O	19/O	25/O	9/N	16/N	24/N	30/N	14/D	21/D	28/D
Centrobacillariophyceae																			
Cyclotella sp. Kutzing						X		X		X	X	X			X		X	X	X
Melosira sp.? Agardh	*X																		
Pennatobacillariophyceae																			
Achnanthes inflata (in E.P.A.).													X						
A. sp. Bory																		X	
Cymbella cistula (Hemprich) Grunow				X						X				X					
C. tumida (Brebission) VanHeurck																		X	
C. ventricosa Kutzing																		X	
C. sp. Agardh									X		X		X		X				X

Table XXXII. (Continued)

Taxon	Sampling Period 6/A	13/A	20/A	27/A	3/S	10/S	17/S	29/S	5/O	12/O	19/O	25/O	9/N	16/N	24/N	30/N	14/D	21/D	28/D
Eutonia pectinalis (Kutzing) Rabenhorst																	X		
Fragilaria arcus (in E.P.A.)?										X	X							X	
F. brevistriata Grunow in VanHeurck																			X
F. capucina Desmazieres																		X	X
F. sp. Lyngbye					X					X					X			X	
Frustulia rhomboides (Ehrenberg) DeT.		X																	
Gyrosigma sp. Hassall															X			X	
Meridion circulare (Grev.) Agardh					X														
Navicula canalis Patrick	X									X								X	

Table XXXII. (Continued)

Taxon	Sampling Period																	
	6/A	13/A	20/A	27/A	3/S	10/S	17/S	29/S	5/O	12/O	19/O	25/O	9/N	16/N	24/N	30/N	14/D	21/D	28/D
N. cryptocephala Kutzing		X	X					X	X	X					X				
N. exigua Gregory ex Grunow		X																	
N. mutica Kutzing					X				X										
N. radiosa Kutzing												X							
N. sp. Bory											X	X			X		X	X	
Nitzschia amphibia Grunow														X					
N. lacunaum (in E.P.A.)?															X				
N. parvula Lewis																	X		
N. sigmoidea (Ehrenberg) W. Smith								X											
N. sp. (Hassall, W. Smith) Grunow							X									X	X	X	X
Pinnularia gibba Ehrenberg											X	X			X				

Table XXXII. (Continued)

Taxon	6/A	13/A	20/A	27/A	3/S	10/S	17/S	29/S	5/O	12/O	19/O	25/O	9/N	16/N	24/N	30/N	14/D	21/D	28/D
	Sampling Period																		
P. (streptoraphe?) Cleve															X				
P. sp. Ehrenberg										X			X		X				
Stauroneis anceps Ehrenberg								X	X										
S. phoenicentron f. graciles Rabh.					X										X				
S. sp. Ehrenberg														X					
Surirella sp. Turpin											X								
Synedra parasitica (in E.P.A.)?					X														
S. rumpens Kutzing																		X	X
S. ulna (Nitzsch) Ehrenberg		X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
S. sp. Ehrenberg		X				X										X			
Tabellaria fenestrata (Lynbye) Kutzing																		X	

Table XXXII. (Continued)

Taxon	Sampling Period																		
	6/A	13/A	20/A	27/A	3/S	10/S	17/S	29/S	5/O	12/O	19/O	25/O	9/N	16/N	24/N	30/N	14/D	21/D	28/D
T. flocculosa (Roth) Kutzing												X							
_T._ sp. Ehrenberg															X				
Juniviles			X								X	X				X			

* Signifies the presence of the taxon during the sampling period

APPENDIX III

In an unpublished investigation of the same Kentucky farm pond from 13 September 1973 through 24 November 1973, this investigator found that both the surface water and air temperature showed the same parallel decline. The water column also exhibited inconsistent stratification as observed in Table XXXIII.

The dissolved oxygen in the surface waters indicated a general increase in concentration as the temperature declined. There was also a noticeable dissolved oxygen depletion in the bottom waters during the warmer months as indicated in Table XXXIV. The Secchi disc values in Table XXXV, showed the same general trend as in the investigation of 1974.

The total hardness values in Table XXXVI, did not conform to those values observed in the investigation of 1974.

The orthophosphate values in the pond water, as shown in Table XXXVII, were very inconsistent and unexplainable.

The nitrate nitrogen values did not reach the levels observed in the 1974 investigation as shown in Table XXXVIII.

The pH values in Table XXXIX were lower than those recorded in the investigation of 1974.

Table XXXIII. Temperatures from station I in a Kentucky farm pond from 13 September 1973 through 24 November 1973, Christian County, Kentucky.

			Location					
Date	A	SW	*30.48	60.96	91.44	121.92	152.40	182.88
13 Sept.	**25	25	25	25	25	22	20	20
23 Sept.	29	27	24	22	21	20	19	19
29 Sept.	28	26	24	23	23	21	19	19
12 Oct.	32	24	22	21	21	20	19	19
20 Oct.	21	16	15	15	15	14	14	14
27 Oct.	19	16	15	15	15	15	15	15
10 Nov.	7	7	7	7	7	7	7	7
17 Nov.	11	10	8	8	8	8	8	8
24 Nov.	24	17	14	11	11	10	10	10

* Depth is expressed as cm

** Temperature is expressed as °C

*** Abbreviations as follow--A = atmosphere, SW = surface water

Table XXXIV. Dissolved oxygen values from station I in a Kentucky farm pond from 23 September 1973 through 24 November 1973, Christian County, Kentucky.

	Location						
Date	Surface	*30.48	60.96	91.44	121.92	152.40	182.88
23 Sept.	**5.0	3.0	0.3	0.3	0.3	0.1	0.1
29 Sept.	***. . .	. . .	2.7	0.1	0.1	0.1	0.1
12 Oct.	7.6	7.6	4.7	3.2	0.3	0.1	0.1
20 Oct.	5.6	5.5	4.8	4.6	4.2	4.0	3.7
27 Oct.	6.6	6.2	6.1	5.8	5.0	4.8	4.8
10 Nov.	9.4	9.2	8.7	8.7	8.4	8.4	8.4
17 Nov.	7.3	6.6	6.1	6.0	5.7	5.5	. . .
24 Nov.	6.4	3.8	1.3	0.1	0.1	0	0

* Depth is expressed as cm
** Dissolved oxygen is expressed as mg/l
*** Periods signify no sample taken

Table XXXV. Secchi disc visibility values from station I in a Kentucky farm pond from 13 September 1973 through 24 November 1973, Christian County, Kentucky.

Dates	Station I
13 Sept.	*304
23 Sept.	**. . .
29 Sept.	254
12 Oct.	330
20 Oct.	457
27 Oct.	368
10 Nov.	330
17 Nov.	127
24 Nov.	76

* Secchi disc values are expressed as mm of visibility
** Periods signify no sample taken

Table XXXVI. Total hardness values from stations I through III in a Kentucky farm pond from 13 September 1973 through 24 November 1973, Christian County, Kentucky.

	Stations		
Dates	I	II	III
13 Sept.	*30.0	**. . .	. . .
23 Sept.	90.0	40.0	. . .
29 Sept.	40.0	. . .	. . .
12 Oct.	50.0	50.0	50.0
20 Oct.	50.0	40.0	50.0
27 Oct.	50.0	40.0	50.0
10 Nov.	40.0	40.0	40.0
17 Nov.	40.0	40.0	40.0
24 Nov.	40.0	. . .	40.0

* Values are expressed as mg/l calcium carbonate
** Periods signify no sample taken

Table XXXVII. Orthophosphate values from stations I through III in a Kentucky farm pond from 13 September 1973 through 24 November 1973, Christian County, Kentucky.

Dates	Stations I	II	III
13 Sept.	*0.40	**. . .	. . .
23 Sept.	0.20	0.00	. . .
29 Sept.	0.35	. . .	. . .
12 Oct.	0.60	0.10	0.20
20 Oct.	0.20	0.00	5.00
27 Oct.	0.12	***7.70	0.01
10 Nov.	0.10	0.11	0.00
17 Nov.	0.25	0.10	0.10
24 Nov.	0.35	0.90	. . .

* Values are expressed as mg/l orthophosphate
** Periods signify no sample taken
*** Averaged from two replicate samples

Table XXXVIII. Nitrate nitrogen values from stations I through III in a Kentucky farm pond from 23 September 1973 through 24 November 1973, Christian County, Kentucky.

	Stations		
Dates	I	II	III
23 Sept.	*0.02	0.03	. . .
29 Sept.	0.12	**. . .	. . .
12 Oct.	0.04	0.02	0.01
20 Oct.	0.09	0.07	0.08
27 Oct.	0.40	0.30	0.20
10 Nov.	0.70	1.00	0.01
17 Nov.	0.90	0.70	0.75
24 Nov.	0.75	0.65	. . .

* Values are expressed as mg/l nitrate nitrogen
** Periods signify no sample taken

Table XXXIX. pH values from stations I through III in a Kentucky farm pond from 13 September 1973 through 24 November 1973, Christian County, Kentucky.

	Stations		
Dates	I	II	III
13 Sept.	6.0	*. . .	. . .
23 Sept.	5.4	5.3	. . .
29 Sept.	5.5	. . .	. . .
12 Oct.	6.1	5.6	5.5
20 Oct.	7.1	6.7	6.5
27 Oct.	5.3	5.7	. . .
10 Nov.	6.0	6.0	6.0
17 Nov.	5.7	5.7	5.7
24 Nov.	6.0	6.0	. . .

* Periods indicate no sample taken