Climate warming negatively affects submerged aquatic vegetation through shading by periphyton

By the end of this century, global average surface temperatures are projected to increase by 0.5-3.5 ◦C over 1995-2014 averages. Lakes and rivers and the organisms that live in them, called hydrobionts, are considered particularly vulnerable to global climate change. Global warming will change the conditions of water bodies, which in turn may affect hydrobionts. In lakes located in the temperate climate zone, global warming is expected to cause an increase in water fertility, which is understood to be an increase in phosphorus and nitrogen concentrations in the water, resulting in a deterioration of water quality and a decrease in water clarity through algal blooms limiting the availability of light for submerged aquatic plants. The decline in the abundance of submerged plants during increased eutrophication (fertility) of water, caused by nutrient loading (nitrogen (N) and phosphorus (P)) is attributed, among other things, to increased shading by periphyton, i.e. small organisms, usually algae, that inhabit various substrates in the water but not the bottom. Evidence for the process of aquatic plant displacement by periphyton comes mainly from eutrophic lakes dominated by vascular plants (angiosperms). However, it has recently been shown that this process also plays an important role in hardwater lakes with low to moderate water fertility, which are usually dominated by the precious and declining group of submerged plants, the macroscopic charophyte algae (Characeae).

The impact of a global warming on periphyton and its effect on aquatic vegetation is still poorly understood. Previous studies suggest that higher water temperatures increase the summer biomass of periphyton. Understanding the response of periphyton and its impact on aquatic vegetation with increasing global warming is crucial for the future management of lakes and valuable aquatic plant habitats. The proposed project aims to investigate the effects of periphyton on vascular plants and charophytes with the increasing process of global warming. *The main research hypothesis of the project states that climate warming will negatively affect the growth rate of submerged aquatic plants and the maximum depth of colonisation in lakes due to increased shading by periphyton*. The field experiment will be conducted in the unique system of heated Konin Lakes, which represent diverse trophic conditions (from meso-eutrophic waters to highly eutrophic waters) and receive warm water from a nearby power plant system, resulting in an average temperature increase of about 3-4 ◦C, which corresponds well with climate change projections for the coming decades. The project involves the implementation of two field experiments and a laboratory experiment to verify the main research hypothesis. In addition, the implementation of the research tasks will verify the validity of the detailed research hypotheses.

The first field experiment on periphyton biomass and its shading effect on submerged macrophytes in heated and control lakes will be conducted in four heated and four unheated lakes. Completion of this research task will allow verification of the following specific research hypotheses: **(a)** periphyton biomass is higher in heated lakes than in unheated lakes, **(b)** charophytes are more sensitive to shading by periphyton than vascular plants along the depth gradient. *A second field experiment on periphyton biomass in lakes dominated by charophytes and vascular plants* (*angiosperms*) will be conducted in four charophyte lakes and four vascular lakes. The completion of this research task will help to verify the following specific hypotheses: **(c)** the shading effect of periphyton on macrophytes is stronger in the deep phytolittoral than in the shallow part of the phytolittoral, **(d)** periphyton biomass is higher in lakes dominated by submerged vascular plants than by charophytes, **(e)** high periphyton biomass negatively affects the species richness and biodiversity of submerged macrophytes. *Laboratory experiments on the potentially negative combined effects of climate warming, eutrophication and shading on submerged macrophytes (charophytes and vascular plants)* will be carried out during a 6-month foreign internship at the Leibniz Institute for Freshwater Ecology and Inland Fisheries in Berlin (Germany). The following specific research hypotheses will be verified: **(f)** the combined effect of increased temperature, increased nutrient concentrations (P and N) and shading negatively affects submerged macrophytes and **(g)** charophytes are more sensitive to this effect than vascular plants.

The results of the project will provide a better understanding of the effects of periphyton shading on macrophytes under global warming conditions. This will be crucial for the future management and conservation of lake ecosystems. The expected results are particularly important for the conservation of two valuable NATURA 2000 habitat types: habitat 3140 ‘Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp’ and habitat 3150 ‘Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition* -type vegetation’.