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ABSTRACT

Physicochemical conditions and chlorophyll *a* standing crop were studied from July 1970 through June 1971 in four commercial catfish ponds at the Arkansas State University Experiment Farm near Walcott, Greene County, Arkansas. Determinations of dissolved oxygen, free carbon dioxide, total alkalinity, temperature, pH, transparency, and chlorophyll *a* standing crop were made at two-week intervals except during fish harvesting operations. One diurnal measurement of dissolved oxygen, free carbon dioxide, and temperature was conducted 25-26 June 1971. Increased oxygen concentrations coincided with increased chlorophyll *a* concentrations. Free carbon dioxide and chlorophyll *a* values varied inversely throughout the study. Diurnal concentrations of free carbon dioxide were greatest between 0300 and 0700 hours. Phenolphthalein and total alkalinity values fluctuated throughout the study period, and could not be correlated with other parameters measured. Thermal stratification occurred during the summer and was more pronounced in the more turbid ponds. Diurnal temperature measurements indicated that stratification was diurnal. An inverse relationship was found between carbon dioxide and hydrogen-ion concentrations, and all ponds were essentially alkaline. Transparency was relatively constant before the ponds were drained but increased when the ponds were refilled. Suspended particulate matter contributed significantly to turbidity. Peaks of chlorophyll *a* concentration were found in summer, early autumn, and late winter.

INTRODUCTION

Farm ponds are becoming increasingly important as inland fisheries. Because water is the medium of fish, knowledge of its natural properties is of utmost significance to the fish culturist. Such factors as light, turbidity, depth, pH, dissolved minerals, concentration of respiratory gases, and phytoplankton abundance determine the quality of water and thereby affect its productivity (Odum, 1959). Studies of productivity and related physicochemical conditions of farm ponds are few and widely scattered. Butler (1964) reported that the interactions of turbidity, dissolved solids, temperature, and surface light intensity influence productivity. Swingle (1966) reported that an increase in primary productivity is influenced by inorganic fertilizers and that an increase in fish production results. Excessive use of inorganic fertilizers increases productivity in the upper layers of water where light conditions are favorable, but production decreases in lower layers where overshading by plankton causes reduced light penetration (Hepher, 1962).

Chlorophyll concentration and its relationship to productivity have been assessed for ponds and other ecosystems in various parts of the world (Brock and Brock, 1967; Manning and Juday, 1941; McConnell and Sigler, 1959; Moss, 1967; Odum, 1956; Verduin, 1956; Yentsch and Ryther, 1957). In ponds, chlorophyll concentration appears to be correlated closely with light intensity and water temperature (Copeland et al., 1964). The writers' study describes seasonal variations in some physicochemical parameters and their effect on phytoplankton productivity as measured by chlorophyll *a* standing crop in four northeast Arkansas commercial catfish ponds.

DESCRIPTION OF AREA

The four ponds studied are at the Arkansas State University Experimental Farm (T16N, R4E, Sec. 7, NW ¼) 1.61 km west of Walcott, Greene County, Arkansas. Greene County is within the alluvial valley of the Mississippi River, which begins near Cape Girardeau, Missouri, and extends south as far as the head of the Atchafalaya River in Louisiana, where the delta plain begins. A thick veneer of loess overlies the bedrock of the valley walls, particularly on the east side of the valley (Thornbury, 1965). The ponds are in soil classified as Falaya silt loam on the loessal plain adjacent to Crowley's Ridge (Robertson, 1969). The four rectangular ponds are easternmost in a series of eight ponds which are numbered from east to west, and are separated only by earthen levees approximately 6.2 m thick. The levees have a minimum distance of 0.76 m between the water surface and top of the levee. The levees are covered with Bermuda grass (*Cynodon dactylon*). Ponds 1 and 2 are 0.53 ha each in surface area, whereas ponds 3 and 4 are 0.26 ha each in surface area. The usual depth ranges from 0.6 m at the north end to 1.36 m at the south end. The water source for the ponds is a well. Maximum wind action is insured by the absence of trees and other obstructions in the surrounding vicinity.

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METHODS AND MATERIALS

Samples were taken from the deep end of the ponds between 0800 and 1100 hours at approximately two-week intervals from July 1970 through June 1971. Diurnal measurements of dissolved oxygen, free carbon dioxide, and temperature were made at four-hour intervals on 25-26 June 1971. All water samples were taken with a Kemmerer sampling bottle. During late winter all ponds were drained to facilitate fish harvesting. Afterward three were refilled. Pond 2 was dry from July until February 1971.

Physicochemical Methods. On each occasion the following determinations were made on surface and bottom water samples. Dissolved oxygen was determined by the sodium azide modification of the Winkler method (APHA, 1960) and by a Yellow Springs Instrument Company Model 54 oxygen meter;

analysis of carbon dioxide and alkalinity followed standard limnological methods (Welch, 1948). A Thermistor and a Yellow Springs Instrument Company Model 54 oxygen meter were employed to determine water temperature. Mean hydrogen-ion concentration was obtained by the Chemtrex Type 40, Beckman Expandomatic, and Coleman Metrion III pH meters. Transparency was determined by use of a 20-cm Secchi disk.

Biological Methods. Arnon's (1949) method was used to analyze water samples for chlorophyll *a* content. Samples for chlorophyll a analysis were placed on ice in a dark container and returned to the laboratory. Aliquots of 100 ml were filtered, and residues were extracted in 20 ml of a chilled aqueous solution of 80% acetone in the dark for 24 hrs at about 5 C. The solution was refiltered and brought to a final concentration of 20 ml. The optical density of the liquid was determined with a Bausch and Lomb Spectronic 20 photoelectric colorimeter at wavelengths of 645 and 663 nm. Chlorophyll *a* concentrations were determined by the equation

$$\text{chlorophyll } a \text{ in mg} = 12.7D_{663} - 2.69D_{645}$$

where 12.7 and 2.69 are specific absorption coefficients for chlorophyll *a* and *b* respectively. D_{663} and D_{645} are optical density at wavelengths 663 and 645 nm.

RESULTS AND DISCUSSION

Oxygen. Vertical distribution of dissolved oxygen was essentially homogeneous for each pond (Figs. 1-4); however, varying differences between surface and bottom concentrations (4-11 ppm) were noted during summer and were attributed to thermal stratification, which was accentuated by increased phytoplankton standing crop. Oxygen concentration was low at the bottom of ponds 3 and 4 during the summer, reaching a low of 0.3 ppm in pond 4 on 12 and 26 June 1971 and 1.2 ppm in pond 3 on 12 June 1971. Surface concentrations on the same dates ranged from 5 to 13 ppm.

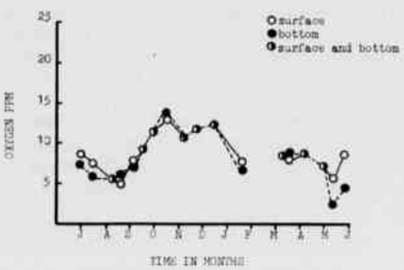


Fig. 1. Seasonal variation of oxygen in Pond 1.

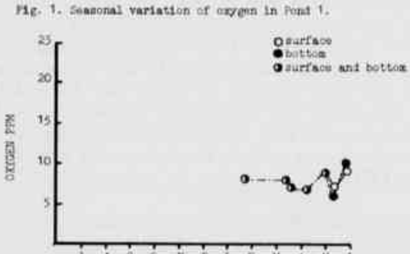


Fig. 2. Seasonal variation of oxygen in Pond 2.

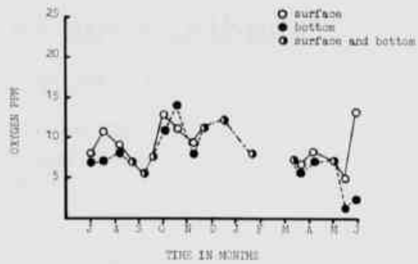


Fig. 3 Seasonal variation of oxygen in Pond 3.

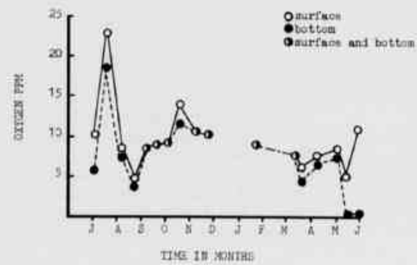


Fig. 4. Seasonal variation of oxygen in Pond 4.

Diurnal oxygen measurements were made on 25-26 June 1971 (Figs. 5-8). Surface concentrations were found to be lowest between 0300 and 0700 hours and increased to a maximum during midday and afternoon when oxygen accumulation from photosynthesis would be expected to reach a maximum. There was a gradual decrease during the night due to decomposition and respiration by aquatic organisms in the absence of photosynthetic activity. Bottom concentrations remained relatively constant (Figs. 5, 7, 8) in a range from 0 to 4 ppm. The difference between surface and bottom concentrations was greatest in pond 4 because of more pronounced thermal stratification (Figs. 9-12). Pond 2 showed the least difference between surface and bottom concentrations as it was the shallowest and clearest.

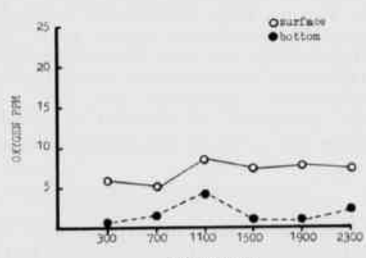


Fig. 5. Diel variation of oxygen in Pond 1.

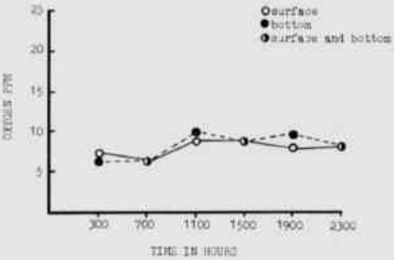


Fig. 6. Diel variation of oxygen in Pond 2.

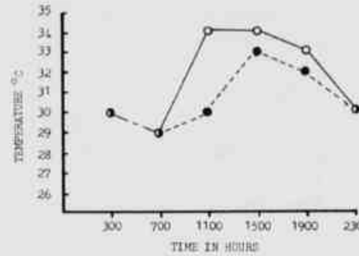


Fig. 10. Diel variation of temperature in Pond 2.

○ surface ● bottom ◐ surface and bottom

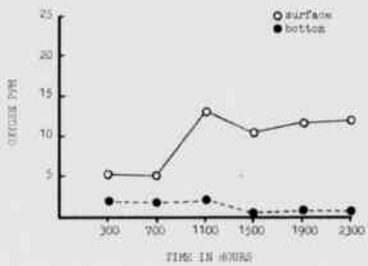


Fig. 7. Diel variation of oxygen in Pond 3.

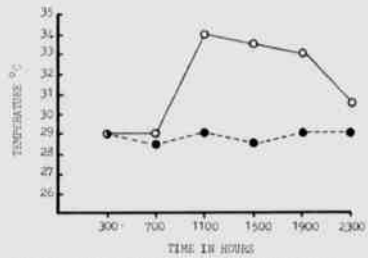


Fig. 11. Diel variation of temperature in Pond 3.

○ surface ● bottom ◐ surface and bottom

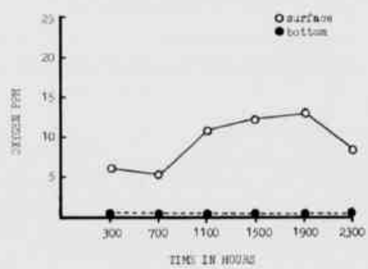


Fig. 8. Diel variation of oxygen in Pond 4.

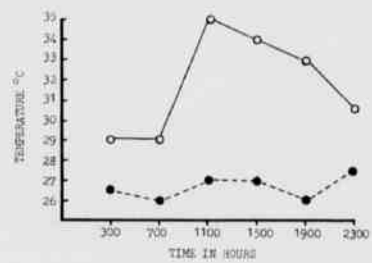


Fig. 12. Diel variation of temperature in Pond 4.

○ surface ● bottom ◐ surface and bottom

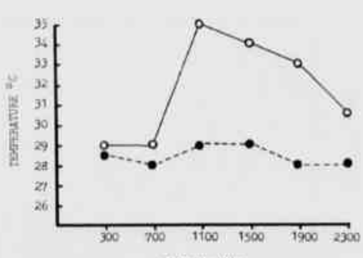


Fig. 9. Diel variation of temperature in Pond 1.

○ surface ● bottom ◐ surface and bottom

In all ponds oxygen concentrations were highest in summer and fall. Increased oxygen concentrations in the fall coincided with decreased temperatures (Figs. 13-16) and increased chlorophyll a concentrations (Figs. 17-20). Chlorophyll *a* concentrations (Figs. 17-20) increased during the summer and coincided with increased temperature, causing dissolved oxygen supersaturation of the surface waters. Maximum saturation occurred in pond 4 on 26 June 1971, reaching a value of 180 ± 5% Smrchek (1970) found that oxygen concentration in ponds increased in the fall coincidentally with decreased temperatures and presumed water circulation.

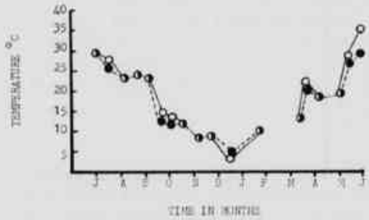


Fig. 13. Seasonal variation of temperature in Pond 1.

O surface ● bottom ◑ surface and bottom

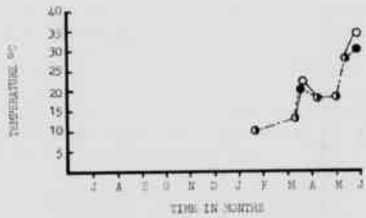


Fig. 14. Seasonal variation of temperature in Pond 2.

O surface ● bottom ◑ surface and bottom

Fig. 15. Seasonal variation of temperature in Pond 3.

O surface ● bottom ◑ surface and bottom

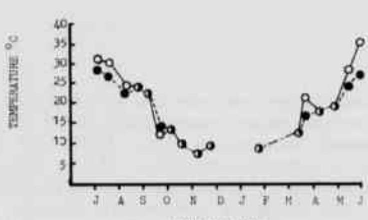


Fig. 16. Seasonal variation of temperature in Pond 4.

O surface ● bottom ◑ surface and bottom

Fig. 17. Seasonal variation of chlorophyll a in Pond 1.

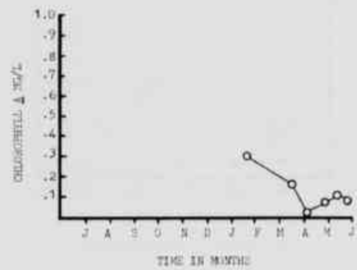


Fig. 18. Seasonal variation of chlorophyll a in Pond 2.

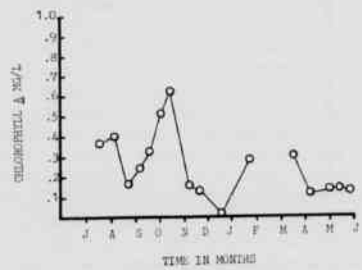


Fig. 19. Seasonal variation of chlorophyll a in Pond 3.

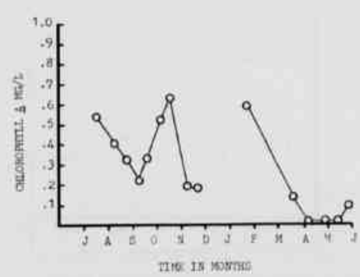


Fig. 20. Seasonal variation of chlorophyll a in Pond 4.

Carbon Dioxide. The vertical distribution of free carbon dioxide in all ponds was basically homogeneous except during the summer when surface values were usually lower than bottom values because of greater uptake by phytoplankton near the surface (Figs. 21-24). The highest surface and bottom carbon dioxide readings were recorded in pond 1 on 28 July 1970 (Fig. 21). This anomaly probably occurred because pond 1 was sampled earlier in the morning before appreciable photosynthesis had begun.

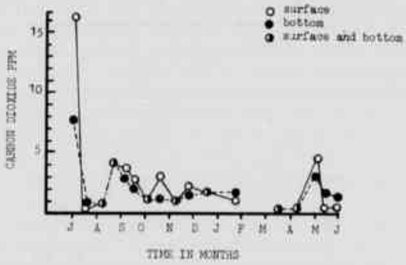


Fig. 21. Seasonal variation of carbon dioxide in Pond 1.

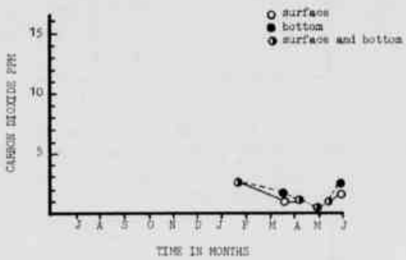


Fig. 22. Seasonal variation of carbon dioxide in Pond 2

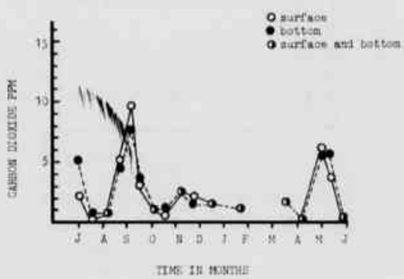


Fig. 23. Seasonal variation of carbon dioxide in Pond 3.

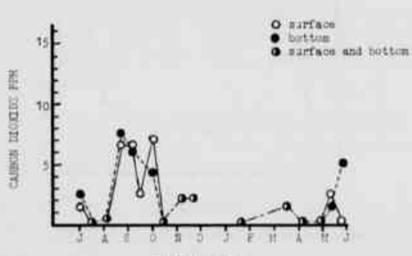


Fig. 24. Seasonal variation of carbon dioxide in Pond 4

Diurnal measurement of carbon dioxide on 25-26 June 1971 showed that free carbon dioxide concentration decreased during the day and increased at night (Figs. 25-28).

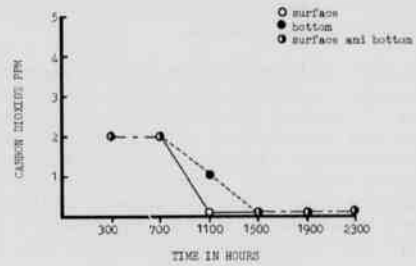


Fig. 25. Diel variation of carbon dioxide in Pond 1.

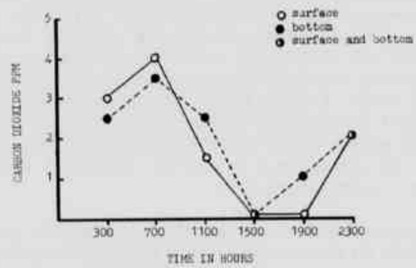


Fig. 26. Diel variation of carbon dioxide in Pond 2.

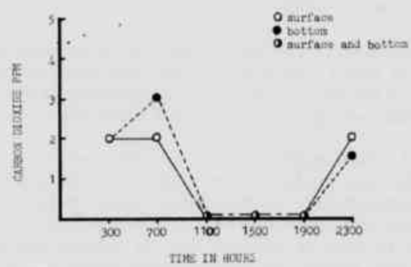
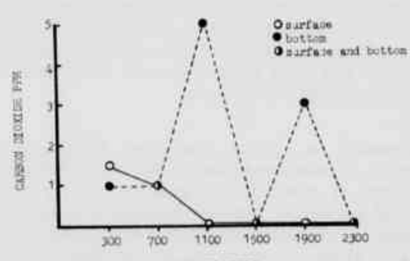


Fig. 27. Diel variation of carbon dioxide in Pond 3.



Diel variation of carbon dioxide in Pond 4.

Seasonal free carbon dioxide concentrations were highest during summer and fall, coinciding with increased water temperatures (Figs. 13-16). An inverse relationship was found between carbon dioxide and chlorophyll *a* concentrations (Figs. 17-20). Presumably, the primary source of free carbon dioxide was respiration by aquatic organisms, as the clay bottom was virtually free of organic material.

Total Alkalinity. Phenolphthalein alkalinity was recorded on a few occasions during the study period and indicated the presence of dissolved hydroxides and carbonates. Total alkalinity was highest in the summer, possibly because of addition of well water, and lowest in winter in all ponds, with no appreciable differences between surface and bottom concentrations (Figs. 29-32). The range of alkalinity in all ponds was between 25 and 91 ppm. The alkalinity of the well water with which the ponds were refilled ranged from 60 to 69 ppm.

Temperature. Because of shallowness and fetch the ponds were comparatively homothermal except during the summer (Figs. 13-16). Thermal stratification occurred because of increased air temperature and decreased light penetration, which caused the upper strata to warm more quickly than the bottom strata. Diurnal temperature measurement on 25-26 June 1971 indicated that temperatures of surface and bottom differed most at midday and converged during the night (Figs. 9-12). All ponds were essentially unithermal because of similarity in depth and fetch.

Hydrogen-Ion Concentration. The pH of all four ponds was essentially alkaline, ranging from a single acidic reading of 6.8 in pond 3 to 9.4 in pond 1 (Table I). An inverse relationship between pH and free carbon dioxide was found (Table I; Figs. 21-24), and these results closely agree with the findings of Irwin and Stevenson (1951).

Transparency. The transparency of water determines the depth to which light will penetrate, and thus establishes the depth of the euphotic zone. The temperature of the strata is dependent on light penetration and absorption.

Irwin (1945) emphasized that turbidity due to silt decreases the total food production and affects the general economy of the impoundment. In the writers' study turbidity did not correlate with chlorophyll a concentrations (Table I; Figs. 17-20). It must be assumed that the relative abundance of particulate matter and phytoplankton fluctuated throughout the year. Pond 2 was the clearest and light penetrated to the bottom on all sampling dates (Table I). Secchi-disk readings in ponds 1, 3, and 4 varied greatly during the study but were relatively constant prior to the addition of water to the ponds in March 1971. No seasonal trends could be established. In most cases the high transparency values were recorded shortly after the ponds had been filled with new water and suspended particulate matter was minimal.

Chlorophyll a. Three quantities related to primary production in lakes are measured by the aquatic biologist: (1) the volume of autotrophic organisms, (2) the ash-free dry weight of suspended particles (organic seston), and (3) the concentration of chlorophyll. Each is expressed per unit volume of water. These are measures of standing crop and they represent quantitative estimates of autotrophic organisms on which primary production is based (Verduin, 1956).

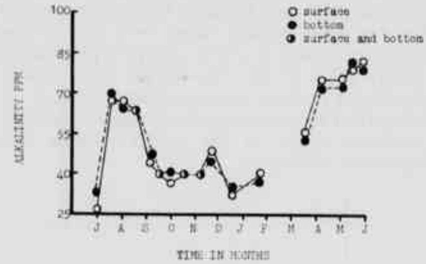


Fig. 29. Seasonal variation of total alkalinity in Pond 1.

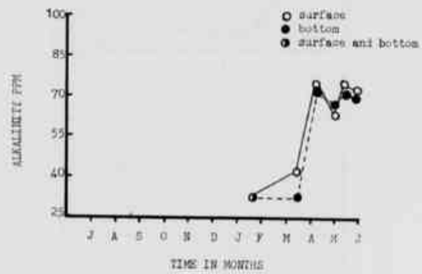


Fig. 30. Seasonal variation of total alkalinity in Pond 2.

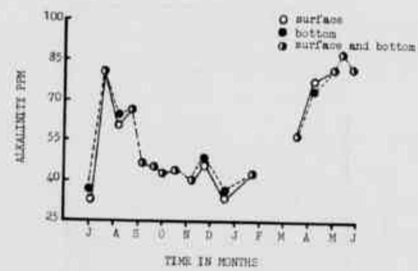


Fig. 31. Seasonal variation of total alkalinity in Pond 3.

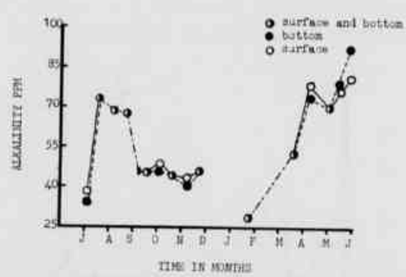


Fig. 32. Seasonal variation of total alkalinity in Pond 4.

Chlorophyll *a* concentrations ranged from 0.0 to 0.7 mg/l in pond 1, from 0.02 to 0.3 mg/l in pond 2, from 0.0 to 0.62 mg/l in pond 3, and from 0.0 to 0.63 mg/l in pond 4 (Figs. 9-12). The results obtained in this study were within the range of those found by Copeland (1963), Minter (1964), and Wright (1959).

In this study, chlorophyll *a* was used as an index of variation for phytoplankton standing crop. Chlorophyll *a* representing phytoplankton standing crop might be utilized as an index for predicting oxygen depletion during spring and summer months. Ponds 1, 3, and 4 showed an increase in phytoplankton standing crop during August 1970 (Figs. 17, 19, 20). Phytoplankton standing crop increased in ponds 1, 3, and 4 during September, October, and November 1970 (Figs. 17, 19, 20). An increase in phytoplankton was shown in ponds 1 and 3 during January and February 1971 (Figs. 17, 19); however, the ponds were drained during the latter part of February. Well water was added in March 1971, and from April to June quantitative fluctuations in phytoplankton were observed.

Even though the ponds were separated only by an earthen levee approximately 6.2 m thick, the recorded data show that they were separate ecosystems. Any treatment applied to ponds in the same locality and in the same manner for algae, lack of oxygen, pH, and turbidity may have a decimating effect on the fish population.

ACKNOWLEDGMENTS

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TABLE 1. Hydrogen-ion concentration and transparency (Secchi disk) in Ponds 1 through 4 from 28 July 1970 to 26 June 1971.

Date	Pond	pH	Transparency (cm)
July 28	1	---	--
	2	---	--
	3	---	--
	4	---	--
August 15	1	---	27
	2	---	--
	3	---	25
	4	---	20
September 5	1	7.5	35
	2	---	--
	3	8.3	28
	4	7.1	27
September 19	1	---	--
	2	---	--
	3	---	--
	4	---	--
October 3	1	7.5	33
	2	---	--
	3	6.8	33
	4	7.3	48
October 17	1	7.4	27
	2	---	--
	3	7.2	20
	4	7.4	31
November 1	1	7.3	38
	2	---	--
	3	7.1	20
	4	7.2	30
November 14	1	8.1	38
	2	---	--
	3	8.1	28
	4	8.7	33
December 4	1	7.8	46
	2	---	--
	3	7.2	26
	4	7.4	28
December 19	1	7.2	61
	2	---	--
	3	7.1	25
	4	7.2	31
January 16	1	7.6	79
	2	---	--
	3	7.8	28
	4	---	--
February 20	1	7.3	28
	2	7.4	41
	3	7.9	28
	4	8.6	20
April 10	1	---	--
	2	---	--
	3	---	--
	4	---	--
April 17	1	9.0	76
	2	8.1	68
	3	7.7	56
	4	8.1	61
May 4	1	9.4	122
	2	7.8	91
	3	8.6	20
	4	8.6	31
May 29	1	7.8	91
	2	8.6	76
	3	7.5	38
	4	8.5	23
June 12	1	7.8	21
	2	7.8	61
	3	7.4	25
	4	7.6	25
June 26	1	---	41
	2	---	82
	3	---	31
	4	---	53

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