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Decreased nitrogen in a shallow lake controls summer cyanobacteria blooms in the long term

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The effectiveness of controlling nitrogen (N) to manage lake eutrophication has been debated for decades. Some scientists argue that decreasing N inputs leads to a proliferation of toxic diazotrophic cyanobacteria, which eventually fix sufficient atmospheric N to offset the reduction of N inputs, making this strategy futile. Therefore, long-term, whole-lake case studies are required to determine whether decreasing N inputs can effectively control cyanobacterial blooms. We document the recovery of shallow, productive Lake Müggelsee (Germany) over 37 yr (sampling interval 1–2 weeks) during a decrease of N and phosphorus (P) loading of 79% and 69%, respectively. Nitrogen concentrations in the lake responded immediately to loading reduction whereas P concentrations remained elevated for about 20 yr. Total nitrogen (TN) in the lake was always lower than TN in the inflow. Accordingly, estimated denitrification and N-burial rates substantially exceeded N2 fixation rates in the long term. Phosphorus was growth limiting in spring whereas N was clearly limiting in summer due to high sediment P-release. TN : TP ratios, normalized to phytoplankton biovolume by regression, were 25.5 (weight) in spring and 3.3 in summer. During the study period, dissolved inorganic N (DIN) concentrations in summer decreased and the duration of low DIN concentrations increased by ca. 100 d. The biovolume of cyanobacteria and total phytoplankton decreased by 89% and 76%, respectively. The proportion of N2-fixing cyanobacteria during summer decreased from 36% to 14% of the total phytoplankton biovolume. The total concentration of heterocysts and estimated total N2 fixation did not change over time. In the long term, decreasing N-inputs effectively controlled summer cyanobacteria including N2-fixing taxa, which did not compensate for the N-deficit. A P-only control strategy would not have been as successful.