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ABSTRACT

THE INFLUENCE OF RESERVOIR BASIN MORPHOMETRY
ON PHYTOPLANKTON COMMUNITY STRUCTURE

The research protocol was designed to compare three reservoirs with similar physical environments but different morphometry. Three reservoirs on the western edge of the Ozark uplift were selected because of their similar substrate and climatic condition. The reservoirs primarily differed in morphometry. Two of the reservoirs were of identical size, Bob Kidd and Prairie Groves Lakes, but of different configuration, semicircular and linear, respectively. The bifurcated lake, Lincoln Lake, was of smaller size. Each lake is dimictic. Each of the lakes were nitrate-N limited while soluble reactive phosphorus-P is available and not restricting the growth of phytoplankton. Although the pattern of nutrient utilization was similar among the nutrient concentrations varied. Phytoplankton succession was alike in each reservoir but differed in quantity.

Richard L. Meyer and G. Keith Trost

Completion Report to the U.S. Department of the Interior, Geological Survey, Reston, VA, December, 1993

Keywords--Reservoirs/Water Quality/Nutrients/Phytoplankton

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Acknowledgments

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The support of the U.S. Department of the Interior, Geological Survey, which provided the funds, and Dr. Kenneth Steele, Director, Arkansas Water Resources Center, is greatly appreciated. The assistance of Mrs. Tammy Berkey, Mrs. Melpha Speak, and Ms. Patti Snodgrass is gratefully acknowledged.

INTRODUCTION

Water quality in reservoirs has become important because of increased dependence on their use as municipal and industrial water supplies. Also, reservoirs, because of their shapes and extended dendritic drainage systems are very susceptible to non-point source enrichment. Water quality, nutrient concentrations, in reservoirs has been associated with algal phytoplankton growth and this growth is considered a reaction to nutrient enrichment (Gloss et al., 1980). These organisms can reduce water quality through the release of products which cause tastes and odors as well as expensive treatment before beneficial usage.

Models of reservoirs have been constructed based upon nutrient loadings or concentrations only (e.g. Volenwider's model for true lakes) and then applied to reservoirs. Differences in climatic, geomorphologic, and nutrient input qualities produced differences in quality and quantity of phytoplankton. Lakes with similar glacial history, climatic zone or biome, morphology and successional experience have been classified and these models applied to distinct aquatic systems. These models have been partially successful or unsuccessful in their application to reservoirs, to aquatic systems with alternate histories and/or in different geographic locales.

A comparison of reservoirs under common climatic influences, upon similar geomorphic substructure but differing in morphometry can identify additional structural parameters which influence phytoplankton structure. This influence can be most clearly detected if primary nutrients are in adequate supply.

To ascertain the influence of shape three reservoirs of varying morphometries were selected for intensive study. A comparison of reservoirs with linear, semicircular and bifurcated morphometries were selected. With the constancy of the geological substrate and similar soil types in the drainage basins, it is anticipated that the chemistry of the inflowing waters would be of similar character. Therefore, the main objective of the study was to understand how the morphometry of the reservoir interacts with the nutrient flux within the reservoir and, thus, its effect on the annual succession of phytoplankton community structure. To achieve this objective an analysis of chemical and physical parameters important in controlling the quality and quantity of phytoplankters were analyzed.

Methods and Procedures

A. Site description

Three reservoirs occurring on the western slope of the Ozark Plateau dome were chosen for research sites; Lincoln Lake, Bob Kidd Lake and Prairie Grove Lake. Each of the lakes are located in west central Washington County, Arkansas and lie on top of the Mississippian age limestone and sandstone formations. The 35.2 ha Lincoln Lake is a bifurcated lake with two drainage basins with a combined drainage area of 3392 ha. The 80.9 ha semicircular Bob Kidd Lake drainage area encompasses 1003 ha. Prairie Grove Lake has a surface area of 80.9 ha and a drainage area of 2047 ha.

B. Sampling Protocol

Initially the lakes were surveyed to determine the depth of the photic zone, depth and lateral extent of the epilimnion and metalimnion, as well as temperature, dissolved oxygen and conductivity vertical profiles. Following preliminary surveys one to five sampling stations were established on each lake. Locations of the stations were determined by the portion of the lake covered by the metalimnion during the period of stratification and morphometry of the lake. Bob Kidd Lake contained a single station, Prairie Grove Lake sampling site was reduced to two; whereas, Lincoln Lake contained four sites but could be reduced to three locations. Each lake included a site that was located in the thalwag near the dam. In Prairie Grove Lake a station was maintained at approximately three-fourths length. Similar sites were positioned within each of the Lincoln Lake arms plus one near the dam in the interconnecting pool. Additional samples were collected near the inlet streams.

C. Analytical Methods

Temperature, dissolved oxygen and photosynthetically active radiation (PAR) were measured at one meter intervals to determine the basic structure of the water column to select water quality grab sample sites and depths. One or more grab samples were collected in the epi-, meta- and hypolimnion. Conductivity, pH, alkalinity, nitrate-N, soluble reactive phosphate-P (SRP), and chlorophyll's a, b and c were determined by Standard Methods (APHA, 1992) at the Arkansas Water Resources Center Water Quality Laboratory following approved quality assurance protocols.

Principal Findings and Significance

The three reservoirs have depths of 10 meters and similar thermal structure. The epilimnetic temperature ranges from a maximum of 29^{o} to a minimum of 6^{o} in Lincoln Lake and 4^{o} in the other reservoirs.

Dissolved oxygen distribution was similar with late January-early February maxima of 11-12 mg/l and late summer-early autumn minima of ca. 6 mg/l. Oxyclines developed in each lake at the 3-4 m level and extended from late April through late September-early October. Stratification and mixing were storm event dependent and thus expressed some year-to-year variation. Each of the reservoirs expressed classical dimictic characteristics with a heterograde oxycline. The photic zone (defined as 1% ambient PAR) extended to slightly greater than 3 m in all reservoirs near the dam site.

The three morphometrically diverse reservoirs had similar general characteristics. This fact suggests that the climatic and geomorphic parameters had a predominant influence on temperature, stratification, mixing and other basic parameters. Thus, qualitative and quantitative differences in the primary biota, the phytoplankton, are under the influence of nutrient dynamics and/or morphometry.

In order to estimate the importance of morphometry on phytoplankton abundance and community structure, nutrients should be greater than limiting concentrations. The concentrations for soluble reactive phosphate-P, nitrate-N and chlorophyll a were analyzed and are presented in the following figures. Further analysis of the community structure of the phytoplankton will be included in a thesis by one of the authors, Gary Keith Trost.

Soluble reactive phosphate-P (SRP) remained near detection limits throughout most of the year except during fall turnover in Bob Kidd Lake in November, 1991 and December, 1993 (Fig. 1). Similar raises in SRP-P concentrations were observed in Prairie Grove Lake and Lincoln Lake (Figs. 2 and 3, respectively). In the latter lakes the increases were less dramatic; 0.25 vs. 0.05 mg/l. In general, phosphorus seems to be quickly utilized as a new phytoplankton assemblage succeeds the previous seasonal assemblage. Each lake had a minor increase in phosphorus concentration during the winter light limiting period.

Nitrate-N concentrations tended to be near detection limits during most of the year except following fall turnover (Figs. 1, 2 and 3). From October through November nitrate-N concentrations increase dramatically; from near zero to 1.5-2.9 mg/l. The concentrations remained high throughout the winter season but decreased with increasing insolation and the onset of the spring phytoplankton assemblage. The precipitous decline of nitrate-N, with the removal of light limitation, indicates a strong demand for the nutrient. The data suggest that these reservoirs become nitrate limited during the summer.

During April, 1993 3,630 kg of 18-46-0 NPK fertilizer was added to a narrow zone in Bob Kidd Lake by the Arkansas Game & Fish Commission. An intensive study conducted by Meyer and Phillips (1993) clearly demonstrated that the addition of the fertilizer resulted in persistent increased SRP-P concentration while the additional nitrate-N disappeared within hours. These unanticipated results added new information concerning nutrient and controlling factors. The intensity of the nitrate-N limitation seemed to overwhelm morphometric influences.

This information is important in preparing prescriptions for the application of confined animal wastes. These recommendations should not be based upon phosphate loading alone while ignoring nitrate concentrations. It is clear that these potential non-point pollution sources should consider nitrate transport via surface run-off and ground water enrichment.

The abundance of the quantity of the phytoplankton assemblage can be measured by the concentration of the primary photosynthetic pigment chlorophyll a. The distribution of chlorophyll a in Bob Kidd Lake (Fig. 4) and Lincoln Lake (Fig. 5) follow similar generalized patterns with certain variations. The concentrations in Lincoln Lake tend to be lower and have less dramatic changes than Bob Kidd Lake. The peak concentrations in Bob Kidd Lake tend to vary between 40 to 50+ ug/l while those in Lincoln Lake are 20 to 35 ug/l. Concentrations decline in March and April as nitrate-N becomes limiting but increase during the fall as nitrate-N concentrations increase with fall turnover. A winter diatom/chrysophyte bloom was detected in Bob Kidd Lake (Fig 4). Prairie Grove Lake typically has chlorophyll a concentrations below 20 ug/l throughout the year. In June, 1991 a temporary spike of 53 ug/l was associated with an increased abundance of chlorophytes, cyanophytes and cryptomonads. The populations in Prairie Grove Lake seem to be less influenced by nutrient dynamics than in the other lakes. The association of nutrient dynamics and quality and quantity of phytoplankton will be further examined by one of the authors (GKT). Further research will be necessary to determine if the morphometry of Prairie Grove Lake is of great enough influence to modify the impact of the nitrate-N limitation

Conclusions

1. The three lakes, Bob Kidd, Prairie Grove and Lincoln, occur on similar geomorphic substrate and experience the same climatic events.

2. Each lake is dimictic with well established periods of thermal stratification.
3. Oxygen has two distinctive distribution patterns. During thermal stratification, an orthograde oxycline develops. The oxygen maximum develops in the winter during isothermal conditions with reduced insolation.
4. Photosynthetically active radiation (PAR) declines quickly with depth thus limiting the euphotic zone to the upper 3-5 meters.
5. Turbidity values are similar between the reservoirs.
6. Phosphorus as SRP-P seems to cycle quickly, be readily available and not restricting to the growth of phytoplankton.
7. Nitrate-N concentrations increase dramatically after fall turnover, remain high through the winter, then decrease precipitously with increasing insolation in the spring.
8. Nitrate-N becomes limiting during the summer.
9. Insolation, intensity and duration of sunlight, limit growth during the winter.
10. Chlorophyll a concentrations in the epilimnion reflect the seasonal succession events of the phytoplankton assemblage. Bob Kidd and Lincoln Lakes had similar successional series, but with qualitative differences. Prairie Grove Lake had a single temporary bloom, while the remainder of the time concentrations remained low and nearly stable.
11. Best management practices for the drainage basins should consider nitrate-N concentrations in the runoff and ground water.

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Gloss, S.P., Mayer, L.M., and Kidd, D. E., 1980. Advective control of nutrient dynamics in the epilimnion of a large reservoir. Limnology and Oceanography 25: 219-228.

Meyer, R.L. and Phillips, J.K., 1993. Determination of the Efficacy of Fertilization Practices on Bob Kidd Lake. Arkansas Water Resources Center. 38 p.

Figures

Fig. 1. Nitrate-N & SRP-P Distribution in Bob Kidd Lake Over Time

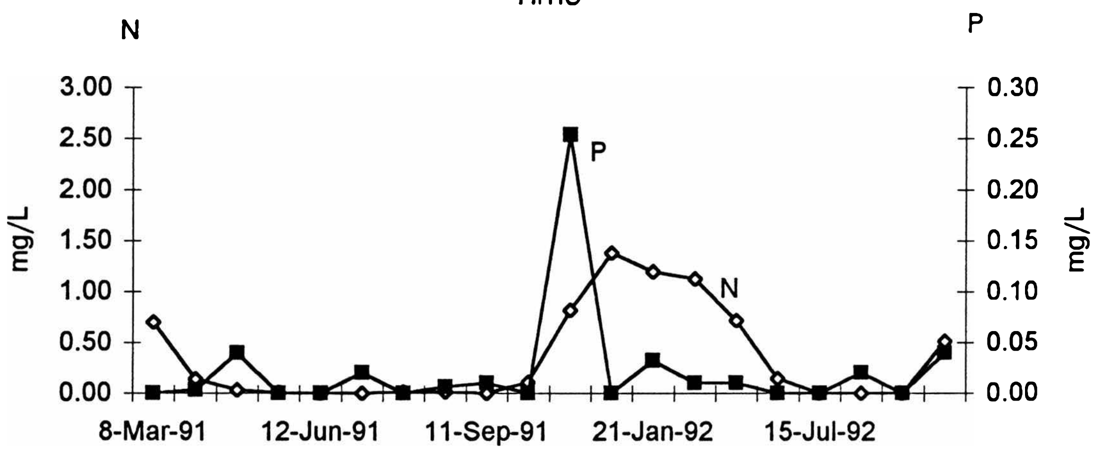

Fig. 2. Epilimnetic Nitrate-N & SRP-P Distribution in Prairie Grove Lake Over Time

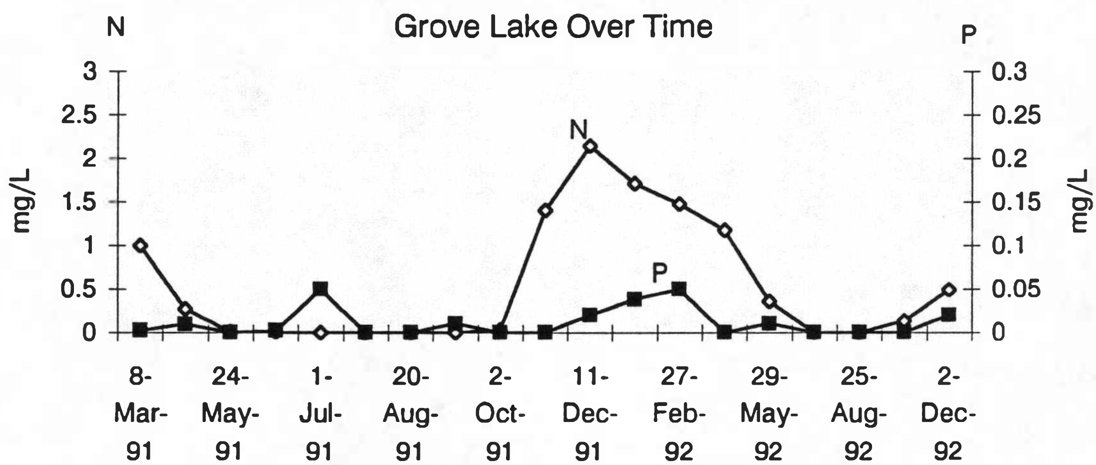

Fig. 3. Epilimnetic Nitrate-N & SRP-P Distribution in Lincoln Lake Over Time

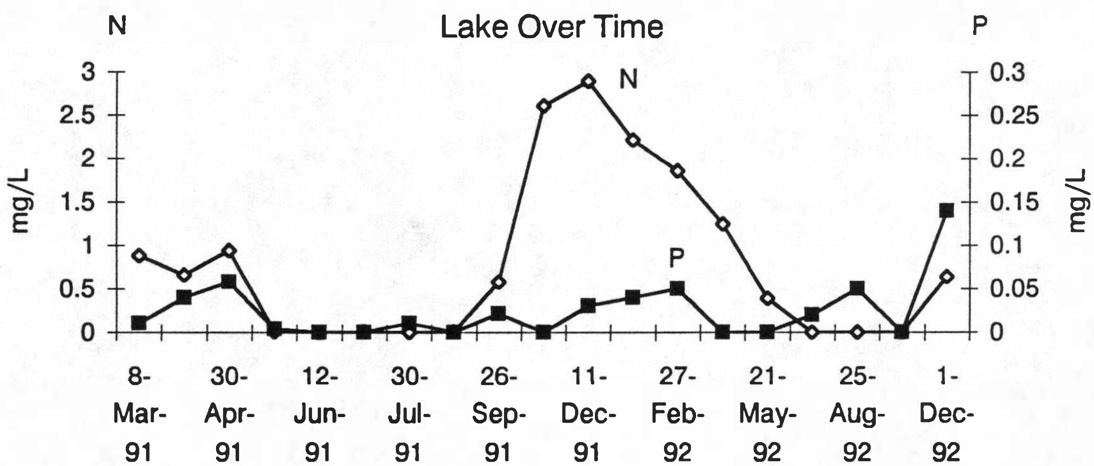

Fig. 4. Epilimnetic Chlorophyll a Distribution in Bob Kidd Lake Over Time

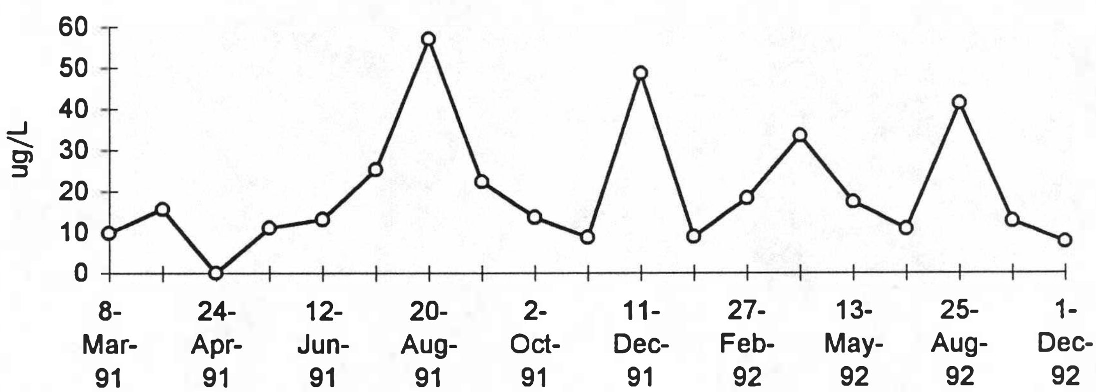

Fig. 5. Epilimnetic Chlorophyll a Distribution in Prairie Grove Lake Over Time

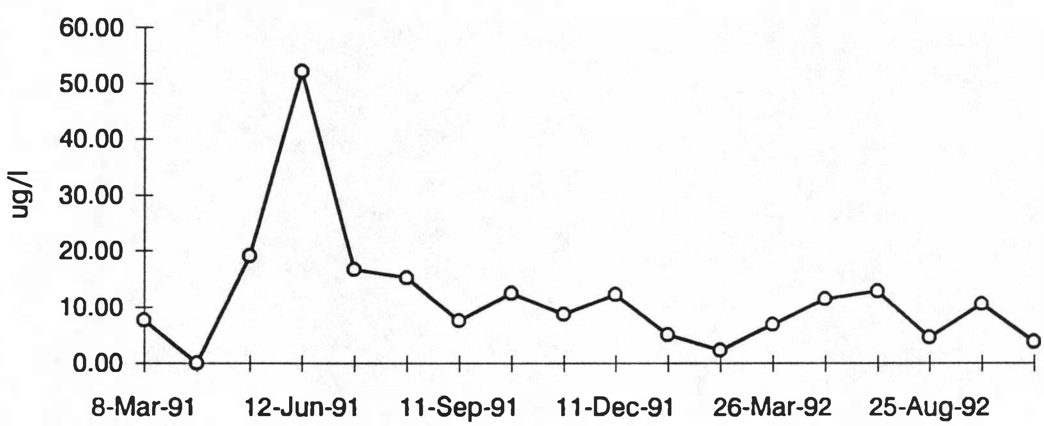

Fig. 6. Epilimnetic Chlorophyll a Distribution in Lincoln Lake
Over Time