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Opinion Article

The Role of Eutrophication and Anoxia in Lake Ecosystem Degradation

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DESCRIPTION

Lake ecosystems in northeastern China are highly sensitive to global environmental shifts and currently face threats from eutrophication and hypo limnetic anoxia. However, the absence of long-term records of lake productivity and anoxia in this region complicates efforts to distinguish between natural ecosystem variations and the effects of recent human activities. This study focuses on varied sediments from the remote maar Lake Xiaolongwan in northeastern China, using high-resolution sediment analysis to reconstruct changes in primary production, anoxia, nutrient cycling and catchment processes over the past 1500 years. Hyperspectral imaging inferred sedimentary total chlorophyll-a and Bacteriopheophytin-a (Bphe-a), combined with data on sedimentary iron and phosphorus fractions, were used to reconstruct these historical changes.

The findings indicate that prior to significant human influences between approximately 600 CE and 1900 CE, lake primary production was higher during warmer periods and lower during colder periods. Bphe-a records suggest that hypo limnetic anoxia was persistent, regardless of temperature fluctuations. A cluster analysis reveals that the algal communities and biogeochemical conditions in the twentieth-century warm period are unprecedented and significantly different from any period over the past 1500 years. These changes are largely attributed to global warming, combined with stronger local disturbances in the early 1900's and intensified atmospheric pollution after the 1950's. The warming climate has also led to stronger seasonal mixing, shortening the ice-cover duration and improving oxygenation levels in the lake. This study highlights the substantial anthropogenic impact on lake ecosystems, even in a relatively pristine area of northeastern China.

Recent anthropogenic environmental changes have posed significant risks to global freshwater ecosystems, primarily due to interactions among multiple stressors like climate warming, nutrient enrichment, land-use changes and internal lake processes (e.g., nutrient cycling and lake mixing). These stressors have contributed to widespread eutrophication and hypo limnetic anoxia, leading to degradation in water quality, biodiversity and other ecosystem services. One of the most harmful effects of lake anoxia is the release of Phosphorus (P) from sediments into the water column, which promotes excessive phytoplankton growth and degrades water quality. Climate warming is expected to exacerbate lake anoxia by strengthening thermal stratification and reducing vertical mixing, particularly in temperate lakes

Although lake anoxia and eutrophication are often seen as recent anthropogenic problems, paleolimnological records reveal that natural climate fluctuations during the Holocene also caused high aquatic productivity and anoxic conditions in deep, stratified lakes of temperate regions. Similar patterns have been observed in northern China, Europe and other regions, where warm periods led to high productivity and anoxia, especially before human-induced changes such as deforestation. However, most studies on lake anoxia have focused on temperate lakes in North America and Europe, with less attention given to northeastern China, where lakes in remote areas have experienced minimal human impact.

Maar lakes in the Long Gang Volcanic Field (LGVF) of northeastern China are particularly sensitive to both climate change and human activities, given their relatively undisturbed environments. Anthropogenic contamination, such as heavy metals and spheroidal carbonaceous particles, has been observed since the mid-20th century. Paleolimnological research shows that changes in lake ecosystems and limnological conditions in this area have been significant over the past century, driven by climate warming, deforestation, agricultural activities and atmospheric nitrogen deposition. For example, in 2018, an algal bloom was observed for the first time in maar Lake Dalongwan. Diatom assemblages in nearby lakes have also shown significant changes since the 20th century, mainly due to warming trends and increased nutrient loading. Despite these observations, the long-term evolution of lake primary productivity and anoxia in this region remains underexplored.

CONCLUSION

In conclusion, this study highlights the significant impacts of recent anthropogenic disturbances and climate warming on the lake ecosystems of northeastern China, as revealed through a 1500-year sediment record from Lake Xiaolongwan. The findings demonstrate that recent changes in primary productivity, anoxia

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and nutrient cycling differ substantially from natural variations observed in past warm periods. Understanding these shifts is important for assessing the future health of aquatic ecosystems in the region, as they face compounded challenges from ongoing climate change, pollution and other human-induced stressors.