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Low atmospheric nitrogen deposition in southern central Siberia does not trigger any nitrogen limitation in the growth of mountain lake phytoplankton

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Anthropogenic disturbances of the nitrogen cycle are one of the most important issues for world ecology. Increased fluxes of atmospheric nitrogen deposition, including ammonium, nitrates, nitrites and other nitrogen oxides characterize the current state of nitrogen cycle. Scientists have found that this process might provide unproductive lakes with nitrogen enough for phytoplankton to turn from nitrogen to phosphorus limitation of growth. Nevertheless, atmospheric nitrogen deposition and its effect on phytoplankton primary production have not been uniformly studied around the world and significant areas remain understudied.

In this study, we measured the winter atmospheric deposition of nitrogen and phosphorus in the snow cover of an understudied region: the Ergaki Natural Park in the south of central Siberia. The concentrations in winter precipitation (40±16 mg of NO3-N m^{-2} 0.58±0.13 mg of total P m^{-2}) were used to estimate yearly yields (119±71 mg of NO3-N m^{-2} $year^{-1}$ and 1.71±0.91 mg of total P m^{-2} $year^{-1}$). These values approximately corresponded to the forecasts of worldwide mathematical models in the literature and were notably low for terrestrial sites, especially in the case of phosphorus. Measurements of $d^{15}N$, total N and P in lake sediment cores confirmed the minor role of eventual atmospheric N deposition in the studied lakes, as compared to terrestrial inputs.

The atmospheric nitrogen deposition on the Ergaki mountain ridge was slightly lower than in northern Sweden, where the low atmospheric nitrogen deposition had been found to trigger nitrogen (instead of phosphorus) limitation of phytoplankton growth in unproductive lakes. Nevertheless, atmospheric phosphorus deposition in the study site was among the lowest ones on the mainland, if not the lowest. Due to this extremely low content of atmospheric nutrient deposition, the stoichiometry of N:P in snow and lake water did not correlate, so our lakes did not belong to the group of lakes in the world that are influenced by atmospheric deposition of nutrients. According to our observations, both nitrogen and phosphorus can periodically be

limiting factors of phytoplankton in Ergaki lakes.

In conclusion, firstly, the Ergaki Natural Park is an ideal place to study the effects of global warming with a minimal interference of atmospheric nitrogen deposition. Secondly, even at low levels of atmospheric nitrogen deposition in places where atmospheric phosphorus deposition is very low, nitrogen is not necessarily the limiting factor of phytoplankton growth, which may contradict the general character of the currently accepted paradigm. Further studies should check the year-round deposition of nutrients and expand the number of lakes and regions in Siberia, where a significant part of the lakes is not subject to severe anthropogenic pollution.

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