EFFECTS OF LIMING ON NUTRIENT LIMITATION OF EPILITHIC ALGAE IN AN ACID LAKE

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Abstract. The processes of lake acidification and lake restoration frequently involve major changes in DIC and DIN, both of which may potentially limit algal growth. We evaluate nutrient limitation of benthic algal biomass and species abundances during summers 1987 and 1989, before and after the liming of Lake Earnest (NE Pennsylvania) in November 1988. Limestone addition caused immediate increases in pH from 4.7 to 7.2. Alkalinity was ~34 µeq L⁻¹ in summer 1987, but rose to 620 µeq L⁻¹ in summer 1989, whereas DIN declined from 10.7 µmol L⁻¹ to 1.1 µmol L⁻¹. The algae were sampled after 45 to 46 d from clay flower pot substrates diffusing combinations of N, P and C. Algal biomass was strongly C-limited in 1987, but NP-limited in 1989. Mougeotia sp., which comprised >99% of total algal biovolume prior to liming, declined to < 1% of the community on control substrates, while Oedogonium sp. increased to 43% of total biovolume in 1989. The stimulation of chlorophyll-a accrual with C-enrichment during 1987 was consistent with the later increase in chlorophyll-a on control substrates following liming. Species enhanced by the diffused nutrients, however, generally differed from those which dominated the natural community.

1. Introduction

Benthic algal communities in acid lakes are often characterized by high overall standing crop and low diversity (Stokes, 1981). Epiphytic and epilithic communities are frequently dominated by filamentous green algae of the order Zygnematales (e.g., Mougeotia, Spirogyra, Zygogonium), which may detach in some lakes, forming extensive 'metaphytic' algal clouds in nearshore areas (e.g., Schindler and Turner, 1982). Cyanophycean mats may also sometimes occur, typically associated with the sediments (Stokes, 1981; Lazarek, 1982). Diatom representation often declines with decreasing pH and alkalinity (Muller, 1980; Stokes, 1984; Stevenson et al., 1985; Roberts and Boylen, 1988), although some species are clearly acidophilic (e.g., Charles, 1985).

Changes in nutrient availability may accompany lake acidification. Dissolved inorganic carbon concentrations (DIC) typically decline, for example, despite partially compensating alkalinity regeneration through increased sulfate and nitrate reduction in the sediments (Schindler et al., 1980). In contrast, the availability of inorganic nitrogen (DIN), and particularly NH₃, may increase in acid lakes because of elevated atmospheric deposition of both NO₃ and NH₃ and diminished rates of bacterial nitrification (Rudd et al., 1988). Sulfate loading is also known to accelerate the release of sedimentary P (Caraco et al., 1989), presumably increasing its

availability to attached algae as well.

‘Before-after’ studies accompanying the liming of an acid lake can provide a convenient test of just which taxa within a benthic algal assemblage are favored by acidic vs more alkaline conditions (Lazarek, 1986; Roberts and Boylen, 1989), but the role of changing nutrient availability in contributing to the observed species shifts has not been examined experimentally. Here we evaluate nutrient (N, P, C) limitation of dominant taxa within the epilithic algal community of an acid lake, both before and after liming.

2. Study Site

Lake Earnest is a 13 ha clearwater kettle lake situated in Pike County, NE Pennsylvania, maximum depth is 3.5 m. The lake is owned by the Blooming Grove Hunting and Fishing Club. Physicochemical measurements taken seasonally during 1983–1984 indicate that the lake was the most acidic of 38 lakes visited in the region at that time (Sherman, unpublished data). The lake currently supports populations of Yellow Perch (Perca flavescens), Chain Pickerel (Esox niger) and Brown Bullhead (Ictalurus nebulosus).

We studied Lake Earnest during summer 1987 to determine effects of nutrient enrichment on periphyton community structure. The lake was subsequently treated with 24 t of limestone (>97% CaCO₃) on 8 November 1988. Alkalinity rose from −37 μeq L⁻¹ (pH=4.7) in September 1988 to 560 μeq L⁻¹ (pH=7.2) in November directly following liming (K. Ersbak, pers. comm.). In order to assess effects of the limestone addition on nutrient control of the periphyton community we repeated the protocol used in 1987 during summer 1989.

3. Methods

During both summers we deployed nutrient-diffusing clay flower pot substrates (Fairchild and Everett, 1988) in the lake to determine which combinations of inorganic N, soluble reactive P and inorganic C controlled the growth of particular algal taxa. Nitrogen was added to the substrates as 0.5 mol L⁻¹ NaNO₃, P as 0.05 mol L⁻¹ Na₂HPO₄ and C as 60 g NaHCO₃ powder mixed in with a 2% agar solution. Eight nutrient treatments including controls (P, N, C, NP, PC, NC, NPC, CONT) were each replicated 4 times (n=32). The substrates were placed at ca. 0.5 m depth and 0.5 m apart in a randomized block design. The site location and arrangement of substrates were the same in both summers, in a portion of the littoral zone dominated by mixed sand and rocks. The substrates remained in the lake for 45 to 46 d (29 May – 14 July) during 1987 and for 46 d (25 May – 10 July) in 1989.

Water samples were collected, both when the pots were deployed and retrieved, for determination of PO₄-P, total P, NO₃-N, NO₂-N, NH₃-N, total Kjeldahl N, and soluble reactive SiO₂ using a Technicon II Autoanalyzer. Alkalinity (Gran titration) and pH were measured in the field with an Orion Model 250 pH meter.