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Hydrogen isotopes from sedimentary lipid biomarkers record changes in algal community assemblages

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Phytoplankton play an important role in biogeochemical cycling, and can impact nutrient cycling as well as atmospheric and aquatic chemistry. However, reconstructing changes in algal productivity and community assembly throughout the geologic past remains challenging. Here, we demonstrate the utility of compound-specific hydrogen isotope compositions (d^2H values) of common algal lipids as a sensitive proxy of past algal ecology. While such measurements have been previously used as indicators of water hydrogen isotope ratios, our results from laboratory cultures and experimental ponds demonstrate that changes in the hydrogen isotopes of ubiquitous lipids such as palmitic acid associated with taxonomic changes are an order of magnitude greater than those caused by hydrologic change. These results indicate that d^2H values of algal lipids, and the relative offset of these values among different compounds, can be used to reconstruct past changes in algal community assemblages, including those driven by changes in nutrient supply.

We applied this approach to a ~180 year sedimentary record from Lake Greifen, a lake in the central Swiss Plateau that underwent well-documented eutrophication and partial recovery in the second half of the 20th century. As total phosphorus concentrations in the lake increased from < 100 mg/L to ~500 mg/L in the 1950s-1970s, palmitic acid d^2H values increased by 40 ‰ and phytol d^2H values by 20 ‰; d^2H values of both compounds subsequently declined with total P following maximum values in the early 1980s. During this entire time interval, mean annual precipitation d^2H values fluctuated within a ~10 ‰ range and are not correlated with the changes in lipid d^2H values. Additionally, the decline in lipid d^2H values is correlated with declining relative abundance of green algae as the eutrophication pressure on Lake Greifen receded in the past decades. This correlation matches the prediction from our culturing and mesocosm results, in which green algae produced exceptionally ^2H-enriched fatty acids compared to other algal taxa. This indicates that lipid d^2H values can be applied to reconstruct historically undocumented shifts in algal populations over timescales that are accessible through sedimentary archives.