CIRCULAR 261 JULY 1982

Solar radiation and dissolved oxygen concentrations in fish ponds

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FIRST PRINTING 3M, JULY 1982

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SOLAR RADIATION AND DISSOLVED OXYGEN CONCENTRATIONS IN FISH PONDS

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INTRODUCTION

THE INTENSITY OF SOLAR RADIATION strongly regulates rates of photosynthesis and oxygen evolution in lakes *(5)* and in the ocean *(8)*. Light intensity is also recognized as an important variable in the oxygen budgets of fish ponds *(7)*, but phytoplankton abundance, density of fish, water temperature, organic matter levels, turbidity, and wind mixing also greatly influence dissolved oxygen budgets for fish ponds *(3, 10)*. It is generally thought that prolonged periods of cloudy weather result in low concentrations of dissolved oxygen—especially in ponds with an abundance of plankton *(4, 9)*. However, there are few data illustrating the strength of the relationship between daily light intensity and dissolved oxygen concentration in fish ponds.

The present study demonstrates that dissolved oxygen concentrations in fish ponds are strongly influenced by daily solar radiation and that periods of low dissolved oxygen correspond to spells of cloudy weather.

MATERIALS AND METHODS

Two ponds, each with an area of 0.1 acre and a mean depth of 3 feet, were used. One was stocked in January, 1981, with 200 bluegill (2-4 inches total length). This pond was fertilized with 18 pounds per acre of diammonium phosphate (N-P_2O_5-K_2O ratio of 18-46-0) on February 12, March 3 and 26, April 28, May 21, June 18, July 16, August 21, September 10, and October 12.

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The other pond was stocked in February, 1981, with 400 channel catfish fingerlings (4-6 inches total length). Catfish were fed 6 days per week with a pelleted (32 percent protein) ration. Feed was applied at 3 percent of body weight, adjusted every 2 weeks for weight gain, until a feeding rate of 50 pounds per acre per day was attained on August 18. This rate was maintained for the rest of the growing season.

Beginning on May 19, water samples were collected twice weekly for chlorophyll *a* analysis *(1)*. Dissolved oxygen concentrations and water temperatures were measured at three depths (surface, middle, and bottom) between 7 and 8 a.m. and again between 4 and 6 p.m. daily (except Saturday afternoons and Sundays) with a Yellow Springs Instrument Company Model 54 Oxygen Meter. Measurements were made from a pier in each pond, and the data for the three depths in a pond were averaged for each time. Total daily solar radiation was recorded at the ponds with a Belfort Instrument Company Pyrheliograph. This instrument measures about 90 percent of radiation with wave lengths from 0.36 to 2.0 microns.

RESULTS AND DISCUSSION

Morning and afternoon dissolved oxygen concentrations in the two ponds and daily solar radiation values for the period May 19 through October 13, 1981, are presented in figure 1. Dissolved oxygen concentrations were highest during periods of high solar radiation (clear days) and lowest during periods of low solar radiation (cloudy days) between May 19 and October 1. Of course, on partly cloudy days, the relationship between solar radiation and dissolved oxygen concentrations was not as obvious. Daily solar radiation values below 200 langleys usually resulted in marked reductions in afternoon dissolved oxygen concentrations. Because less dissolved oxygen was present for nighttime use, morning dissolved oxygen concentrations would be lower when the previous day had low radiation than when it had high radiation. Considering the large number of variables that affected dissolved oxygen concentration, the correlations between afternoon dissolved oxygen concentrations and daily solar radiation, figures 2 and 3, are remarkably high.

After October 1, water temperatures dropped appreciably and dissolved oxygen concentrations remained high in spite of low radiation. When water temperature is low, respiration is greatly supressed and little oxygen is consumed by the pond

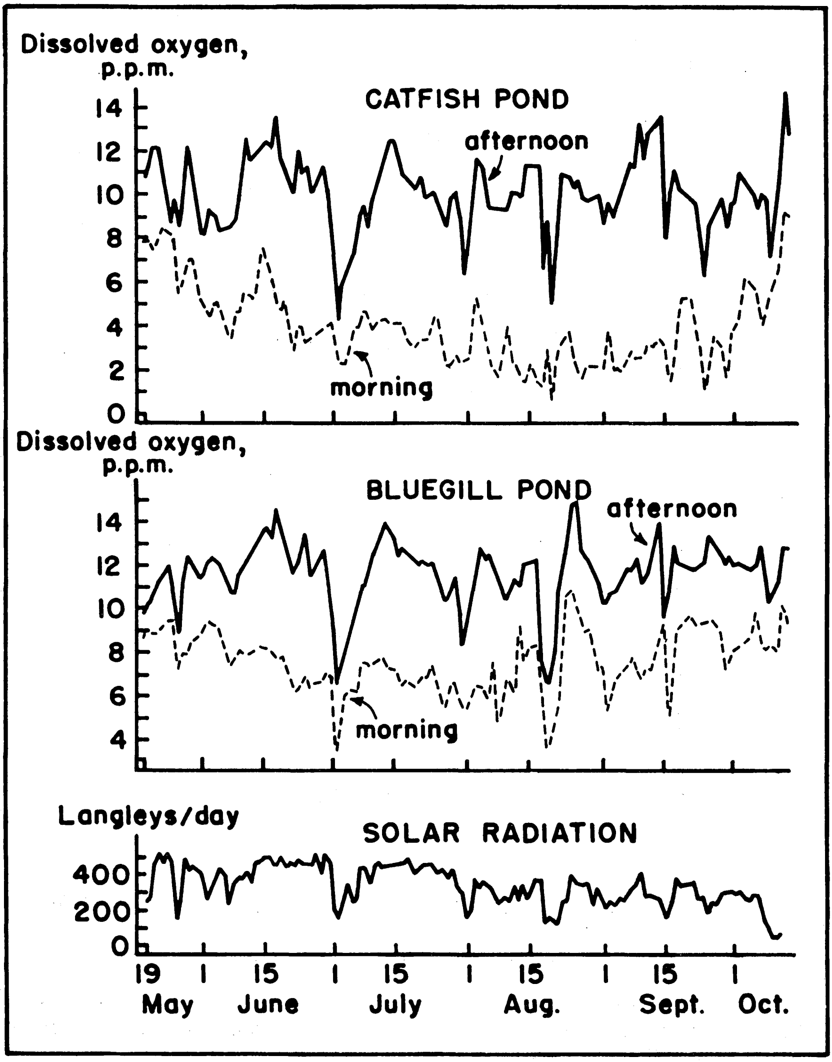

FIG. 1. Average concentrations (surface, mid depth, and bottom) of dissolved oxygen in the morning (7 to 8 a.m.) and afternoon (4 to 6 p.m.) in a bluegill pond and a catfish pond during late spring, summer, and early fall, 1981. Total daily solar radiation values are also presented.

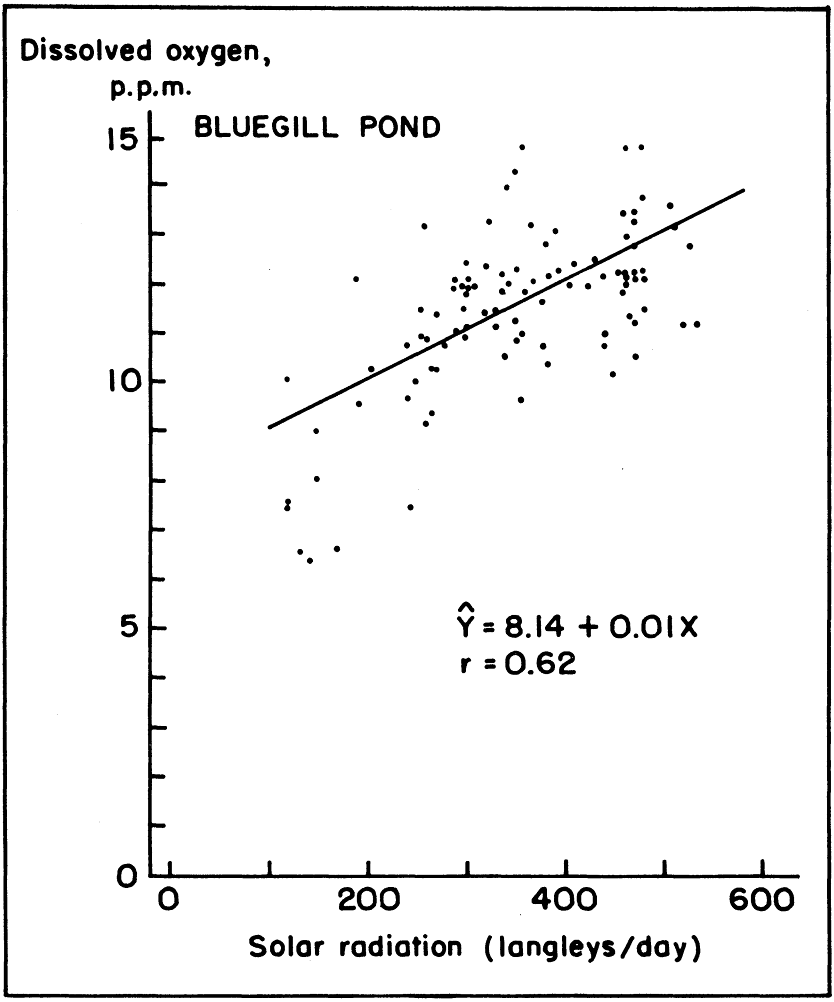

FIG. 2. Relationship between solar radiation and afternoon (4 to 6 p.m.) dissolved oxygen concentrations in a bluegill pond.

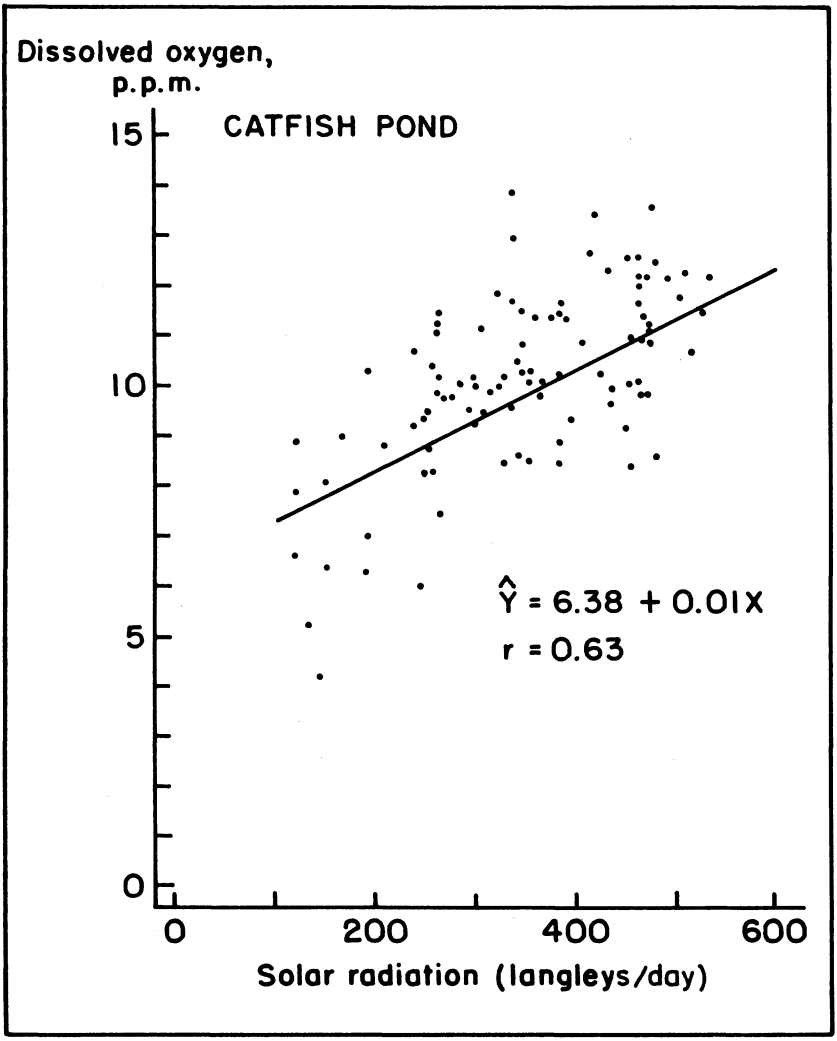

FIG. 3. Relationship between solar radiation and afternoon (4 to 6 p.m.) dissolved oxygen concentrations in a catfish pond.

biota. Halverson et al. *(6)* demonstrated that oxygen budgets for ponds during winter are governed primarily by diffusion rather than photosynthesis and respiration.

Water temperatures in the small, shallow ponds were also greatly influenced by solar radiation. If morning and afternoon temperatures, figure 4, are compared with daily solar radiation, figure 1, periods of low water temperatures—also periods when morning and afternoon temperatures were similar—occurred when solar radiation was low. Of course, this relationship would not hold for large bodies of water with greater heat storage. The small ponds thermally stratified on clear and partly cloudy days; afternoon temperatures at the surface were often 5 to 7°F higher than bottom temperatures. Morning temperatures were almost invariably the same at the surface and bottom. On cloudy days, thermal stratification did not develop. Dissolved oxygen concentrations were normally 3-6 parts per million greater at the surface than at the bottom on afternoons of clear or partly cloudy days, but dissolved oxygen concentrations were not stratified in mornings or on cloudy afternoons.

Afternoon dissolved oxygen concentrations were of similar magnitude in the two ponds, but the channel catfish pond usually had lower morning dissolved oxygen concentrations than the bluegill pond. Dissolved oxygen was never below 3.5 parts per million in the morning in the bluegill pond, but values were often below 3 parts per million in the catfish pond.

Chlorophyll *a* concentrations were not appreciably different between ponds, figure 5; the averages for the study period were 19.6 parts per billion in the bluegill pond and 22.9 parts per billion in the catfish pond. Neither pond had remarkably high phytoplankton abundance; many fish ponds have average chlorophyll *a* concentrations above 50 parts per billion *(2)*. By August, the weight of fish in the catfish pond was about 2,200 pounds per acre while the bluegill pond had only about 200 pounds per acre of fish. In addition, considerable organic matter reached the catfish pond as metabolic waste and uneaten feed. Hence, greater respiration by the biota of the catfish pond resulted in greater depression of oxygen concentrations during the night.

Chlorophyll *a* concentrations exhibited sudden and drastic changes. Several of the sudden increases in chlorophyll *a* concentration in the bluegill pond followed fertilizer applications. The addition of feed gradually increased to a maximum level and then remained constant in the catfish pond; yet,

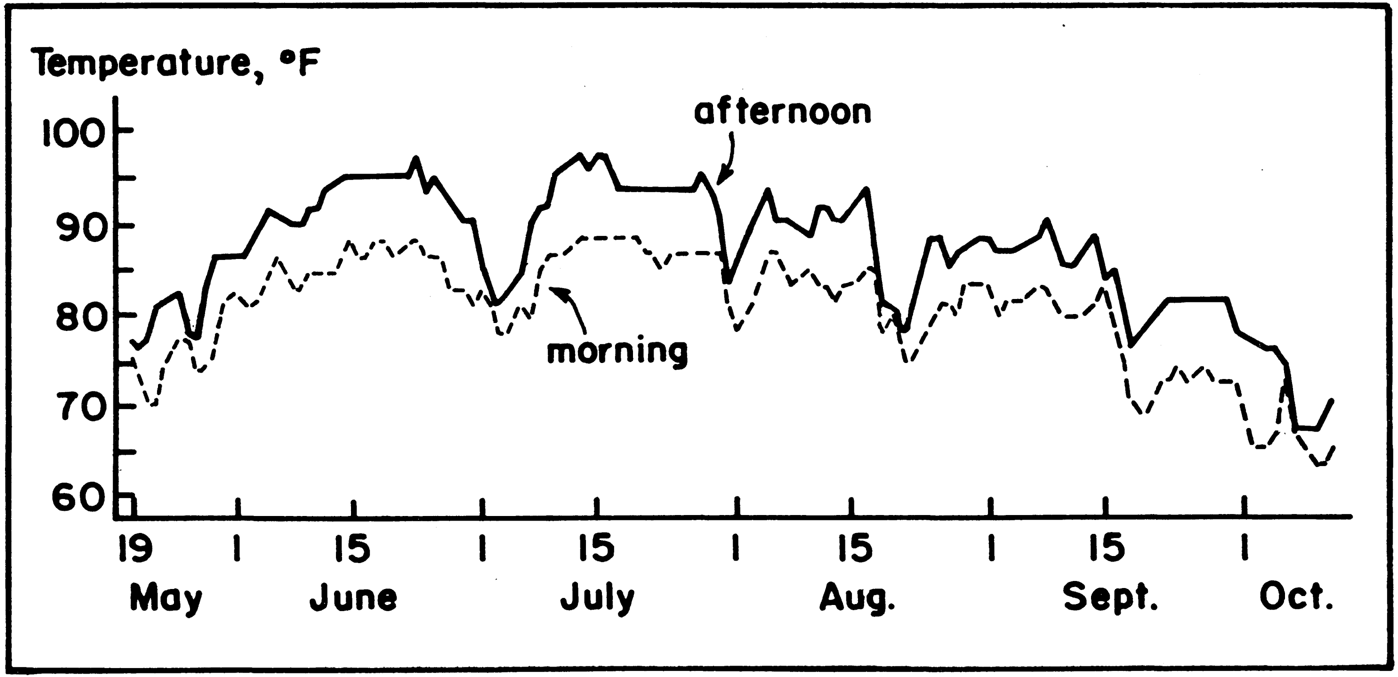

FIG. 4. Average water temperatures (surface, mid depth, and bottom) in the morning (7 to 8 a.m.) and afternoon (4 to 6 p.m.) in a catfish pond.

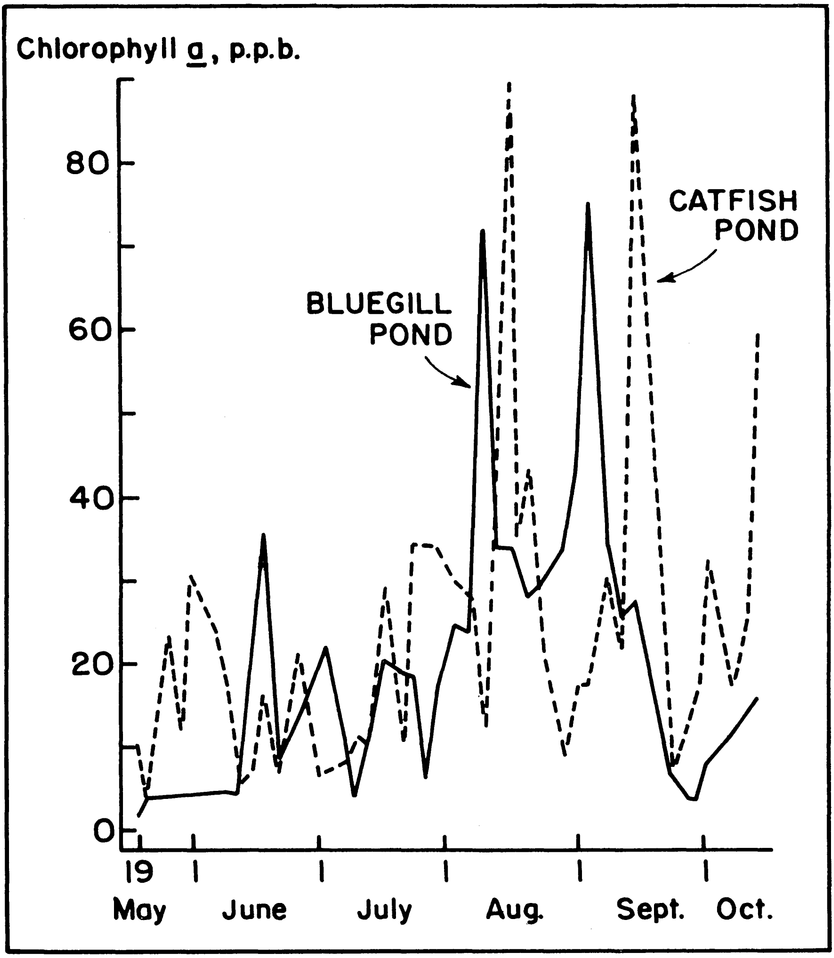

FIG. 5. Chlorophyll *a* concentrations in a bluegill and a catfish pond.

chlorophyll *a* concentrations fluctuated. Some of the sudden declines in chlorophyll *a* concentration corresponded to spells of cloudy weather; others did not.

Afternoon concentrations of dissolved oxygen were not related to phytoplankton abundance. However, in the catfish pond, the lowest morning oxygen concentrations occurred during periods in August and September when water temperatures, phytoplankton abundance, and fish density were high.

Bluegill ponds seldom have severe oxygen depletion, but oxygen depletion is a common problem in catfish ponds *(2)*. The catfish pond used in the present study did not have a sufficiently high stocking and feeding rate to cause extremely low concentrations of dissolved oxygen. At a stocking rate of 4,000 fish per acre and a maximum daily feeding rate of 70 pounds per acre per day, oxygen depletion is a common phenomenon *(11)*.

The results in figure 1 indicate that periods of low dissolved oxygen may be expected during periods of prolonged cloudy weather. Hence, fish culturists could use weather forecasts as a method of predicting when oxygen depletion is likely and be ready to take preventative measures.

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