POLICY BRIEFING NOTE 2

Exploring the effects of climate on lakes using long-term and multi-site data.

AUTHORS: Eleanor Jennings[1], Malgorzata Golub[1], Nasime Janatian[2], Peeter Nõges[2], Truls Hveem Hansson[3], Hans-Peter Grossart[3].

1. Centre for Freshwater and Environmental Studies, Dundalk Institute of Technology, Ireland.
2. Institute of Agricultural and Environmental Sciences, Estonian University of Life Sciences, Tartu, Estonia.
3. Department Experimental Limnology, Leibniz Institute for Freshwater Ecology and Inland Fisheries, Berlin, Germany.

June 2021

INTRODUCTION

Algae are important components of the food web in lakes, as they are a food source for other organisms. The concentration of cells in a lake and their community composition are also commonly used by lake managers to assess water quality. Some of these species are highly sensitive to on-going changes in local weather linked to global warming, but are also affected by other pressures such as increased inflow of fertilisers to lakes (i.e. eutrophication). We still do not fully understand how different types of algae respond to concurrent changes in, for example, climate and nutrients. This policy brief describes new advances in understanding the implications of changes in climate and other pressures over recent decades based on an assessment of long-term datasets undertaken in the MANTEL Innovative Training Network*.

BACKGROUND

- Phytoplankton are microscopic algae and are found in lakes and other water bodies. They build up organic matter through photosynthesis using dissolved carbon dioxide (CO_2) from the water and solar energy. The algae, in turn, can become a food and carbon source for grazers in the lake when they are consumed.
- Although there are many different groups of algae in lakes, the total quantity of algal cells present is commonly used as a measure of water quality.
- Some phytoplankton species are very sensitive to changes in climate. It is now recognised that the Earth's climate has warmed over recent decades and that this warming is highly likely to continue over the coming century.
- Phytoplankton are also sensitive to other human-related pressures that have changed over time. When fertiliser, for example, is spread on land, a portion will get washed into lakes. Many wastewater treatment plants and other human related sources of pollution also discharge nutrients into water bodies. Algal cells are then fertilised and can grow rapidly as an 'algal bloom'.
- Nutrient concentrations from fertilisers and from wastewater treatment plants have also increased and decreased, and sometimes increased again, over recent decades.

- Long-term datasets from single lakes, or data from many lakes over whole regions, can be used to provide information on the drivers of change in phytoplankton in response to pressures.
- This policy brief describes advances in **our understanding of the role of climate change and other human-related pressures in driving changes in lake phytoplankton** based on outputs from MANTEL.

OVERVIEW OF ADVANCES IN OUR KNOWLEDGE

There have been **four** outputs from MANTEL researchers and colleagues that have increased our understanding of how phytoplankton respond to pressures:

1. Since the 1990s, the quantity of phosphorus exported from land into two large lakes in Estonia, Võrtsjärv and Peipsi, has decreased relatively more than the quantity of nitrogen exported to the lakes (Fig. 1). Phosphorus is usually considered the nutrient that controls algal growth in lakes. The change in phosphorus export over time was related to a decreasing trend in discharge from local wastewater treatment plants, while the concurrent increase in nitrogen export was related to higher fertiliser use in agriculture (Fig. 1). The study did not, however, find clear evidence of improved water quality despite the reduction in phosphorus. In fact, the researchers found that the change in the relative concentrations of the two nutrients (the ratio) actually favoured the growth of algal bloom forming cyanobacteria.

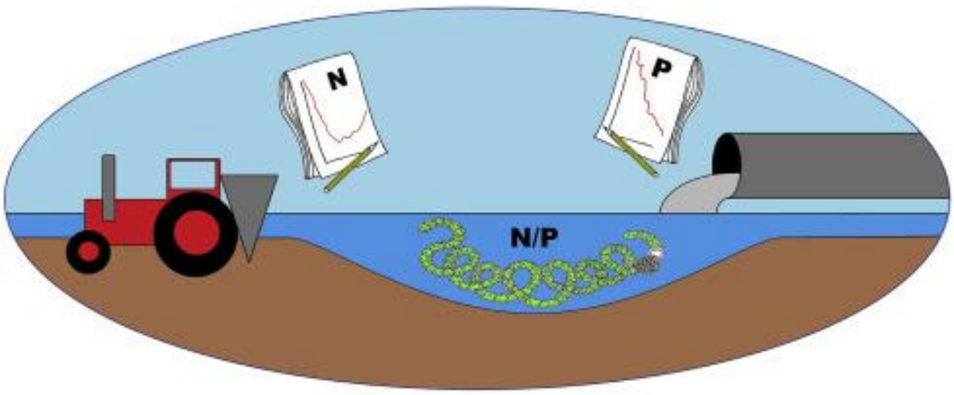

Fig. 1. a decrease in phosphorus (P) from wastewater treatment plants and an increase in nitrogen (N) from fertiliser changed the ratio of the two nutrients (N/P), thus affecting algal blooms (after Janatian and others[1]).

2. The overall concentration of algal cells in a lake at any time can be made up of individuals from different algal groups. These groups can respond in very different ways to changes in weather and climate, and changes in other pressures. Janatian and others[2] used a 54-year dataset from large, shallow and eutrophic Lake Võrtsjärv (Estonia) and found that the lake algae could be divided into three groups, each of which had a different response to pressures over time. The dominant, slow-growing cyanobacteria were influenced mainly by long-term seasonal to decadal scale variation. Temperature was found to have no effect on this group. A second group included fast growing opportunistic species that readily utilised pulses of nutrients to the lake to rapidly increase. A third group was largely controlled by strong pressure from grazers in the lake. Understanding such differing pressures and responses is critical for interpreting long-term changes in lake algal biomass to climate or other pressures. The authors note that faithfully implementing short-term measures to control algal blooms where the causes are acting on a decadal scale may lead to frustration when measures do not work.

3. Temperature is not the only climate variable that is showing long-term change over recent decades. There has been a 30% decrease in average wind speed since 1996 in southern Estonia[3]. At the same time, there have been changes in nutrient export into the lake as described above, with a peak in the 1970s–80s and a decline thereafter. Analysis of the 54-year phytoplankton dataset (1964–2017)[3] showed distinct break points in the record that coincided with abrupt changes in local wind speed and/or lake water level and that matched with change points found in phytoplankton community composition. The total quantity of phytoplankton in the lake, however, showed an increasing trend over time, despite reduced nutrient levels since the 1980s. This increase was related to lower levels of suspended sediment in the water due to calmer conditions. This allowed species of shade-adapted phytoplankton that were adapted to these light levels to thrive. The results suggest that wind stilling is another global climatic factor, occurring at the same time

as global warming, that may counteract mitigation measures undertaken as part of management of lakes.

4. Some phytoplankton, called ‘mixotrophs’, are able to use other forms of dissolved carbon from the water, as well as CO_2. This other coloured carbon leads to increased browning of lake waters and mainly originates from decomposition of organic matter (humic matter) in the catchment soils or within the lake. Hansson and others[4] used data from 69 lakes from across boreal Quebec in Canada. They found that the biomass of mixotrophs was controlled by the concentrations of both coloured dissolved organic matter (CDOM) and dissolved CO_2 in the lake but was also limited by the abundance of lake grazers. They concluded that where the algae in a lake have a capacity for mixotrophy, they provide a superior and stable food source for grazers, and are therefore a vital component of boreal lake food webs.

ABOUT MANTEL

MANTEL (Management of Climatic Extreme Events in Lakes & Reservoirs for the Protection of Ecosystem Services) was an EU funded Maire Skłodowska Curie Action (MSCA) European Joint Doctorate Innovative Training Network (2017-2021, Grant Agreement 722518) that focused on training a cohort of Early Stage Researchers to investigate the effects of the climate extremes on water quality, providing training in state-of-the art technology, data analysis and modelling, and linking to the water management sector.

REFERENCES

1. JANATIAN, N., OLLI, K., NÕGES, P. (2021). PHYTOPLANKTON RESPONSES TO METEOROLOGICAL AND HYDROLOGICAL FORCING AT DECADAL TO SEASONAL TIME SCALES. HYDROBIOLOGIA, 848: 2745–2759.
DOI: 10.1007/s10750-021-04594-x

2. NÕGES, T., JANATIAN, N., LAUGASTE, R., NÕGES, P. (2020) POST-SOVIET CHANGES IN NITROGEN AND PHOSPHORUS STOICHIOMETRY IN TWO LARGE NON-STRATIFIED LAKES AND THE IMPACT ON PHYTOPLANKTON. GLOBAL ECOLOGY AND CONSERVATION, 24: E01369. DOI:10.1016/J.GECCO.2020.E01369

3. JANATIAN, N., OLLI, K., CREMONA, F., LAAS, A., NÕGES, P. (2019) ATMOSPHERIC STILLING OFFSETS THE BENEFITS FROM REDUCED NUTRIENT LOADING IN A LARGE SHALLOW LAKE. LIMNOLOGY AND OCEANOGRAPHY, 65: 717-731. DOI: 10.1002/LNO.11342

4. HANSSON, T.H., GROSSART, H.P., DEL GIORGIO, P.A., ST-GELAIS, N.F., BEISNER, B.E. (2019). ENVIRONMENTAL DRIVERS OF MIXOTROPHS IN BOREAL LAKES. LIMNOLOGY AND OCEANOGRAPHY, 64: 1688-1705. DOI: 10.1002/LNO.11144

CONTACT AND FUNDING DETAILS

Policy brief and MANTEL coordinator: Prof. Eleanor Jennings
eleanor.jennings@dkit.ie

MANTE website: https://www.mantel-itn.org

MANTEL (2017-2021) was financed under the European Union's Horizon 2020 Research and Innovation Programme under the Marie Skłodowska-Curie Actions Grant Agreement No. 722518.