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Temporal variability of phytoplankton community structure: An individual-based modelling approach

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Abstract: We investigated the temporal variability of the phytoplankton community in a temperate lake (Peter Lake, Michigan, USA) to provide insight into why certain species are found under certain environmental conditions (Litchman et al. 2010). With the aim of addressing the mentioned objective, we have developed an individual-based model (IBM) that takes into account various traits of the cyanobacterium *Dolichospermum* and chrysophytes. The model incorporates factors such as growth, respiration, and floating/sinking velocity. For cyanobacteria, the model considers a floatation rate of 1 m per day, a maximum growth rate of 0.8 per day, an optimal temperature of 24 °C, and a constant θ that governs the respiration response to water temperature of 1.09 per day. As for chrysophytes, the model takes into account a sinking rate of 0.2 m per day, a maximum growth rate of 1.2 per day, an optimal temperature of 20 °C, and a constant θ of 1.06 per day. The IBM was coupled with a three-dimensional hydrodynamic model to capture the mixing and transport of cyanobacteria and chrysophytes. The model was applied to the period between 24 June and 1 July 2015 – during an experimental nutrient enrichment (Pace et al. 2017). The modelling system was calibrated against observed water temperatures, Schmidt stability, chlorophyll *a*, and algal respiration.

The model results showed that buoyant cyanobacteria increasingly dominated over chrysophytes during the stratification period when filament buoyancy outcompeted turbulent eddies. As a result, cyanobacteria accumulated near the water surface where elevated water temperatures promoted increased cyanobacteria growth rates. However, a mixing event caused by a cold front led to the entrainment of cyanobacteria. Consequently, the cyanobacteria were exposed to low and fluctuating light conditions, which restricted their growth due to light limitations. Furthermore, the cold front and mixing event resulted in the cyanobacteria encountering cooler water temperatures, leading to a decrease in their growth rate. On the other hand, low and variable light and reduced water temperatures during the mixing event increased the growth of chrysophytes because of their higher light affinity and lower optimal temperature. The modelling system was also used to assess the impacts of changes in wind speed on phytoplankton community structure since wind speed is predicted to be affected by climate change. The decrease in wind speed – atmospheric stilling – strengthened the dominance of cyanobacteria, whereas strong wind conditions caused a change in community structure from the dominance of cyanobacteria to chrysophytes.

Our results suggest that wind speed is a sensitive driver of phytoplankton community structure, and atmospheric stilling, especially in combination with climate warming, can lead to a more substantial dominance of cyanobacteria, posing more significant threats to water quality and ecosystem services worldwide. The trait-based individual-based modelling approach used in this study was shown to be an effective way to capture the interspecific variations and community structure of phytoplankton, with the potential for advancing aquatic ecology models and community predictions under climate change conditions.

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