Relationships between benthic communities, land use, chemical dynamics, and trophic state in Georgetown Lake

by Paul Allen Garrett

A thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Botany
Montana State University

Abstract:
The relationship between land use, chemical dynamics, arid benthic plant corrmunities in Georgetown Lake was investigated from 1973-1975 and 1981-1982. Experimental enclosures were used to isolate littoral macrophyte communities and evaluate effects on aquatic chemistry. Over 90% of the Georgetown Lake drainage was covered by natural vegetation, primarily coniferous forest. Cultural development is concentrated around the reservoir, but does not appear to be affecting basin water quality or recreational values due to the small relative area (<3% of the total) developed. Results of a septic system survey indicated that domestic wastes are not having a significant impact csi water quality. Macrcphyte communities were found to dominate primary productivity and strongly influence chemical dynamics in the reservoir. Canopy coverage of Potamoqeton praelonqus doubled between 1975 and 1981. An exponential growth rate of 0.1155/yr was calculated for this population. Standing crops of other macrophyte communities appeared to vary annually in response to meteorological and hydrological conditions. During July-September, 1974, benthic communities accounted for an average of 90% of gross reservoir photosynthesis and 73% of reservoir respiration. Carbon limitation was suggested as a cause of declining photosynthetic rates in late summer. Rooted aquatic vascular plants were not limited by nitrogen or phosphorus availability, as indicated by tissue analysis. Ccmmunity oxygen consumption under ice cover ranged from 0.08-0.32 g O2/m^2/day. Positive rates of oxygen production (0.089-0.174 g O2/m^2/day) were measured at shallow sites and attributed to algal photosynthesis. The majority of oxygen uptake was attributed to benthic communities. Concentrations of inorganic dissolved phosphorus remained low thoughout the ice-free periods and suggested regulation by calcium hydroxyapatite solubility equilibria. Regulation of pH by macrophyte photosynthesis is implicated in control of phosphorus solubility. Rates of internal phosphorus loading up to 3.83 mg P/m^2/day were calculated. Major internal sources of nitrogen identified were release from sediments during winter anoxia and release from littoral sediments during late summer. Sediment accumulation rate was estimated at 0.25 cm/yr, equalling 1050 g dry matter/m^2/year. Vertical distribution of sediment phosphorus indicated an upward mobilization, which was attributed to uptake and redeposition by rooted vascular plants. Mass budgets for nitrogen and phosphorus indicate that major nutrient sources are natural and within acceptable levels. Phosphorus loading rates are negative, but dissolved phosphorus supplies are being buffered by sediment phosphorus supplies.

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APPROVAL

of a thesis submitted by

Paul Allen Garrett

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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May 26, 1983
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Date 26 May, 1983

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ABSTRACT

The relationship between land use, chemical dynamics, and benthic plant communities in Georgetown Lake was investigated from 1973-1975 and 1981-1982. Experimental enclosures were used to isolate littoral macrophyte communities and evaluate effects on aquatic chemistry. Over 90% of the Georgetown Lake drainage was covered by natural vegetation, primarily coniferous forest. Cultural development is concentrated around the reservoir, but does not appear to be affecting basin water quality or recreational values due to the small relative area (<3% of the total) developed. Results of a septic system survey indicated that domestic wastes are not having a significant impact on water quality. Macrophyte communities were found to dominate primary productivity and strongly influence chemical dynamics in the reservoir. Canopy coverage of Potamogeton praelongus doubled between 1975 and 1981. An exponential growth rate of 0.1155/yr was calculated for this population. Standing crops of other macrophyte communities appeared to vary annually in response to meteorological and hydrological conditions. During July-September, 1974, benthic communities accounted for an average of 90% of gross reservoir photosynthesis and 73% of reservoir respiration. Carbon limitation was suggested as a cause of declining photosynthetic rates in late summer. Rooted aquatic vascular plants were not limited by nitrogen or phosphorus availability, as indicated by tissue analysis. Community oxygen consumption under ice cover ranged from 0.08-0.32 g O_2/m^2/day. Positive rates of oxygen production (0.089-0.174 g O_2/m^2/day) were measured at shallow sites and attributed to algal photosynthesis. The majority of oxygen uptake was attributed to benthic communities. Concentrations of inorganic dissolved phosphorus remained low thoughout the ice-free periods and suggested regulation by calcium hydroxyapatite solubility equilibria. Regulation of pH by macrophyte photosynthesis is implicated in control of phosphorus solubility. Rates of internal phosphorus loading up to 3.83 mg P/m^2/day were calculated. Major internal sources of nitrogen identified were release from sediments during winter anoxia and release from littoral sediments during late summer. Sediment accumulation rate was estimated at 0.25 cm/yr, equalling 1050 g dry matter/m^2/year. Vertical distribution of sediment phosphorus indicated an upward mobilization, which was attributed to uptake and redeposition by rooted vascular plants. Mass budgets for nitrogen and phosphorus indicate that major nutrient sources are natural and within acceptable levels. Phosphorus loading rates are negative, but dissolved phosphorus supplies are being buffered by sediment phosphorus supplies.

INTRODUCTION

Georgetown Lake is a multiple use reservoir located between Anaconda and Philipsburg, Montana, on the Philipsburg Divide. Highway 10A parallels the shoreline for about 5 miles (8 km). Major uses of the reservoir have included water storage for industrial processing, downstream irrigation, power generation, and, as a by-product, recreation. The beautiful natural setting and absence of other similar resources in the area have lent particular importance to the recreational use aspect. Over time, secondary uses of a resource may assume primary importance under changing economic and social conditions. So it may be with Georgetown Lake. With the closure of the Anaconda Company smelting facilities in Anaconda and the development of alternative power generation facilities, recreational uses of the reservoir have assumed more importance to the local community, from a standpoint of both personal enjoyment and economic assets. It thus becomes more important to maintain and protect the conditions and qualities which endow the reservoir with its unique esthetic and recreational values.

Georgetown Lake has a history of excellent fishing, easy accessibility, and intense recreational use. Recreational activities include fishing, power-boating, sailing, water-skiing, swimming, waterfowl hunting, and in winter, snow-mobiling, cross-country skiing, and ice fishing. The reservoir also has a history of periodic algal blooms, occasional winter fish kills of varying severity, and, to some but not all recreationists, excessive aquatic vascular plant growth.

As a result of these problems, coupled with accelerated cultural development in the area and intense public concern, Georgetown Lake has been the subject of considerable limnological investigation over the past nine years. The work now being reported began in 1973. Local concern over the problems stated relative to recreational use of the reservoir and development in the drainage resulted in a research grant from the Department of Interior's Office of Water Research to Montana State University for the investigation of limnological relationships in Georgetown Lake. Paul Garrison, William Geer, William Foris, and Jonathan Knight, and the author participated in these studies, which continued into 1976, and have been reported, in part, by Geer (1977), Garrison (1976), Foris(1976), Knight et al (1975), and Knight (1980). Several significant questions remained unanswered by these reports. The following are of particular concern, relative to lake management:

1) What are the causes of the dense macrophyte growths observed in Georgetown Lake?

2) What are the relationships between macrophytes and other aspects of recreational water quality, such as clarity, algal growth, and dissolved oxygen concentrations during ice cover?

3) What is the probable pattern of macrophyte community development and growth in the reservoir in the near future?

4) Are there any feasible management options which may bring biological conditions more in line with those desired in a multiple-use recreational reservoir?

5) What impacts are recreational use of the reservoir and cultural development of the surrounding drainage having on the condition of the reservoir, and what restrictions may be necessary to maintain or improve the esthetic qualities of the reservoir as a recreational resource?

Subsequent to 1976, a perceived rapid increase in the density and distribution of macrophytes brought renewed local concern about water quality/land use/macrophyte relationships. Under the provisions of Section 14, Public Law 92-500 (Federal Water Pollution Control Act Amendments of 1972), EPA administers the Clean Lakes Program to assist the states in maintaining the recreational water quality of lakes and reservoirs through pollution control and lake restoration projects. Through the efforts of local citizens, Montana Department of Natural Resources, and the Montana Water Quality Bureau, EPA funded a diagnostic/feasibility study for Georgetown Lake to attempt to answer the above questions. This program was initiated in August, 1980 and continued through August, 1982. The author was involved in the program as Project Scientist, and much of the data used in this report were collected during the project.

The following specific objectives were identified and research efforts throughout the project focused on answering the critical questions involved:

1. Identify cultural impacts on trophic state and macrophyte growth through analysis of land use and nutrient budgets.
2. Determine contribution of macrophytes to primary production through analysis of seasonal dynamics of biomass and community metabolism.
3. Investigate factors influencing winter oxygen budgets in Georgetown Lake relative to macrophytes, phytoplankton, and morphometry.
4. Identify changes in distribution, composition, and productivity of macrophyte communities.
5. Establish nutrient status of macrophytes relative to the availability of nitrogen and phosphorus.
6. Investigate the relationships of macrophytes to internal nutrient cycles.
7. Determine rates of sediment accumulation and evaluate sediment relative to nutrient budgets, nutrient supplies and lake management.
8. Investigate other factors affecting the expression of productivity or implementation of management programs in Georgetown Lake.

Classification systems of lakes and reservoirs based on "trophic state" have been extensively developed and almost universally accepted (Reckhow, 1979). Categories used are usually eutrophic, mesotrophic, and oligotrophic, in the sense of nutrient supply

(Hutchinson, 1957a). Parameters of classification systems include morphometry (Rawson, 1955); hypolimnetic oxygen demand (Hutchinson, 1957a); Secchi disc depth (Megard, et al, 1980); alkalinity (Wright, 1980b); phytoplankton pigment concentrations (Reckhow, 1979; Dobson et al, 1974; EPA, 1974a); phosphorus and nitrogen concentrations in lake waters (Hutchinson, 1957a; Edmondson, 1969; EPA, 1974a; Sawyer, 1947; and many others); phosphorus loading rates (Vollenweider, 1968; 1976); community metabolism (Odum, 1961; Hooper, 1969); nitrogen loading rate (Shannon and Brezonik, 1972). Suggested systems of classification containing discussion of parameters, their values, and applications are found in Reckhow (1979), Carlson (1977), EPA (1974), and Uttormark and Wall (1975). There are many other excellent references dealing with the subject of eutrophication and related limnological processes.

The relationship of surface land use to the process of cultural eutrophication is well established (Edmondson, 1969; Vollenweider, 1968). Coefficients of nutrient export have been estimated for a variety of surface land uses (Uttormark, et al, 1974; Reckhow, et al, 1980). Lake managers have had considerable success in controlling or reversing cultural eutrophication by control of point and non-point sources; examples include Shagawa Lake (Larsen and Malueg, 1981), Lake Washington (Edmondson, 1969), and Lake Onandaga (Bartsch, 1981). Although implicated in many cases of cultural eutrophication, on site treatment systems (septic tank/drainfield systems) have been shown to be much less troublesome as non-point sources than suspected