Submerged plants under the pressure of global warming and chemical restoration in eutrophic lakes

Global warming and eutrophication are two major co-occurring threats to freshwater ecosystems. Europe is the fastest-warming continent. In Poland, the average air temperature in the western part is 1.5°C higher than in the eastern region. Consequently, we observe poor water quality in lakes, with frequent cyanobacterial blooms, low water transparency, and the disappearance of submerged plants. The role of aquatic plants is crucial for the proper functioning of water ecosystems. They improve water transparency or provide refugium for fish and invertebrates. Various restoration methods are applied to improve water quality, eliminate cyanobacterial blooms and recover submerged plants (which stabilise clear-water conditions). The most common method is chemical restoration, based mainly on iron and aluminium coagulants. Despite many studies of lake ecosystem reactions to restoration treatments, still, little is known about the joint impact of climate warming and coagulants on the growth and development of submerged plants in restored lakes. Most studies focused on a single factor without considering the interaction between them. However, it is crucial to know the pattern of the reaction of submerged macrophytes to climate warming coupled with restoration treatments.

The aim of this project is to analyse the influence of coagulants used in lake restoration, together with the temperature elevation, on the germination and performance of submerged plants in degraded lakes (Fig. 1).

We base our project on a series of experiments: 1) germination and 2) experiments on a micro-scale (microcosm) in laboratory conditions, and 3) outdoor experiments on a large scale (mesocosm). First, we will conduct a seed bank experiment using sediments from lakes from two different climatic regions: warmer (western Poland) and cooler (northern-eastern Poland) to test the germination success of aquatic plants in the presence of coagulants at elevated temperature. Three coagulants, iron chloride, iron sulphate, and polyaluminium chloride, will be tested in three concentrations (Control, Low, and High) in lower (20°C) and higher temperature (24°C). Next, we will use 2 common submerged species, which occur in lakes, where coagulant is/can be added: Eurasian watermilfoil *Myriophyllum spicatum* and hornwort *Ceratophyllum demersum*. The plant populations will be collected from lakes located in the same regions as sediments in the first experiment. The impact of coagulants on plants will be examined at the same temperatures as the previous experiment. The microcosm experiments will last 2 weeks. At the beginning and end of the experiments, we will measure the variables of plants (length and biomass of plants to calculate relative growth rate, number of branches, the content of chlorophyll *a*, *b*, carotenoids, iron, aluminium, sulphur, oxidative stress), water and sediments. Then, we will use only *C. demersum* to conduct an outdoor experiment on a larger scale (mesocosm) to obtain conditions similar to those in nature. The experiment will last 3-4 weeks. We will analyse the same aspects as in laboratory experiments.

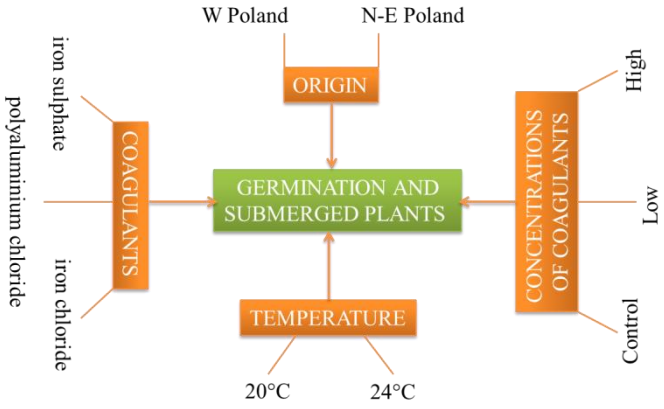

Fig. 1. The aspects which will be investigated in the project

The recovery and development of vegetation in the lake depends on the availability of light, nutrients, and temperature, which may be disturbed by global warming and the use of coagulants. Examination of responses of plant populations from warmer and cooler regions to elevated temperature and coagulants will indicate if they can survive and develop in a warmer and more eutrophicated future. In addition, it will be possible to analyse the plants' reactions from different populations to various concentrations and types of coagulants. The planned experiments will provide new insight into the recovery and development possibilities of submerged macrophytes in restored lakes, especially in a warmer future.