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The isotopic imprint of fixed nitrogen elimination in the redox transition zone of Lake Lugano, Switzerland

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Nitrogen (N) loading in lakes from natural and anthropogenic sources is partially mitigated by microbially mediated processes that take place in redox transition zones (RTZ) in the water column and in sediments. However, the role of lakes as a terrestrial sink of fixed N is still poorly constrained. Furthermore, modes of suboxic N2 (and N2O) production other than canonical denitrification (e.g. anaerobic ammonium oxidation, or anammox) have barely been investigated in lakes, and the microbial communities involved in N transformations in lacustrine RTZ are mostly unknown. The isotopic composition of dissolved nitrogen species can serve as a reliable indicator of N-transformations in aquatic environments. However, the successful application of N (and O) isotope measurements in natural systems requires a solid understanding of the various N-transformation-specific isotope effects.
The deep, south-alpine Lake Lugano, with a permanent chemocline in its North Basin, is an excellent model system for a biogeochemically dynamic lake, in which to study N isotope ratio variations associated with fixed N elimination and regeneration processes.

We present the first comprehensive dataset of hydrochemical parameters (including N2/Ar and dissolved N2O concentrations), natural abundance stable isotope ratios of dissolved inorganic nitrogen (DIN) compounds (nitrate, nitrite, ammonium, dinitrogen, nitrous oxide), and the isotopomeric composition of water column N2O for the North Basin of Lake Lugano. Isotopic data will be integrated with molecular microbiological phylogenetic analyses and results from incubation experiments with 15N-labeled N-substrates.

Strong gradients in DIN concentrations, as well as in the N and O isotope (and isotopomeric) compositions of nitrate and N2O towards the redox-transition zone indicate nitrate reduction, occurring with a high community N-fractionation. The site preference of N2O isotopomers above the chemocline indicates that the N2O is not only produced by denitrification. Furthermore, the ratio of nitrate N versus O isotope enrichment is 0.6, significantly lower than the ratio expected for sole water column denitrification. Ammonium concentrations in the hypolimnion constantly decrease to 0μM at about 20m below the oxycline, suggesting that anammox, the anaerobic oxidation of ammonium, takes place below the RTZ. First results from 16S rDNA analysis confirmed the presence of anammox bacteria (Candidatus 'Kuenenia') in the water column. Further phylogenetic and isotope-labeling experiments will provide more information on the spatial and seasonal distribution of anammox bacteria in the water column, on the quantitative partitioning between the candidate N elimination processes, and thus likely on the N isotope fractionation of single N transformation pathways.