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Holocene Climate Change
Reflected in a Remote High Alpine Lake
A multi-proxy investigation of a sediment record

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Summary

High alpine lake ecosystems are remarkably sensitive to climate change as even a small increase in temperature shortens the duration of the snow and ice cover of the lake and its catchment. This simultaneous effect on in-lake and catchment processes amplifies the response to climate change. Climate history remains stored in the lake sediments, the muddy depositions at the bottom of the lake which grow a few mm every year. Cutting sediment cores in thin layers, enables us to look back into history and reconstruct past environmental conditions. Through dating, every sediment layers is given a certain age thus setting the changes in a chronological context.

Here we investigated the impact of Holocene (last 10000 years) climate oscillations in the sediment of a remote high alpine lake. We investigated changes in diatoms, chironomids, pigments, pollen, plant macrofossils, geochemistry, and mineralogy. The sediment core covered the entire lake history from the last deglaciation to present. Changes in the stratigraphies, e.g. in species composition or iron carbonate content, were compared to known climate oscillations during the Holocene and to glacier mass trends from the same region. Chironomid analyses allowed for the reconstruction of Holocene July air temperature from fossil chironomid head capsules (FWF Lise Meitner Post Doc mobility program M964, E. Ilyashuk). Special attention was given to the detection of climate impact on water quality, particularly in-lake productivity, acid base balance, oxygen depletion, and weathering rates. 25 years of limnochemical monitoring and a high resolution short sediment core covering the instrumental period enhanced the interpretation of the sediment record.

Results

After deglaciation, during a warm and presumably dry climate, the lake was rapidly colonized as seen from the diatom and chironomid record. However, it took over 2000 years (until 8000 years before present) until the lake became more productive as reflected in an increase in organic carbon content, and algae and chironomid concentrations. During this period the climate was still warm but wetter. The increase in productivity is consistent with a shift from a plankton dominated carbon/nitrogen ratio to a higher C/N ratio that reflects a higher input of organic matter from terrestrial plants. This increase also triggered the development of anoxic - alkaline bottom water conditions and thus affected the whole biogeochemistry of the lake. Although the catchment had only a scarce and thin soil layer, the development of a slightly more productive soil layer during favourable climatic conditions had significant effects on the lake properties. With the onset of a colder period around 5000 to 4500 cal BP (i.e. after the death of the iceman "Ötzi"), the C/N ratio decreased again and the lake became less productive. The July air temperature remained low until the 20th century. Recently an increase became visible in temperature and productivity but not yet the level observed before.