QCL WATER SCIENCE

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

PyroScience FireSting

Quantifying Microbial Respiration in Glacier-Fed Streams

Introduction to Subject and Research

The Vanishing Glaciers project (www.glacierstreams.ch) investigates how glacier retreat reshapes the functioning of high-alpine stream ecosystems, focusing on carbon and nutrient cycling. Glacier-fed streams are rapidly transforming due to climate-induced changes in hydrology and resource availability. Microbial metabolism plays a central role in mediating carbon fluxes, yet its global variability and drivers remain poorly constrained, also due to challenges associated with monitoring microbial metabolism in such cold, nutrient deprived and low-biomass systems. We designed and employed an experimental device to quantify in situ microbial respiration as part of a broader assessment of ecosystem energetics in over 170 glacier-fed streams worldwide.

Set-Up and Sample/Method

Streambed respiration was measured using custom-built incubation chambers filled with stream sediments and sterile-filtered streamwater (Fig. 1).
Each of the 8 chambers consisted of 50mL glass vials

Fig. 1a: Logging system deployed at a glacier-fed stream near the glacier snout for microbial respiration measurements

sealed with Teflon-coated silicon septa and equipped with oxygen sensor spots connected to two PyroScience FireSting-O2 optical oxygen meters. Chambers were kept in the stream to preserve in situ temperature. Oxygen concentrations were logged every 15 seconds over a 2-hour period. Measurements were corrected for temperature drift, and normalized to sediment dry mass to yield oxygen consumption rates.

Fig. 1b: Incubation vials submerged in streamwater to maintain in-situ temperature

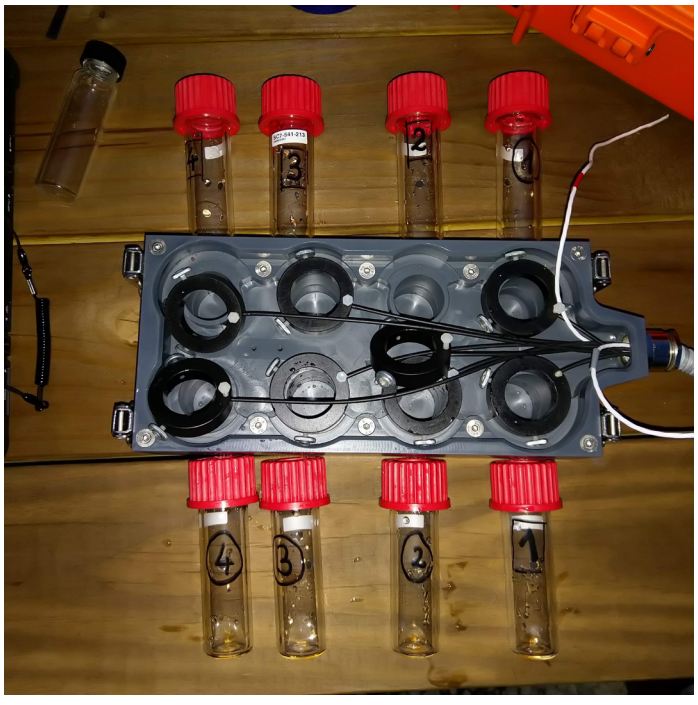

Fig. 1c: Custom-built respiration box with labeled vials and fibre connections

The oxygen timeseries enabled precise quantification of aerobic microbial respiration in benthic biofilms (Fig. 2). Data processing included discarding the initial 3000 seconds of measurements, a threshold of temperature variation smaller than 1°C and linearity in the oxygen consumption. These data were integrated with bacterial carbon production (measured via ^{3}H-leucine

incorporation) to compute microbial carbon use efficiency (CUE). Respiration was detected in 88% of the streams sampled, with values indicating predominantly maintenance metabolism, especially in upstream reaches closer to the glacier snout. Coupled with enzymatic activity assays and resource stoichiometry, the respiration data contributed to a global synthesis of microbial energetics across environmental gradients in glacier-fed streams.

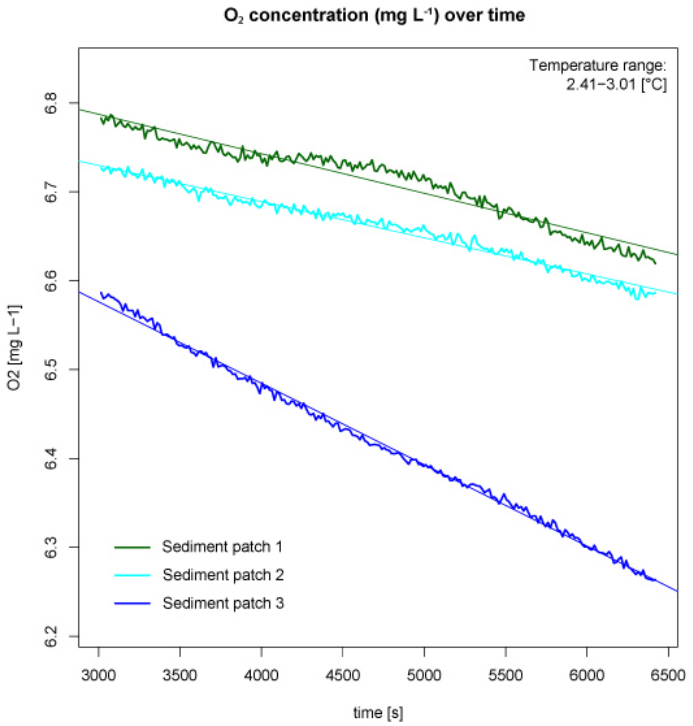

Fig. 2: Decline in dissolved oxygen during a microbial respiration incubation. The linear decrease of O_2 concentration (mg L^{-1}) over time reflects aerobic microbial respiration in the benthic sample. Samples were typically incubated for 2h, the initial 3000 seconds of measurements were discarded

Conclusion from Data and Application

In situ respiration measurements revealed consistently low carbon use efficiencies across glacier-fed streams, with median CUE values of 0.15, indicative of strong resource limitation and metabolic stress. Respiration data helped disentangle the relative influence of temperature, light availability, and nutrient stoichiometry on microbial functioning in global glacier-fed streams.

A key outcome was the identification of a global pattern in which benthic microbial communities shift from carbon to phosphorus limitation as glacier influence declines.

These findings suggest that as glaciers disappear, stream ecosystems undergo a fundamental shift in microbial energetics, toward higher productivity but also potential nutrient bottlenecks. The ability to capture fine-scale oxygen dynamics under field conditions was essential to quantifying this transition and linking local processes to global carbon cycling in alpine freshwater systems.

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