Short communication

ISSN 2658-3518
LIMNOLOGY FRESHWATER BIOLOGY
www.limnolfwbiol.com

Late Glacial and Holocene environmental history of the Oka Plateau, East Sayan Mountains (Siberia): a palaeolimnological study of several lakes

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ABSTRACT. Palaeoenvironmental changes including vegetation, chemical weathering intensity, lake's water level fluctuations, and climate dynamics in the East Sayan Mountains were investigated using pollen, mineralogical, petromagnetic, X-ray fluorescence analyses and radiocarbon dating. Based on these data sets from three high-mountain lakes, we reconstructed the variations in local and regional vegetation, biomes, and climate during the Late Glacial and Holocene in the Oka Plateau, East Sayan Mountains, and the surrounding areas.

Keywords: vegetation and chemical weathering history, climate, Late Glacial-Holocene, Oka Plateau, Siberia

1. Introduction

Climate and natural ecosystems change has become unusually pronounced in recent decades, impacting the environment and vegetation in Siberia and in the Russian part of the Altai-Sayan region. The current climate warming observed in southern Siberia is most evident in the alpine belts and ecotone zone between alpine and forest belts of the Altai and Sayan Mountains (Kharlamova et al., 2019) and is leading to aridification of the mountain steppes, altitudinal tree-line migration and restructuring of mountain biotopes. To understand the nature and possible causes of variations in recent ecosystems, it is necessary to assess the long-term patterns of their development. Mountain lake sediments provide continuous, high- to relatively high resolution sequences that embody a richness of physical, chemical and biological "proxies", tracers that can be used to infer paleoclimate, -hydrology, -soils and –vegetation. The main goal of our study is to reveal the long-term evolution of the natural environment on the Oka plateau in the Late Glacial-Holocene time.

2. Materials and methods

Sediment cores from glacial lakes Kaskadnoe-1, Khikushka and Khara-Nur were recovered using a rope-operated UWITEC Piston Corer with PVC liners. Seventeen AMS^{14}C ages were obtained at different laboratories (Poznan and Moscow). Radiocarbon ages were then calibrated using R package version 2.3.9.1. (Blaauw and Christen, 2019) and the IntCal20 calibration curve (Heaton et al., 2020). Magnetic susceptibility (MS), biogenic silica SiO_{2bio}, dry bulk density (DBD) were measured at 1 cm intervals. A standard procedure was used to extract pollen (Berglund and Ralska-Jasiewiczowa, 1986). The potential of the biome reconstruction ('biomization') method (Prentice et al., 1996) was used for the quantitative interpretation of the pollen spectra.

3. Results and discussion

The obtained dates suggested accumulation of the recovered core sediment during the Late Glacial and Holocene. According to the age-depth relationship, the lower part of the silty clay in the Kaskadnoe-1 and Khikushka cores were accumulated ~ 13.3-10.1 ka BP (calibrated thousands years before present) and ~ 13.5-10.5 ka BP, respectively. Since then, biogenic terrigenous silt enriched with diatoms has formed. The sediments in the Khara-Nur lake core are represented by biogenic terrigenous silts, underlined by thin layers of peat-peaty sands.

The pollen records indicates a considerable development of shrub and herb tundra around

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Received: May 19, 2022; ***Accepted:*** June 24, 2022;
Available online: September 02, 2022

Kaskadnoe-1 and Khikushka lakes ca. 13.4-12.1 ka BP during cold climate. But rather high abundances of spruce *Picea* and larch *Larix* pollen indicate their presence around the lakes suggesting rather humid local environments (Fig.). Maxima in MS and DBD values in the records indicate a significant contribution of terrigenous material from the catchment area, probably carried by water originating from melting glaciers. *Abies* pollen rise since 12.1 ka BP points out to fir arrival close to Kaskadnoe-1 and Khikushka lakes under more favorable than earlier climate that lasted until ca. 8.0 ka BP (Fig.) being in line with predominantly warm and humid Early Holocene across western Mongolia and Altai and Baikal Regions (Klinge and Sauer, 2019). Warming favors the regional rather than local rise in the upper elevational limits of *Pinus sibirica* and the steady increase in *Pinus sylvestris* across the region since ca. 11.2 ka BP. An expansion of pines at higher elevations shortly after local deglaciation in the study area as opposed to their significantly later spread (7500-6000 ka BP) on plains of south East Siberia (Kobe et al., 2020) could be related to early spring melting and a longer growing season due to higher summer insolation. Although, other data support a predominantly treeless landscape in the lake basins ca. 8.0-4.5(4.0) ka BP. A strong reduction in dark coniferous fir and spruce trees in the middle Holocene in the lake basins could be a result of the higher-than-present summer insolation that could lead to warm summers, high evaporation and moisture deficit for dark coniferous trees.

A reconstructed spread of *Larix* after 4.5 ka BP in the vicinity of all three lakes and approach of *Pinus sibirica*, are in parallel to a decrease in summer insolation and an increase in winter insolation, which in turn, led to weakening in the activity of both summer monsoon and winter anticyclone. Moreover, the westerlies, bringing rain and snow precipitation to the middle latitudes of Eurasia, Altai Mountains (Rudaya et al., 2009) and Baikal Region (Kostrova et al., 2020) became stronger.

4. Conclusions

Based on pollen data from three high-mountains lakes, we reconstructed the variations in local and regional vegetation, biomes, and climate during the Late Glacial and Holocene in the Oka Plateau, East Sayan Mountains, and the surrounding areas. Our data revealed new insights into the Late Quaternary climate and environmental history of this region.

Predominantly open steppe- and tundra-like vegetation dominated the area during the Late Glacial, with noticeable participation of boreal trees. A short-term reduction of the forest biome at ca. 12600-12500 cal. yr BP could be a response of regional vegetation to climate deterioration during the YD stadial. Climate warming and decrease in effective moisture after 11.2 ka BP led to the degradation of dark coniferous forests in the study area and to a gradual expansion of *Pinus sylvestris* and *Pinus sibirica*. Warmest climate existed during the Early-Middle Holocene. The *Larix* stands may have re-established in the study region soon after 4.5 ka BP. This trend is in parallel to a decrease in summer insolation and an increase of winter insolation. Our new results provide additional evidence for sensitive responses of various boreal lacustrine ecosystems to global climatic changes in the Late Glacial-Holocene.

Acknowledgements

The research presented here was financially supported via research grants from the RFBR and RS (project number 21-55-10001), and via the state assignment of the Vinogradov Institute of Geochemistry SB RAS (project no. 0284-2021-0003).

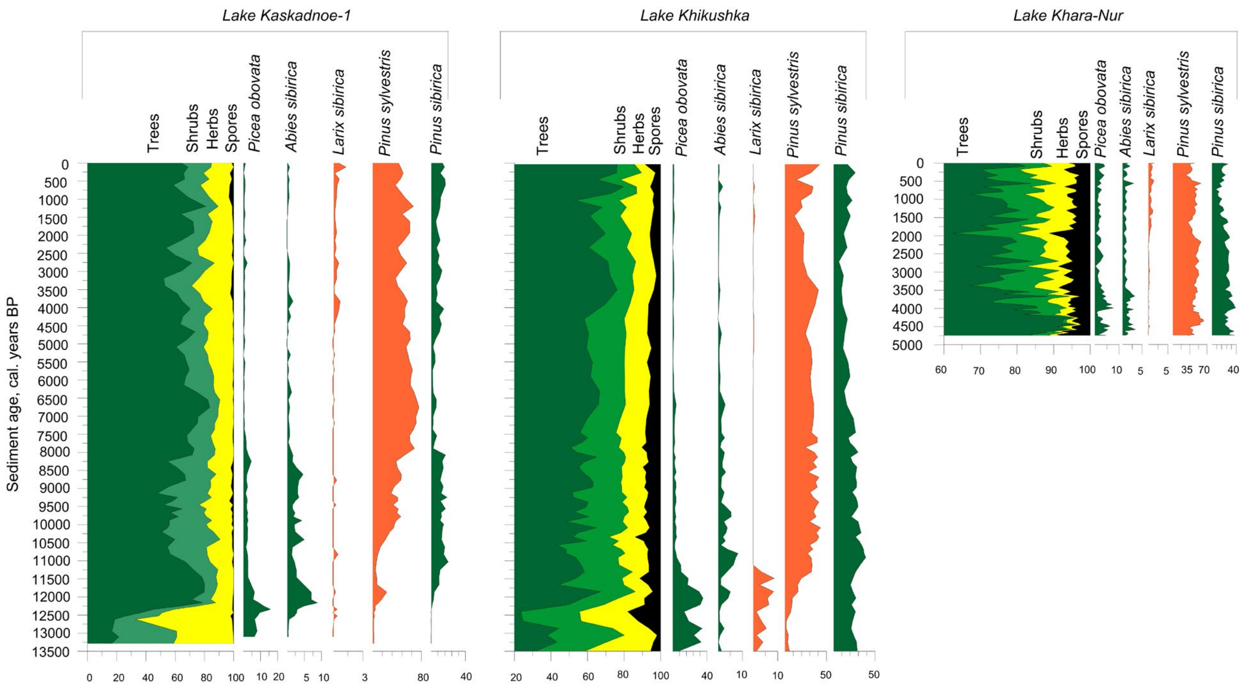

Fig. Variations in the total composition of pollen and spores in the sediments of the lakes studied as an indicator of the regional vegetation progress, and arboreal taxa pollen as an indicator of local/regional vegetation

Conflict of interest

The authors declare no conflict of interest.

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