AGRICULTURAL EXPERIMENT STATION / AUBURN UNIVERSITY
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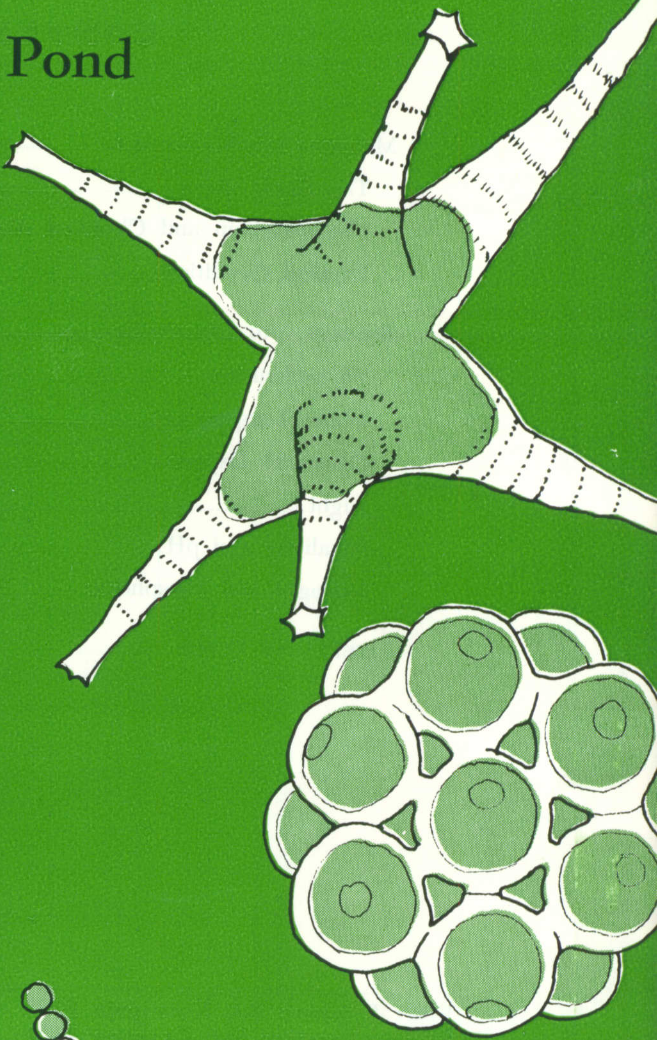
Phytoplankton and Water Quality in a Fertilized Fish Pond

CIRCULAR 224
NOVEMBER 1975



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FIRST PRINTING 2M, NOVEMBER 1975
SECOND PRINTING 2M, OCTOBER 1976

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Phytoplankton and Water Quality in A Fertilized Fish Pond[1]

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FERTILIZERS ARE FREQUENTLY added to fish ponds to increase the abundance of microscopic plants (phytoplankton) and animals (zooplankton) and thereby stimulate fish production *(17, 22)*. High concentrations of nutrients often favor the development of dense blooms of blue-green algae *(5)*. Under certain conditions, heavy blooms of blue-green algae are responsible for a number of problems in ponds, including odors *(21)*, bad tastes in fish *(15)*, presence of toxic substances *(21)*, and shallow chemical and thermal stratification of the water *(4)*. Some populations of algae, particularly species of *Microcystis* and *Anabaena*, may die suddenly *(8,23)*. Decomposition may cause oxygen depletion and fish kills *(8,23)*.

The present investigation was initiated to monitor changes in phytoplankton and water quality in a fertilized fish pond. Emphasis was given to determining relationships between the abundance and periodicity of phytoplankton and changes in water quality.

METHODS AND MATERIALS

The Study Area

Pond S-3 on the Fisheries Research Unit of the Auburn University Agricultural Experiment Station has an area of 9.75 acres and an average depth of about 5 feet. It is filled by overflow from other ponds (S-2, S-24, and S-25) and by runoff. The pond

[1] This research was supported by the Office of Water Research and Technology the Department of the Interior through the Water Resources Research Institute of Auburn University under provisions of the Water Research Act of 1964.

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was drained in November, 1967, and stocked on February 5, 1968, with 9,780 fingerling bluegill sunfish (*Lepomis macrochirus* Rafinesque), 4,875 fingerling redear sunfish (*Lepomis microlophus* (Gunther)), 19,500 fathead minnows (*Pimephales promelas* Rafinesque), and 20 subadult largemouth bass (*Micropterus salmoides* (Lacepede)). Threadfin shad, *Signalosa petenensis* (Gunther) were also present. Ten applications of 17.4 pounds per acre of triple superphosphate were made during each growing season. Fishing was allowed in the pond on a limited basis.

Phytoplankton and Chemical Analyses

A sampling station was selected near the dam of S-3 where the depth of water was 10 feet. Water for phytoplankton enumeration was collected at 18-inch intervals with a weighted bottle sampler *(16)*. Samples were taken at approximately 8 a.m. at 2 or 3-day intervals while phytoplankton growth was slow, and daily when phytoplankton was growing rapidly. Phytoplankton was concentrated by filtration through sand and counted in a counting chamber under a microscope fitted with an ocular micrometer *(2)*.

Dissolved oxygen determinations were made at the various depths at the sampling station with a polarographic oxygen meter.

Water samples for chemical analyses were taken each time phytoplankton samples were collected. These samples were collected with a brass water column sampler which enclosed a column of water 36 inches in length by 2 inches in diameter *(5)*. Soluble orthophosphate, nitrate, and ammonia concentrations were measured by standard colorimetric procedures described by the American Public Health Association *(2)*. Alkalinity was measured by titration with 0.02N H_2SO_4 and free carbon dioxide was titrated with 0.02N NaOH *(2)*. A glass electrode was used to measure pH.

Physical Conditions

A temperature profile was taken on each sampling date with a submersible thermometer. An underwater light meter was used to measure light intensities at 18-inch intervals. A Secchi disk was used to determine the depth of visibility on each sampling date. A recording solarimeter recorded incoming solar radiation continuously from a location on the shore of the pond. Records of average daily air temperature and total daily wind run were obtained from the Environmental Studies Service Center, Auburn University. The data were collected at a weather station on the Auburn University campus.

RESULTS AND DISCUSSION

Phytoplankton

Data on the abundance of different genera of phytoplankton are presented in figures 1, 2, 3, 4, and 5. Two genera, *Anabaena* and *Microcystis*, were more important numerically and ecologically than other genera. The abundance of these two genera is reported as individuals per milliliter, figures 1 and 2. The abundance of other genera is expressed as logarithms to the base 10 of the numbers of individuals per milliliter, figures 3, 4, and 5.

Algae present in the winter and early spring included the following groups; blue-green algae-*Anabaena, Microcystis, Spirulina, Oscillatoria, Raphidiopsis,* and *Gomphosphaeria,* green algae-*Selenastrum, Kirchneriella, Cosmarium, Arthrodesmus, Staurastrum, Sphaerocystis, Pandorina,* and *Oocystis,* euglenophytes – *Trachelomonas.* In late March, *Anabaena* began to increase in abundance and during late April and May individuals of this genus comprised 50 percent or more of the total phytoplankton. Most of the other genera declined in abundance or disappeared from the phytoplankton community with the increase in *Anabaena.*

Filaments of *Anabaena* were buoyant and accumulated in the surface water, Figure 1. Buoyancy of the blue-green algae results from gas vacuoles which form in cells exposed to low light intensity *(10,11).* Plankton absorbs and reflects light and is a major factor affecting the penetration of light in fertilized ponds *(4).* Therefore, the depth of penetration of adequate light for photosynthesis is inversely related to the abundance of phytoplankton *(4).* Surface scums of *Anabaena* formed on calm days and drifted to the leeward shore. Moderate or heavy winds or rain prevented scums by mixing *Anabaena* in the water column.

A number of partial die-offs of *Anabaena* occurred between late March and early June. The dates for five of the best defined die-offs are marked on Figure 1. Data on weather conditions, which were apparently responsible for die-offs, are presented in figures 6 and 7. A similar pattern of events was associated with each die-off. Surface scums of *Anabaena* were present in the morning after a night of calm weather. On clear calm days, the scum persisted and the bright light apparently injured filaments in the scum. Algae in the scum turned brown by afternoon and began to disintegrate and decompose. These observations are in agreement with findings for another pond where light injury to *Anabaena* in a surface scum apparently triggered a massive phytoplankton die-off with subsequent depletion of dissolved oxygen *(8)*. Fortunately, only a portion of the *Anabaena* in S-3 died on

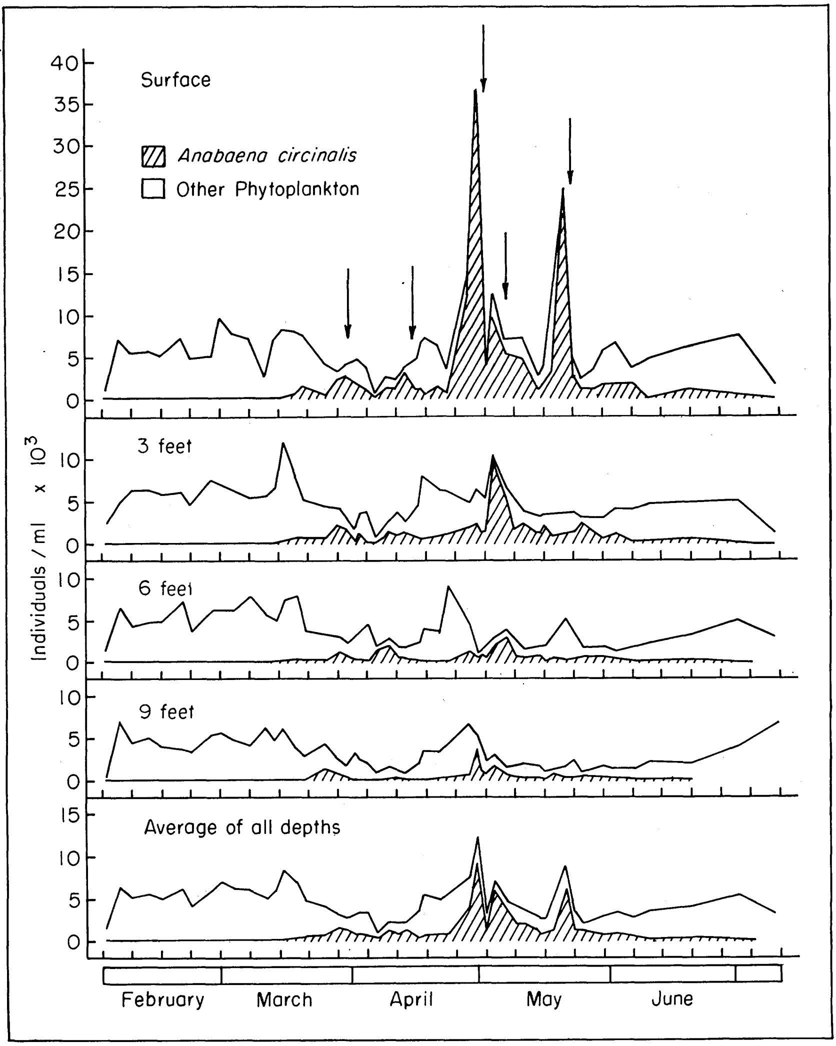

FIG. 1. Abundance of *Anabaena* in relation to the total abundance of phytoplankton in S-3. Arrows indicate partial die-offs of *Anabaena*.

each occasion, Figure 1, and water quality was not seriously impaired.

Observations made during the present study do not reveal the mechanism by which *Anabaena* attained dominance in the phytoplankton community. However, the two following possibilities are most appealing to the authors. First, the buoyant filaments of *Anabaena* accumulated near the surface and shaded phytoplankton that was unable to rise towards the surface where light intensities were higher. Second, laboratory studies have revealed that *Anabaena* excretes substances into the water which are toxic to other algae *(6,19)*. Admittedly, many other factors

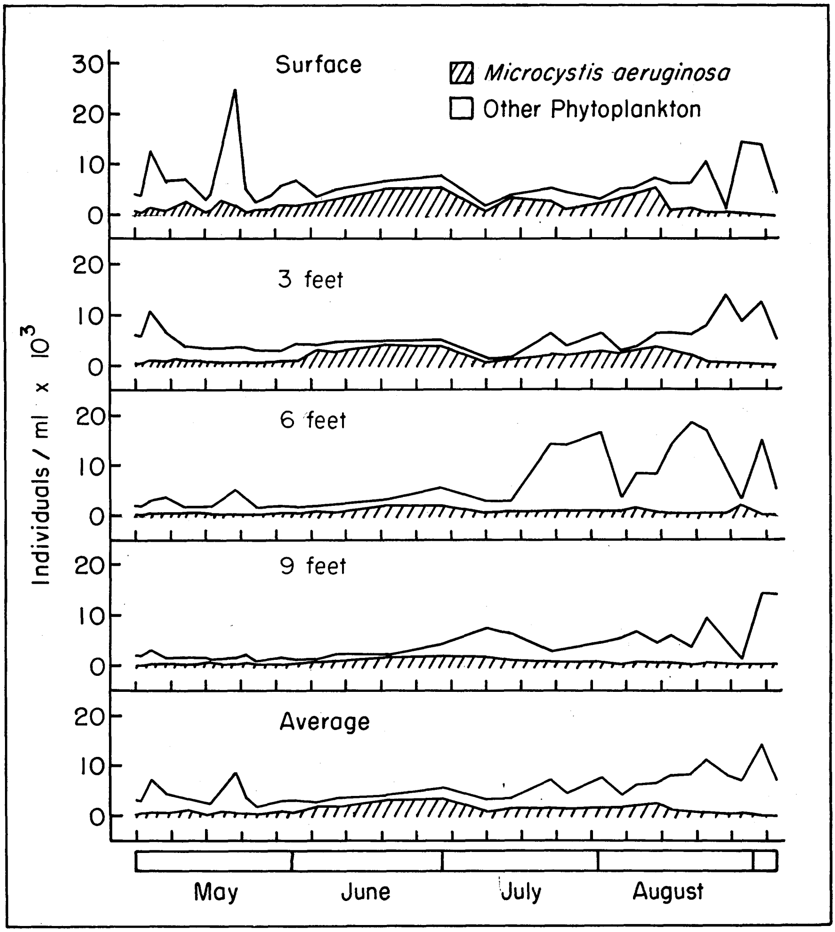

FIG. 2. Abundance of *Microcystis* in relation to the total abundance of phytoplankton in S-3.

including temperature, pH, and nutrient concentrations may also have contributed to the increase in *Anabaena*.

The abundance of *Microcystis* increased rapidly in June after *Anabaena* declined in number. The abundance of *Microcystis* also was greater in surface waters, Figure 2, and surface scums of *Microcystis* were observed often. No die-offs or scums of *Microcystis* occurred. This suggests that bright light was not as harmful to *Microcystis* as it was to *Anabaena*. A number of genera, *Microcystis, Selenastrum, Arthrodesmus, Spirulina, Merismopedia, Oscillatoria, Raphidiopsis, Gomphosphaeria, Sphaerocystis, Trachelomonas, Pandorina, Oocystis, Kirchneriella, Cosmarium,* and *Staurastrum* were present in samples taken on one

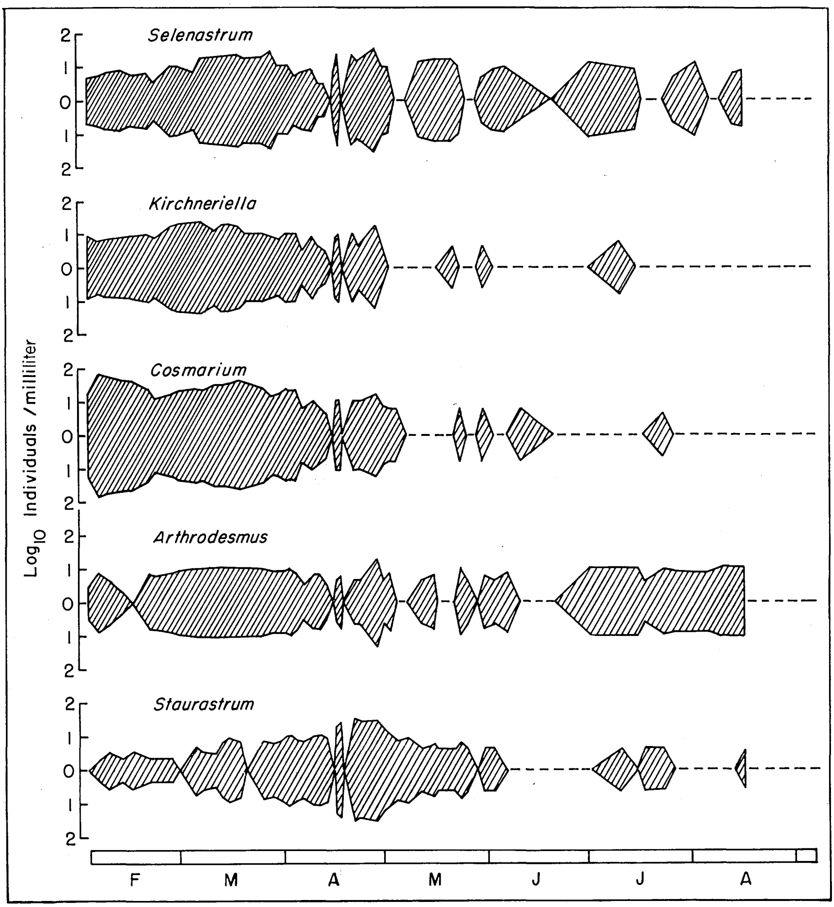

FIG. 3. Seasonal succession of planktonic algae in S-3 from February 1974 to September 1974. Data represent the average abundance of phytoplankton in the water column.

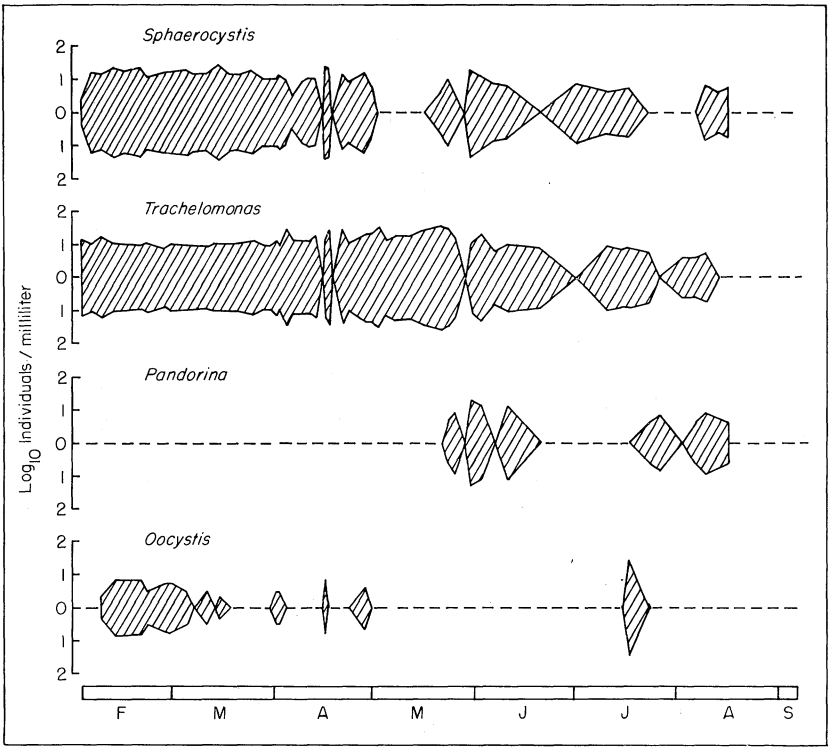

FIG. 4. Seasonal succession of planktonic algae in S-3 from February 1974 to September 1974. Data represent the average abundance of phytoplankton in the water column.

or more dates between June 1 and August 15. Individuals of *Microcystis* greatly outnumbered individuals of any other genus during this time. Reasons for the dominance of *Microcystis* cannot be explained from data at hand. *Microcystis* is known to excrete substances toxic to other algae *(6,19)* and individuals of this genus have a competitive advantage for light and carbon dioxide since they accumulate near the surface.

The abundance of *Microcystis* declined to a low level after August 15. Three other blue-green algae, *Spirulina, Merismopedia,* and *Oscillatoria* were abundant after the decline of *Microcystis*. The decline of *Microcystis* may have been related to any one or more of the factors mentioned above.

Changes in the abundance of individual species of phytoplankton such as those observed in S-3 are common in natural waters *(7,9,20,22,25)*. These changes have been attributed to a number of factors including, pH, temperature, nutrient concentrations,

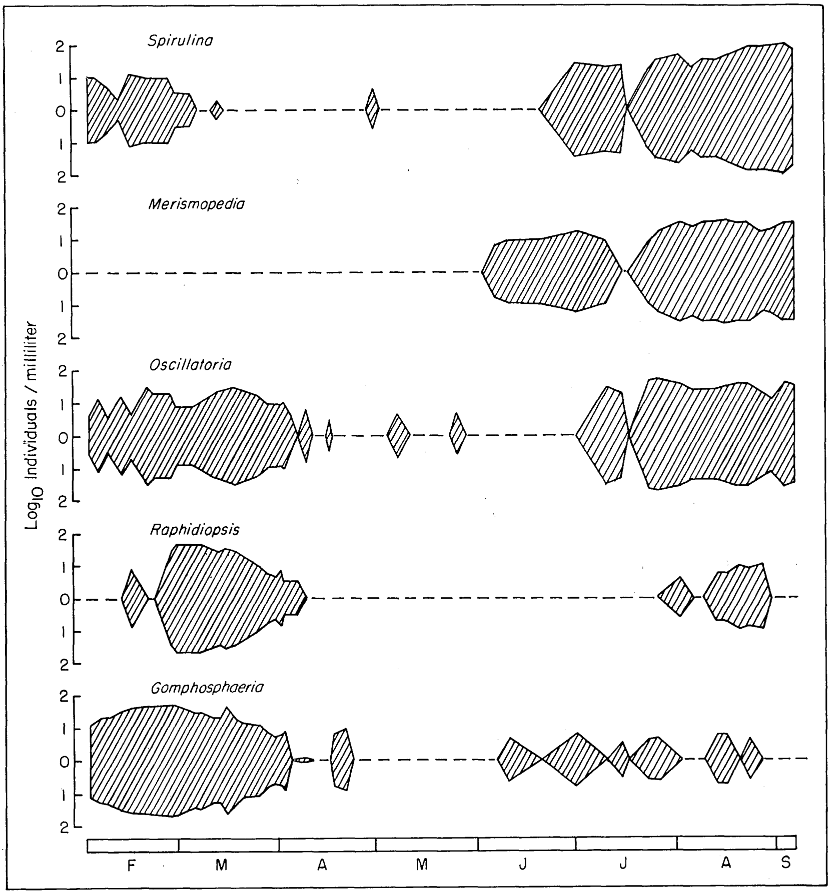

FIG. 5. Seasonal succession of planktonic algae in S-3 from February 1974 to September 1974. Data represent the average abundance of phytoplankton in the water column.

light, weather, diseases, parasites, grazing by fish and zooplankton, and toxins (9). Unfortunately, data collected in most studies have not been adequate to isolate with certainty the factor or factors affecting these changes in algal species.

Water Temperature

Water in S-3 was nearly isothermal in the early morning from February until early March, Figure 8. Water temperatures, then increased faster in the upper 3 feet of water than in the lower waters, and on March 10 the surface water was 22° Fahrenheit warmer than water at a depth of 9 feet. Heavy winds during

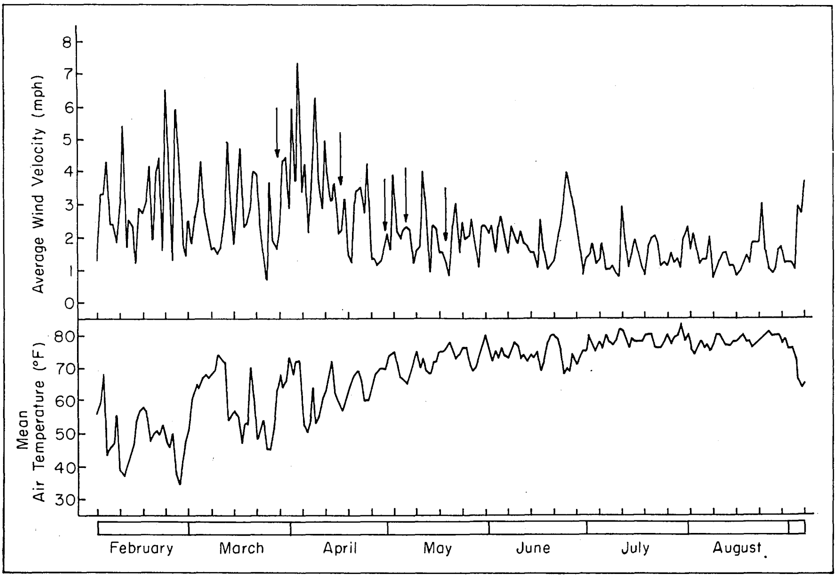

FIG. 6. Mean air temperatures and total wind runs as recorded by the Environmental Studies Service Center, Auburn University, Auburn, Alabama. Arrows indicate times when partial die-offs of *Anabaena* occurred.

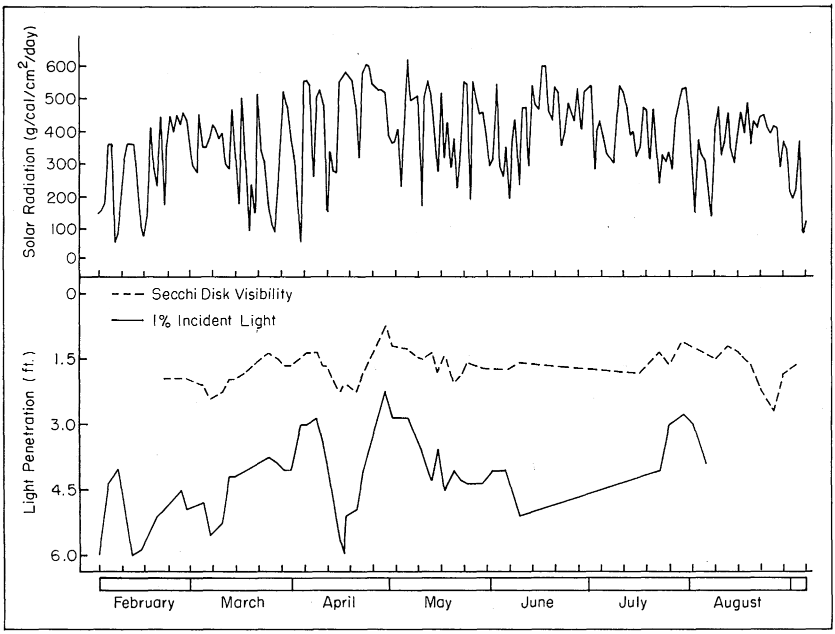

FIG. 7. Incident solar radiation and underwater light penetration for pond S-3.

mid March mixed the waters, and by March 25 waters were again almost isothermal. There was a general subsidence of winds as spring progressed and water temperatures stratified again. Surface waters were usually 15° to 20° Fahrenheit warmer than bottom waters from mid April until the end of the study in early September. Temperatures at the Surface and at a depth of 3 feet were usually similar, but below 3 feet temperatures dropped sharply. There was little mixing of the upper 3 feet of water with deeper water.

The average temperature of the water column increased as the study progressed; 50° Fahrenheit on February 26, 74° Fahrenheit on May 25, and 81° Fahrenheit on August 27. The plankton organisms absorbed heat and increased the heat content of near surface waters. Wind mixing of the surface water aided in distributing heat within the upper 3 or 4 feet.

Warming of the water column has a direct effect on phytoplankton succession. Hammer *(12)* found that blooms of blue-green algae appeared in Canadian lakes when water temperatures increased above 57° Fahrenheit. In S-3, the appearance of dense blooms of *Anabaena* occurred when surface waters reached 59°

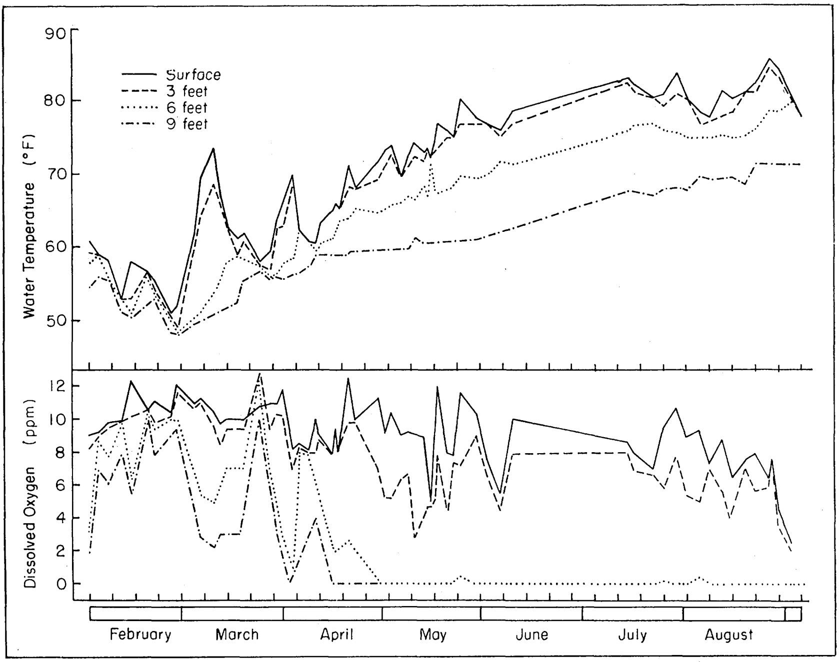

FIG. 8. Dissolved oxygen and temperature data for selected depths in S-3.

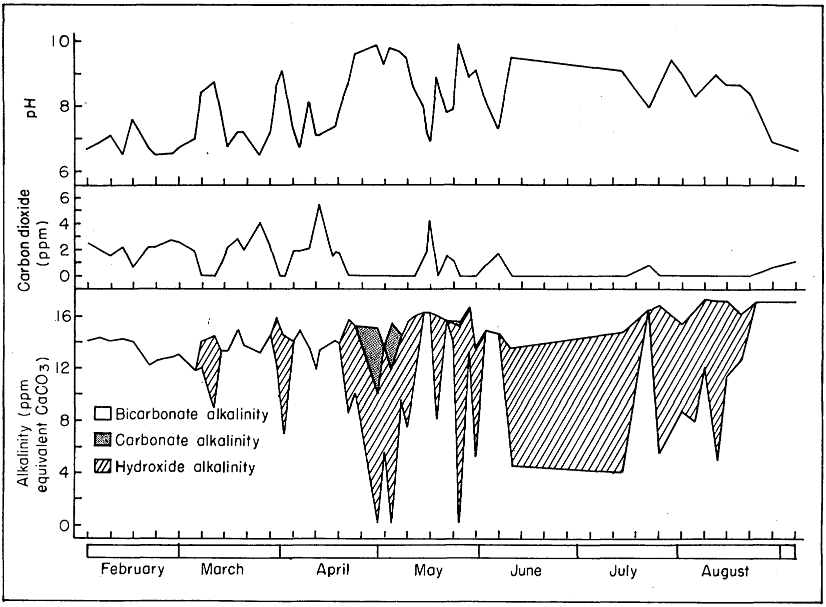

FIG. 9. Values for alkalinity, pH, and free carbon dioxide in the upper 3 feet of water in S-3.

Fahrenheit and *Microcystis* blooms appeared when surface waters reached 68° Fahrenheit.

Dissolved Oxygen

Concentrations of dissolved oxygen were normally highest at the surface and lowest near the bottom of S-2 during February and March, Figure 8. In early April, dissolved oxygen concentrations near the bottom declined to 0 ppm, and by the end of April dissolved oxygen concentrations reached 0 ppm at 6 feet. Concentrations of dissolved oxygen at the surface at a depth of 3 feet were usually above 6 ppm and at no time did they drop below 3 ppm. Surface waters often were supersaturated with dissolved oxygen. The frequent sharp declines in dissolved oxygen concentrations of the upper waters were caused by periods of cloudy weather or by partial die-offs of the phytoplankton. Beasley *(4)* reported that only the upper 2 to 4 feet of water in fertilized fish ponds contained enough dissolved oxygen during the summer for fish survival.

Light

Variations in total solar irradiance are illustrated in Figure 7. The variations from day to day followed no statistically discernable pattern because cloud cover strongly influenced the amount of irradiance striking the surface of the earth. For example, on two successive days solar radiation often varied by a factor of 2 or more, Figure 7.

Photosynthesis of plankton is usually insignificant at levels where the intensity of the light is less than 1 percent of that at the surface *(25)*. In S-3, the depth at which the average light intensity was less than 1 percent of incident radiation varied from 2.5 to 6 feet, Figure 7. The period of least light penetration, as measured by Secchi disk visibility and underwater light meter, came at the times of greatest surface abundance of *Anabaena* or *Microcystis*, indicating the influence of phytoplankton turbidity on the light penetration.

Alkalinity and pH

Waters of S-3 were soft (total hardness and total alkalinity below 20 ppm) and poorly buffered. Data for pH, carbon dioxide, and the various forms of alkalinity are presented in Figure 9. The changes in these parameters were associated with phytoplankton productivity and were similar to the changes reported in other fertilized ponds *(3,7)*. When the phytoplankton community was growing well, carbon dioxide was used in large amounts in photosynthesis and the pH of the water increased, often to the point that carbonate and hydroxide alkalinity were measurable. The pH declined during periods when conditions were unfavorable for growth (cloudy weather, and after die-offs of certain species) and only bicarbonate alkalinity were present.

King *(14)* suggested that blue-green algae are more efficient at obtaining carbon dioxide at low concentrations than are green algae. Results of this study are constant with his findings because blue-green algae were particularly dominant during periods when the pH was continuously above 8.4. However, it is difficult to determine whether the high pH favored growth of blue-green algae or if the rapid growth of blue-green algae caused the high pH.

Nitrogen and Phosphorus

Concentrations of soluble inorganic phosphorus were normally below 0.01 ppm, Figure 10. Sharp increases of concentrations of soluble inorganic phosphorus to 0.09 ppm on March 10, 0.045 ppm on March 21, and 0.075 ppm on April 5, resulted from applications of triple superphosphate. However, phosphorus is removed from the water quickly by absorption by phytoplankton and adsorption by bottom muds *(13)* and increases in concentrations of soluble inorganic phosphorus following fertilization were short lived. Applications of triple superphosphate on other dates were not followed by increases in concentrations of soluble inorganic phosphorus, Figure 10. Since these applications were made during periods of intense phytoplankton growth, the assumption was made that the phytoplankton removed most of the added phosphorus from the water.

Concentrations of nitrate-nitrogen and ammonia-nitrogen are given in Figure 10. There were no additions of nitrogen to S-3 during the study. Nitrate-nitrogen ranged from 0.005 ppm in early April to 0.11 in early August. The maximum concentration of ammonia-nitrogen, 0.30 ppm occurred in a sample taken in mid-March. From early June to the end of the study there was no measurable ammonia-nitrogen in S-3 at the time samples were taken. This decline in ammonia-nitrogen was probably related to the favorable influence of increased temperature on nitrification *(1)*.

Anabaena is a nitrogen fixer *(18)* and the fixation of nitrogen by *Anabaena* and by certain bacteria is a major source of nitrogen in fish ponds *(24)*.

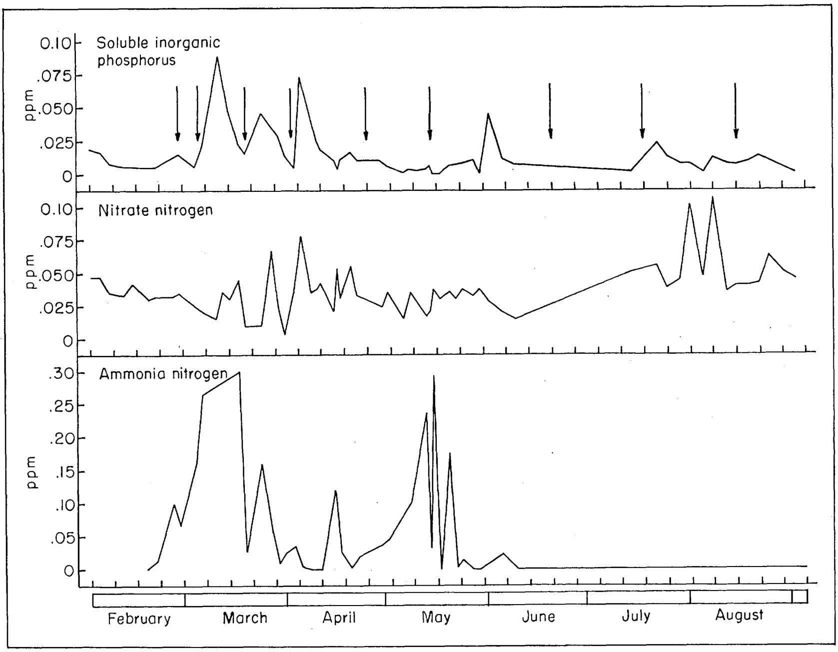

FIG. 10. Concentrations of soluble inorganic phosphorus, ammonia and nitrate in the upper 3 feet of water in S-3. Dates of triple superphosphate additions are indicated by arrows.

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