Ecosystems (2018) 21: 1088–1100
https://doi.org/10.1007/s10021-017-0204-2

ECOSYSTEMS

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Biological Nitrogen Fixation Prevents the Response of a Eutrophic Lake to Reduced Loading of Nitrogen: Evidence from a 46-Year Whole-Lake Experiment

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Abstract

A whole-ecosystem experiment in Lake 227 (L227) at the Experimental Lakes Area, ongoing since 1969, examined the roles of carbon (C), nitrogen (N), and phosphorus (P) in controlling eutrophication. During 2011, we conducted a series of sub-experiments and more intensive monitoring to improve estimates of N fixation and its ability to meet algal growth demands in the decades following the cessation of artificial N loading, while maintaining long-term high artificial P loading. Stoichiometric nutrient ratios indicated both moderate N and P limitation of the phytoplankton during spring, preceding a shift in phytoplankton community structure toward dominance by N fixing cyanobacteria. During bloom development, and for the remainder of the stratified period, stoichiometric nutrient ratios indicated moderate to strong P limitation. N fixation rates, corrected using $^{15}N_2$ methods, increased 2× after 1990, when N loading ceased. Ambient dissolved inorganic nitrogen prior to the bloom represented less than 3% of N demands of the phytoplankton. N fixation accounted for between 69–86% of total N loading to the epilimnion during the period of rapid bloom development, and 72–86% of total N loading during the May–October period. Phytoplankton biomass did not decline in L227 during the 40 years since artificial N loading was reduced, or the nearly 25 years since artificial N loads ceased entirely (1990–2013), and remained approximately 20× higher than four nearby reference lakes. These results suggest that despite constraints on biological N fixation, it retains a large capacity to offset potential N loading reductions in freshwaters.

Key words: eutrophication; freshwater; phytoplankton; nutrient limitation; lake management; whole-lake experiment.

Received 21 July 2017; accepted 6 November 2017;
published online 27 November 2017

Electronic supplementary material: The online version of this article (https://doi.org/10.1007/s10021-017-0204-2) contains supplementary material, which is available to authorized users.

Author contributions SNH conducted 2011 experiments, analyzed data, and wrote the manuscript; MJP, REH, DWS conceived and undertook the long-term study and analyzed the long-term data; DLF analyzed algal taxonomy and heterocyst abundance: JJV and SNH conducted and analyzed the $^{15}N_2$ experiment.

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