Universität Basel

Research Project

Seasonal Dynamics of Coupled Nitrogen, Sulfur and Carbon Cycling in Redox Transition Zones of Lake Lugano

Third-party funded project

Project title Seasonal Dynamics of Coupled Nitrogen, Sulfur and Carbon Cycling in Redox Transition Zones of Lake Lugano

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Nitrogen (N) is an essential element for all living organisms, but extensive use of fertilizer and additional input of reactive N of domestic origin has led to the eutrophication of rivers, lakes, and coastal marine ecosystems. Denitrification, the anaerobic respiratory reduction of nitrate to N_2, has traditionally been seen as the most important process converting reactive N to N_2. Recent observations in natural environments and the discovery of new groups of N-transforming microorganisms with previously unknown metabolisms and unexpected links to the sulfur, iron or manganese cycles suggests, however, that the canonical concepts of certain redox pathways are incomplete, casting doubt on the current general understanding of the global N cycle. Lake Lugano is an excellent model system for an anthropogenically impacted lake and represents a hot-spot for redox-driven transformations including nitrogen, carbon, sulfur, and iron.

1. Research **Project A** investigates the dynamics, environmental controls, and isotope fingerprints of coupled microbial nitrogen-sulfur transformation in the RTZ of the Lake Lugano North Basin
2. Research **Project B** aims at understanding the sedimentary nitrogen cycling and associated microbial community dynamics in the South Basin, with particular focus on links to other element cycles (e.g., Fe)

Using a combination of biogeochemical, isotope, and microbiological tools we propose ă**A1)** to identify the mechanisms that regulate the relative importance of the different N loss processes, anammox, chemolithotrophic- and organotrophic denitrification in the RTZ of the north basin; **A2)** to identify the sulfur-dependent nitrate reducing bacteria that drive denitrification in the RTZ of the Lake Lugano north basin, and **A3)** to elucidate possibly synergistic interactions between anammox bacteria and the chemolithotrophe denitrifiers. **A4)** Moreover we will determine the so far unknown N and O isotope fractionation during S-dependent nitrate-reduction in laboratory experiments. **A5)** As part of our efforts to use the dual nitrate isotopic composition to diagnose specific nitrate reductase activities, we also plan to extend the database of isotope effects associated with Nap, the periplasmatic nitrate reductase, which is frequently present in S-dependent denitrifiers.

Extremely high transient accumulation of N_2O and inconsistencies regarding nitrate uptake have been observed in the previous project, illustrating the lack of understanding of N-cycling in the iron-rich sediments of the south basin. **B1)** By means of high-resolution porewater-N profiling with microsensors, the first measurements of their kind in Lake Lugano, and supplementary ^{15}N isotope tracer experiments, we will identify and quantify the pathways and rates of benthic N-transformations. Moreover we will **B2)** test experimentally the potential for anaerobic ammonium oxidation with Fe(III) (feammox) within the sediments and **B3)** verify first putative evidence for the presence of nitrate-storing, and potentially -respiring, benthic microorganisms – ăboth N-cycling phenomena, for which the environmental significance in freshwater ecosystems is not known thus far. These time-resolved biogeochmical data, including fluxes, as well as measured and modeled process rates, will serve as contextual data for **B4)** exploring the seasonal dynamics of the sedimentary microbial communities using Illumina next generation sequencing technology and bioinformatics. The planned study will investigate microbial dynamics associated with reactions that were relatively unknown a decade or so ago, and barely investigated in freshwater environments. Moreover, our research may help gain insights into novel forms of symbiotic associations between chemolithotrophic bacteria in lakes, efficiently coupling the lacustrine nitrogen and sulfur cycles. The proposed research is thus not only relevant for the understanding and quantification of reactive N-loss in Lake Lugano. It will result in a better comprehension of N turnover pathways in general.

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