Factors Controlling Eutrophication in Lake Monroe

William Chang
Department of Biology, Indiana University
Bloomington, Indiana 47401

Introduction

The principal result of lake eutrophication is increased algal productivity. This increase is regulated by a variety of environmental factors, of which light and nutrients, particularly phosphorous, are the prime limiting factors in Lake Monroe, Indiana (1, 2). Sufficient solar radiation and nutrient enrichment are of great significant in controlling algal productivity, and the interdependence of these factors is of significant importance in accelerating primary productivity in this lake (2). Similar findings were obtained in the study of two Illinois rivers by Wang (6). The Illinois River was characterized by turbid conditions and was generally void of algal blooms, whereas the Fox River was usually clear except during periods of frequent algal blooms. His report attributes this effect to high turbidity conditions, which cause a light-inhibition effect and thus retard algal growth.

In Lake Monroe, during the summer months of 1975 and 1976, surface light-inhibitions in productivity were observed. Nutrient enrichment experiments were also performed; however, no significant increase in algal productivity was observed during these experiments. A hypothesis of the existence of a factor inhibiting algal productivity was formed. This hypothesis assumes that the factor occurred concurrently with increased productivity in summer months when the concentration of alkalinity in the lake rose above 0.48 meq (this concentration was determined by the value that best correlated with significant changes in algal assays) and disappeared when the concentration of alkalinity fell below 0.48 meq. The effect could be neutralized by the addition of EDTA (a chelator). The hypothesis was further tested by Chang (2), who confirmed the existence of this inhibiting factor.

This paper focuses on the characteristics of the inhibiting effect. From what is known, two hypotheses can be formed: (A) the change in alkalinity, which results from the increased productivity in summer, alters the permeability of algal membranes, which in turn prevents algal intake of nutrients present in the water during the experiment (Grossman, pers. comm.); or (B) the increase in alkalinity in summer causes a chain of chemical changes in the water, thereby rendering the enriched nutrients, in particular soluble reactive phosphate, inaccessible to the algal population (7). In hyopothesis A, the addition of EDTA may cause an increase in the permeability of algal membranes and thus increase algal productivity. With respect to hypothesis B, when EDTA is added, it chelates with cations in these phosphate-bonded compounds releasing phosphate in accessible form to algae and thereby increasing algal productivity.

Materials and Methods

Bioassay experiments were conducted from May to August, 1977, in Lake Monroe by monitoring the flux of carbon dioxide molecules. This method involves measuring the differential metabolism in transparent and darkened bottles with C-14 labelled carbon dioxide. The bottles were filled with water samples collected at one-meter intervals from 0-6 meters and incubated for six hours at the depth from which the sample was taken. A detailed discussion of the method can be found in Lewis (5) and Chang and Frey (1).

Stock solutions were prepared containing 5 ug/ml phosphate as KH_2PO_4 and 300 ug/liter EDTA. In each experiment the amount of nutrient varied according to the experimental design (Table 1). The concentrations of soluble reactive phosphate in the water before and after the addition of EDTA were determined by the extraction method of Golterman and Clymo (3). In the laboratory, the samples from each depth were separated into two groups. One group served as the control; the other group was treated with EDTA, and immediately analyzed for soluble reactive phosphate. Glassware used for the determination was acid-washed and rinsed in double-distilled water just prior to use. The determination was made with a Cary-14 spectrophotometer in a 10-cm cell at a wavelength of 885 mu. The results are shown in Tables 2 and 3. Bottles were artificially aerated with CO_2 to lower the alkalinity concentration in the water to that existing prior to the summer increase in productivity. This technique decreased pH by 0.3 degrees.

Comparisons of the productivity results between the bottles with various nutrient enrichment and CO_2 treatments, and the control were made using Fisher's distribution-free sign test (4). The results are shown in Table 1.

TABLE 1. *Comparison of the productivity results between the bottles with various nutrient enrichment and the control using Fisher's distribution free sign test. (— not significant; * significant increase at 5% level; ** significant increase at 1% level; x significant decrease at 1% level.)*

Lake water & EDTA (1 ml)	Lake water & 5 ug/l of PO_4	Lake water & 15 ug/l of PO_4	Lake water & 5ug/l of PO_4 & CO_2 aeration
Control * (June 29)	—	—	no data
Control ** (July 13)	—	no data	x

Results and Discussion

If hypothesis A is correct, then the reduction of alkalinity in the water to the level prior to the summer increase in productivity should alter the permeability of the algal membranes, thereby causing a significant increase in productivity in the enriched bottles as compared to the control. However, the results of the artificial reduction of alkalinity by CO_2 aeration in the phosphate-enriched bottles showed no significant increase in productivity when compared to the control, but instead a significant reduction in productivity (Table 1). These

results indicate that this hypothesis is not likely to explain the mechanism that regulates this sytem.

Hypothesis B assumes that a chain of chemical changes occurs in the water due to the increase in alkalinity in the summer months, thereby rendering some nutrients, in particular soluble reactive phosphate, unavailable to the algal population. It is known, however, that when added to the water, EDTA chelates with cations of the phosphate-bonded compounds, thereby releasing phosphate in accessible form to the algae. Therefore, if this process does indeed take place in the water, the addition of EDTA should cause a significant increase in soluble reactive phosphate in the water. The results of the experiments with EDTA conducted on June 29, 1977, and July 13, 1977, showed EDTA not only had a significant effect on algal productivity, but also triggered an increase in the concentration of soluble reactive phosphate in the water (Tables 2 and 3). This suggests that hypothesis B may offer an explanation for the phenomenon under study.

TABLE 2. *The concentration of soluble reactive phosphate (in ug per liter) before and after the addition of EDTA as determined on July 29, 1977.*

Depth in meters	Prior to the addition of EDTA		After the addition of EDTA	
	Mean	S. D.	Mean	S. D.
1	3.4	4.5	0.2	0.3
2	0.1	0.1	0	0.1
3	0.4	0.4	0.9	1.5
4	1.6	0.6	6.5	0.8
5	0	3.1	0	0

TABLE 3. *The concentration of soluble reactive phosphate (in ug per liter) before and after the addition of EDTA as determined on July 13, 1977.*

Depth in meters	Prior to the addition of EDTA		After the addition of EDTA	
	Mean	S. D.	Mean	S. D.
0	0	0	8	0
1	10.5	0.7	15	2.8
3	0	0	0	0
5	0	0	0.2	0

However, some questions also arose when the results shown in Tables 2 and 3 were reviewed. Significant increases in soluble reactive phosphate were found only in the sample taken from the four meter depth on June 29, and from the surface and the one meter depth on July 13. It was also noted that the amount of the increases was small. These results hardly support this hypothesis, in particular regarding the chelating power, and cannot fully account for the increase in productivity caused by EDTA. Therefore, there must be other accompanying physiological changes that are triggered by the addition of EDTA, or other complex mechanisms that interact with EDTA not yet

understood. Nevertheless, it is certain that the unavailable nutrients, in particular phosphate, are released to the algae in an accessible form through EDTA-chelation.

In summary, the inhibiting factor of algal productivity in Lake Monroe is probably affected by changes in the physical environment, and the chemical chelating power of EDTA may be one of the mechanisms which control this process. However, the complete dynamics of this system appear to be very complex, and a satisfactory explanation has yet to be found.

Literature Cited

1. CHANG, W., and D. G. FREY. 1977. Nutrient relations. pages 71-117 in: Technical report no. 87, Indiana University Water Resources Research Center.
2. CHANG, W., 1977. The use of path analysis to determine the factors affecting eutrophication. 34 p. M.S.
3. GOLTERMAN, H. L., and R. S. CLYMO. 1969. Methods for Chemical Analysis of Fresh Water. IBP Handbook no. 8. Blackwells, Oxford. 166 p.
4. HOLLANDER, M., and D. WOLFE. 1973. Nonparametric Statistical Methods. John Wiley and Sons, New York. 503 p.
5. LEWIS, W. M., Jr. 1974. Primary production in the plankton community of a tropical lake. Ecol. Monogr. **44**:377-409.
6. WANG, W. C., 1974. Effects of turbidity on algal growth, Technical report no. ISWS-74-CIR-121. Illinois State Water Survey, Urbana. 14 p.
7. WETZEL, R. G., 1966. Productivity and nutrient relationships in marl lakes of northern Indiana. Verh. Int. Verein. Limnol **16**:321-332.

Acknowledgements

The author would like to thank the Indiana Academy of Science for the support received through a research grant. The author would also like to thank L. Chang, M. Slovin, M. Tamura, and M. Binford for reviewing this paper.