Climate versus human impacts on Lake Atnsjøen ecosystem (south-eastern Norway) during the last millennium

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The main aim of our study was to trace long-term natural and human-induced ecological changes in the Lake Atnsjøen ecosystem.

Lake Atnsjøen is located in a mountain area (Rondane) at 701 m a.s.l., in the south eastern part of Norway. Due to the remote location and because a large part of its catchment is located in the Rondane National Park (and hence protected by law), we expected that human impact on the lake has been relative week. The climate of the area has continental features, annual precipitation varies between 400-600mm. Lake Atnsjøen is surrounded by a lichen rich pine and birch forests. Above the tree line dominating vegetation type is alpine tundra. Lake Atnsjøen has steep slopes and flat bottom, with a maximum depth of 80.2m. Macrophytes, dominated by *Isoëtes lacustris*, are limited to a narrow zone close to the shore.

A sediment core from 20m depth taken in the South-Eastern part of the lake was used in order to study the history of Lake Atnsjøen. We applied the multi-proxy approach and made several paleolimnological analysis of the sediments; pollen, cladocerans, chironomids, diatoms, macrofossil, chemical and sedimentological properties. The chronology of the core was established by ^{210}Pb and ^{14}C dating.

The Chironomid-based reconstruction of the mean July temperatures show distinct cooling that started around 1390 AD and ended approximately at 1850 AD. This is within the range of generally accepted frame of the LIA (Little Ice Age). The reconstruction shows slight warming around 1450 AD which may suggest that LIA in Lake Atnsjøen region consisted of two cold. The pollen analysis revealed that there has been continuous human activities within the catchment due to agriculture through the last 1000 years. The effect of human activity was less pronounced during the LIA and in the 14th century. The latter was likely caused by the “black death”, the pandemic plague which decimated the population in whole Europe, including Norway

The Cladocera analysis showed that the lake ecosystem changes were mainly driven by climate. In LIA the rate of Cladocera remains per 1cm^2 was lowest during last 1000yrs and the Bosminid sex ratio

highest, indicating unfavourable edaphic conditions for pelagic species. The Cladocera diversity measured by Shannon index was also lowest between 1590-1800 AD. The dry density of the sediment showed fluctuation in the last 1000yrs but the most prominent increase was recorded between 1620-1770 AD.

The analysis of cladocerans showed that the lake ecosystem changes were driven mainly by climate. The cladocerans' remains per cm^2 had a minimum while the Bosminid sex ratio had a maximum during the LIA, indicating hard conditions for pelagic species. The diversity of cladocerans (Shannon index) also had a minimum between 1590-1800 AD.

The pollen and macrofossil analysis showed that dominant water plant in Lake Atnsjøen during last millennium was *Isoëtes lacustris*, a species characteristic for oligotrophic lakes. Its abundance decreased between 1590-1880 AD which coincide with LIA and may indicate that the littoral zone was affected by climate cooling.

The LIA ended in the Lake Atnsjøen region around 1810 AD and was followed by a rapid increase in temperature that continued until the present, however with a slower pace. This resulted in a slight increase of lake productivity represented by higher TOC concentrations and an increase in cladoceran diversity. Higher productivity was also due to increased number of farms established in the catchment from the 1750ies, specially from late 19^{th} century to early 20^{th} century. Furthermore, the introduction of chemical fertilisers in the area between World War I and World War II have likely also contributed to higher productivity.

The multi-proxy studies allowed us to conduct a complex reconstruction of the climate changes and their influence on Lake Atnsjøen ecosystem evolution during the last 1000 yrs. The climate was the main driver of changes and LIA cooling strongly impacted environment in the Rondane National Park Region.

The multi-proxy studies allowed us to conduct a complex reconstruction on how ecosystem of Lake Atnsjøen was altered during the last 1000yrs. The climate has been the main driver of changes in the studied region which was strongly affected by cooling during LIA and climate warming that started in 19^{th} century. In resent time agricultural activities has led to an increase in lake productivity.