

# Assessing nonpoint-source nitrogen loading and nitrogen fixation in lakes using $\delta^{15}N$ and nutrient stoichiometry

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ABSTRACT: Runoff from human-dominated watersheds has greatly altered nitrogen (N) and phosphorus (P) cycling in lakes. Nutrients from human sources are distinct from those from undisturbed ecosystems in several ways including lower N : P ratios, which can drive ecosystems to N-limited conditions, and enriched stable N isotope ratios. In this study, we used these distinct characteristics to estimate shifts in N sources to 27 lakes across a human density gradient in western Washington. We compared an N stable isotope two-source mixing model with a mixing model that coupled N stable isotopes to N : P stoichiometry and included N fixation. We found that a two-source mixing model (human and watershed sources) did not explain observed variation in $\delta^{15}N$ of particulate organic matter (POM) and primary consumers ($R^2 = 0.60$) as well as a model that included a third N source (N fixation; $R^2 = 0.72$). When fixed N was facultatively added to the ecosystem below a critical N : P ratio, the more complex mixing model captured the observed patterns in POM and primary-consumer $\delta^{15}N$ among lakes extremely well. In lakes with P concentrations > 20 μg $L^{-1}$ (N : P mass ratio < 15.3), N fixation became an increasingly important component of the N cycle, accounting for > 50% of lake N budgets. This model provides a novel way to estimate the contribution of nonpoint N sources and N fixation to lakes in watersheds subject to human nutrient inputs.

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