Long-term trends in Danish lake plankton and the effects of nutrient reduction and climatic changes

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A two-decade (1989-2008) bi-weekly time series of lake phyto- and zooplankton in 17 Danish lakes were analysed for long-term temporal changes. Time-series of lake water characteristics and climatic variables were also analysed to elucidate their role in driving the changes in lake plankton. Each time series was analysed using the Mann-Kendal test for long-term trends, and temporal change in annually-pooled plankton genera composition was analysed using Non-metric Multidimensional Scaling. Six lakes, which were previously eutrophicated, had strong decline in their total phosphorus (TP) concentrations with a strong corresponding decline in phytoplankton biomass and a shift from Chlorophyta dominance in phytoplankton towards more heterogeneous communities, as well as an increase in plankton genera richness. Furthermore, plankton composition of these lakes changed towards that of lakes, which were not previously eutrophicated, indicating recovery of plankton community composition in response to improved ecological conditions. Notably, a widespread significant positive trend in plankton richness was observed across all lakes. The increase in plankton richness coincided with widespread nutrient reductions (re-oligotrophication), specifically with decreased phosphate and total nitrogen concentrations. These trends in plankton and water chemistry also coincided with significant increases in mean annual air temperature and precipitation and a decrease in wind speed during two decades of monitoring. Although the effects of lake chemistry and climate could not be separated due to their collinear changes, the climatic trends did not result in a strong corresponding trend in lake water characteristics, like surface temperature and stratification, and the trends in plankton variables were more consistently associated with the widespread nutrient reductions. Overall, the nutrient loading reduction across Danish landscape mostly due to the implementation of better agricultural practices have probably resulted in a widespread increase in plankton diversity, and resulted in marked recovery from eutrophication, especially in lakes with strong TP reduction.

Keywords phytoplankton, re-oligotrophication, lake recovery, plankton diversity ,temporal coherence, zooplankton