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Aquatic ecosystem responses to Holocene climate change and biome development in boreal, central Asia

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ABSTRACT

Boreal ecosystems are highly vulnerable to climate change, and severe ecological impacts in the near future are virtually certain to occur. We undertook a multiproxy study on an alpine lake (ESM-1) at the modern tree-line in boreal, southern Siberia. Steppe and tundra biomes were extensive in eastern Sayan landscapes during the early Holocene. Boreal forest quickly expanded by 9.1 ka BP, and dominated the landscape until c 0.7 ka BP, when the greatest period of compositional turnover occurred. At this time, alpine meadow landscape expanded and *Picea obovata* colonised new habitats along river valleys and lake shorelines, because of prevailing cool, moist conditions. During the early Holocene, chironomid assemblages were dominated by cold stenotherms. Diatoms for much of the Holocene were dominated by alkaliphilous, fragilarioid taxa, up until 0.2 ka BP, when epiphytic species expanded, indicative of increased habitat availability. C/N mass ratios ranged between 9.5 and 13.5 (11.1–15.8 C/N atomic ratios), indicative of algal communities dominating organic matter contributions to bottom sediments with small, persistent contributions from vascular plants. However, $\delta^{13}C$ values increased steadily from −34.9‰ during the early Holocene (9.3 ka BP) to −24.8‰ by 0.6 ka BP. This large shift in magnitude may be due to a number of factors, including increasing within-lake productivity, increasing disequilibrium between the isotopic balance of the lake with the atmosphere as the lake became isotopically 'mature', and declining soil respiration linked to small, but distinct retreat in forest biomes. The influence of climatic variables on landscape vegetation was assessed using redundancy analysis (RDA), a linear, direct ordination technique. Changes in July insolation at 60 °N significantly explained over one-fifth of the variation in species composition, while changes in estimates of northern hemisphere temperature and ice-rafted debris events in the North Atlantic were also significant, but considerably less important. The potential importance of climate and biome development (tundra, steppe, cold deciduous forest and taiga) on different trophic levels (i.e. chironomid and diatom communities) in lake ESM-1 was also assessed using RDA. Climate predictors had a more significant influence on Holocene chironomid assemblages, especially July insolation at 60 °N, estimates of regional precipitation and estimates of northern hemisphere temperature, while only the development of the taiga biome had a significant impact on these primary consumers. Diatom communities also had a small, but significant influence on Holocene chironomid populations, perhaps linked to variation in faunal feeding strategies. In contrast, climatic and biome predictors explained similar amounts of variation in the Holocene diatom assemblage (approximately 20% each), while chironomids themselves as predictors explained just under 7% of diatom variation. Lake acidity was inferred using a diatom inference model. Results suggest that after deglaciation, the lake did not undergo a process of gradual acidification, most likely due to the presence

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