26th Annual International Workshop on Physical Processes in Natural Waters

Girona, 1-5 July 2024

PROCEEDINGS

Abstracts

Tuesday 2nd July 2024

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Thermal patterns in a proglacial pond create Windows of Opportunity for periphyton growth (Cevedale glacier, Italy)

In high mountain areas, deglaciation is the most evident effect of anthropogenic climatic changes. Glacier retreat is inducing worldwide an increase of both number and size of proglacial lakes and ponds, i.e., lentic water bodies located in the proglacial area and directly linked to the glacier activity: the depressions carved in the land surface allow meltwater impoundment and accumulation of glacier sediment. Over the past decades, glacier-fed lakes have become an increasingly represented ecosystem in the Alpine landscape. However, their ecological characteristics are only partially known. Glacial runoff determines cascade effects in glacier-fed standing waters. It influences both water temperature, by delivering cold meltwater to the system, and water transparency, because of the high amount of inorganic suspended solids (so called "glacial flour") that determine high water turbidity. Therefore, proglacial lakes are highly selective habitats, where planktonic communities are quantitatively scarce and taxonomically simplified. On the other hand, given the low input of allochthonous organic matter from bare proglacial forefields, benthic primary producers (periphyton) are the major autochthonous carbon source sustaining food webs in glacially fed water bodies. Studies on glacial streams show that periphyton growth is concentrated in "Windows of Opportunity" (WOs), mainly occurring in periods of reduced glacial runoff, i.e., autumn. In the euphotic zone along the littoral area of proglacial lakes, local conditions can allow algal growth (e.g., cyanobacteria), and the abrasive impact of glacial flour is low due to scarce water turbulence. Furthermore, in lentic proglacial ecosystems, periphyton ecological niches appear to be influenced also by water thermal stratification dynamics. Previous studies observed different mixing patterns in proglacial and clear mountain lakes (i.e., without glacial influence); high-altitude ponds (surface area < 2 ha) are expected to show even different patterns of response to physical environmental setting. To better understand the link between thermal dynamics and ecology of proglacial lentic systems, we investigated temperature dynamics in the water column of a proglacial pond located in the Eastern Italian Alps (South Tyrol, Italy) and compared them with density and taxonomic composition of benthic diatom communities, which are key components of littoral periphyton in lakes and are useful bioindicators of environmental changes. Diatoms are eukaryotic photosynthetic microalgae, characterised by a cell wall composed of silica (frustule), whose morphological characteristics are used for taxonomical identification. Specific aims of the study were: (i) to characterise the temperature dynamics in a shallow proglacial pond; (ii) to investigate how thermal dynamics can influence the presence of WOs for periphyton growth. The proglacial pond is located at 2850 m a.s.l. in the Martell valley (Stelvio National Park, CE Italian Alps). It is moraine-dammed and originated from the retreat of the Cevedale glacier about 10 years ago. Its surface area is about 4270.5 m^2 with a maximum depth of around 3 m. In the ice-free seasons 2022 and 2023, we installed water level sensors and performed water discharge measurements at

the pond outlet with the salt dilution method, to build a flow rating curve and estimate outlet and inlet discharge time series. In summer 2023, we installed two buoys, one in the upstream part of the pond and one in the downstream part. Each buoy was equipped with 5 temperature sensors, located at 0, 0.2, 0.4, 0.8, 1.6 m depth, recording water temperature at 5-minute intervals. We applied the CE-QUAL-W2 model, a 2-D hydrodynamic laterally averaged model, to reconstruct the temperature time series in the water column for both ice-free seasons 2022 and 2023. We calibrated the parameters of the model based on field buoy data. Meteorological data and discharge time series were used as boundary conditions for the model. We developed a simplified numerical model to estimate the inflow water temperature (i.e., glacial runoff running on debris-covered ice) as a function of air temperature and solar radiation. Preliminary results show good agreement between the observed and modelled temperature data (RMSE < 1.5°C). During the Alpine glacial summer, we observed periods of pronounced daily thermal stratification. In these periods, shallow layers showed daily fluctuations, while deeper layers were colder. Total mixing and cooling of the water column followed intense precipitation events, with lower air temperature and solar radiation. In 2022 and 2023, we analysed the benthic diatom communities collected from a known area of colonised substrata (stones covered by a layer of consolidated sediment). In the laboratory, we eliminated the organic matter in the samples by chemical oxidation, to allow the morphological observation of diatom frustules. We equalised the sample volumes at 6 ml and added an aliquot (1 ml) of solution containing a known concentration of divinylbenzene microspheres, which served as reference to compare diatom densities in the different samples. Permanent diatom mounts were prepared, and diatom frustules and microspheres were counted under the optical microscopy. Diatom communities in the Cevedale proglacial pond reached higher density values (1-43 and 2.8-404.9 × 10^3 N valves/cm^2, respectively) than in glacier-fed streams investigated in the same geographical area (Vulcano 2020, unpublished data). Moreover, we observed a density peak in August 2022 (404.9 × 10^3 N valves/cm^2), and not in autumn as expected. In all samples, the community was numerically dominated by the pioneer species Achnanthidium minutissimum s.l. The observed diatom density patterns suggest that periphyton growth in the proglacial pond can be sustained also in periods of high glacial runoff. Accordingly, the model results suggest the presence of additional temperature-driven WOs for periphyton growth during the Alpine summer, with respect to the ones described in glacier-fed streams. The presence and temporal extension of the WOs in the proglacial pond depend on meteorological conditions, as thermal gradients form during dry and warm periods. In a climate change perspective, this implies that colonisation processes in the periphyton of newly formed proglacial ponds may be accelerated by prolonged periods of drought, high air temperatures and increased glacial runoff. Consequently, the natural ecological evolution of proglacial ponds may be accelerated by global warming.