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Lakes Under Pressure

View of a nutrient-rich eutrophic lake

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The quality of water in lakes is shaped by numerous factors. Understanding them better allows us to prevent degradation more effectively.

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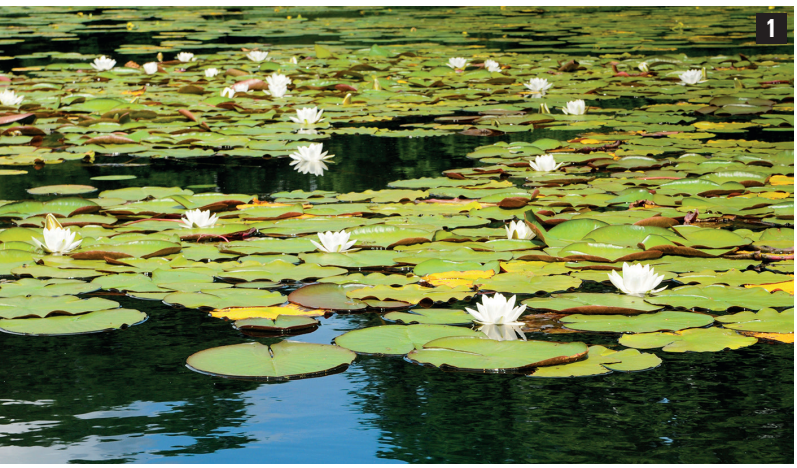
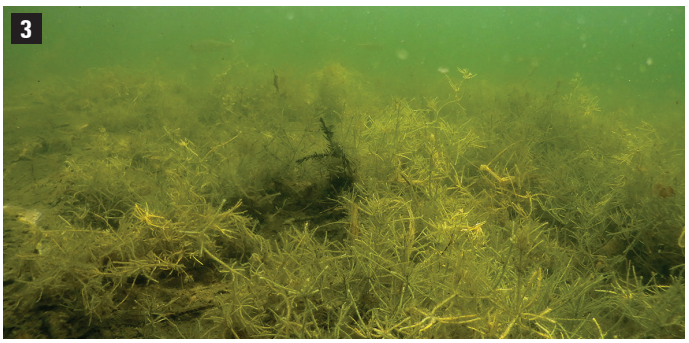
Lakes serve many vital functions that support human activity, including supplying drinking water, water for agriculture and industry, and providing habitats for aquatic life. They act as natural water purification systems and offer recreational opportunities. However, the extent and quality of these functions depend on the ecological state of the lake ecosystem. In Europe, the implementation of the Water Framework Directive (WFD – Directive 2000/60/EC) in 2000 made it mandatory to monitor and assess the ecological status of lakes. Understanding the current condition of a lake is essential for managing water quality and planning restoration efforts.

Natural productivity

The ecological status of a lake is determined by evaluating a variety of biological, hydromorphological, and physicochemical factors. This process is complex and time-intensive due to the numerous ele-





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ments involved. However, a lake's condition can also be assessed in terms of its *trophic state*. This is a concept that focuses on the lake's biological productivity, measured by determining the levels of total phosphorus, chlorophyll, and water transparency. Based on these a lake is classified into a specific trophic category, such as those defined by the OECD classification system.

Lakes with the clearest water and very low levels of phosphorus and chlorophyll are classified as *ultra-oligotrophic* or *oligotrophic*. In contrast, lakes with murky water and high levels of these substances are categorized as *eutrophic* or *hypertrophic*, indicating high productivity. *Mesotrophic* lakes lie in the middle, representing a transitional state between eutrophic and oligotrophic conditions.

Over time, lakes naturally undergo *eutrophication* – a process in which water fertility and productivity increase. This occurs as lakes age, accumulate sediments in their basins. In climates like Poland's, eutrophication affects the majority of lakes. A naturally eutrophic lake can support a rich diversity of organisms, including algae, plants, and animals. The pace of eutrophication depends on factors such as the lake's depth and the characteristics of its surrounding watershed.

Today, the process of eutrophication is often viewed negatively because it often accelerates dramatically, leading to severe deterioration in lake quality. This acceleration is mainly due to human activity, such as the discharge of untreated industrial and municipal wastewater into lakes and intensive agricultural practices near their shores. As a result, nutrients such as phosphorus, nitrogen, organic matter, and pollutants like heavy metals and harmful microorganisms (like *E. coli*) enter the lakewater. Excessive nutrient enrichment significantly degrades water quality and fosters algal blooms, including toxic cyanobacteria harmful to humans.

Other less common but impactful stressors on lake ecosystems include human-induced hydrological changes, such as artificially raising water levels by pumping water from reservoirs with different trophic states. These interventions can severely disrupt

Photo 1
A cluster of white water lilies

Photo 2
The nearshore zone of a low-trophic lake (Lake Białe Wigierskie)

Photo 3
Underwater charophyte meadows in the mesotrophic Lake Siekierowo

Photo 4
An oligotrophic lake with sparse aquatic vegetation

Photo 5
The nearshore zone – a safe haven for fish fry

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Photo 6
The underwater labyrinth of life

Photo 7
Underwater perspective

lake ecosystems and cause irreversible environmental changes.

Effective management

To effectively manage lakes and preserve their good condition, it is essential not only to define and monitor their current state but also to identify the environmental factors that most strongly influence their productivity. Certain lake characteristics, such as size and depth, are known to play a crucial role in shaping their trophic state. While numerous environmental factors can affect a lake's condition, a few primary ones are typically the most impactful. Understanding these key parameters is critical for designing and implementing measures to improve or sustain lake health.

With this approach in mind, we carried out a study identify the main drivers of productivity in 60 lakes located in northeastern Poland, within the areas known as the Lithuanian, Masurian, and Iława Lake Districts. The selected lakes were small to medium in size and exhibited varying trophic states. Twenty-five environmental variables important for lake ecosystems were analyzed. These variables described the shape and dimensions of the lake basins, the volume of water they held, the geometry of their watersheds, land cover and use in the surrounding areas, and factors reflecting the relationship between the lake and its watershed.

Using machine learning, the study assessed how these environmental variables influenced the lakes' trophic states, represented by levels of total phosphorus, chlorophyll, and water transparency. The analysis provided insights into how each variable affected individual lakes and grouped the lakes based on the dominant environmental factors influencing their trophic states.

This classification of lakes can help develop realistic management strategies tailored to the specific challenges faced by each group. Threshold values for each variable were also defined, offering valuable guidance for planning integrated watershed management to maintain or enhance lake conditions.

Environmental influence

In northeastern Poland, the most significant factors influencing lake eutrophication were found to be related to the impact of the watershed on the lake. Lakes with large watersheds relative to their size and volume were particularly vulnerable to eutrophication. Other important parameters included factors like maximum depth and the steepness of the watershed slopes. Deep lakes were less prone to eutrophication than shallow ones, while steep slopes in the watershed accelerated the enrichment of lakes with nutrients.

Notably, the highest levels of water productivity result from the combined influence of several environmental factors, stemming both from the natural characteristics of the lakes and the intensity of human activity. Our study also identified threshold values for the most influential environmental variables. For example, even as little as 5% land development within a watershed was found to significantly accelerate lake productivity.

Understanding the relationship between environmental variables and a lake's trophic state is essential for effective lake management and spatial planning. This approach helps pinpoint the most impactful factors and enables the implementation of targeted solutions to slow eutrophication. The findings clearly demonstrate that effectively and sustainably reducing eutrophication requires managing the processes occurring within the watershed. ■

Further reading:

Zawiska I. et al., Long-term consequences of water pumping on the ecosystem functioning of Lake Sekšu, Latvia, *Water* 12/2020.

Jasiewicz J., Zawiska I., Rzodkiewicz M., Woszczyk M., Interpretative machine learning as a key in recognizing the variability of lakes trophy patterns, *Quaestiones Geographicae* 2022, vol. 41.

Zawiska I., Jasiewicz J., Rzodkiewicz M., Woszczyk M., Relative impact of environmental variables on the lake trophic state highlights the complexity of eutrophication controls, *The Journal of Environmental Management* 2023, 345.