



Seasonal changes in temperature and nutrient control of photosynthesis, respiration and growth of natural phytoplankton communities

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Summary

- To investigate the influence of elevated temperatures on photosynthesis, respiration and growth of natural phytoplankton assemblages, water was collected from a eutrophic lake in spring, summer, autumn, winter and next spring and exposed to ambient temperature, +2°C, +4°C and +6°C for two weeks with and without addition of extra inorganic nutrients (Figure 1 and 2).
- Rates of photosynthesis, respiration and growth generally increased with temperature, but this effect was strongly enhanced by high nutrient availability, and therefore most evident for nutrient amended cultures in seasons of low ambient nutrient availability (Figures 3).
- Temperature stimulation of growth and metabolism was higher at low than high ambient temperature showing that long-term temperature acclimation of the phytoplankton community before the experiments were of great importance for the measured rates. Replete nutrient conditions were furthermore needed to fully utilize the temperature induced enhancement (Figure 4).
- Although we found distinct responses to relatively small temperature increases, the interaction between nutrient availability, time of the year and thus ambient temperature was responsible for most of the observed variability in phytoplankton growth, photosynthesis and respiration.
- Our study suggests that a forecasted increase in global temperature of 2-6°C over the coming century may have significant effects on production and degradation of organic material and thus the metabolic balance (-P/R ratio) of a lake. Importance of ambient temperatures and nutrient conditions, however, indicate that effects will be most pronounced during winter and early spring, while the remaining part of the growth season will be practically unaffected by increasing temperatures.

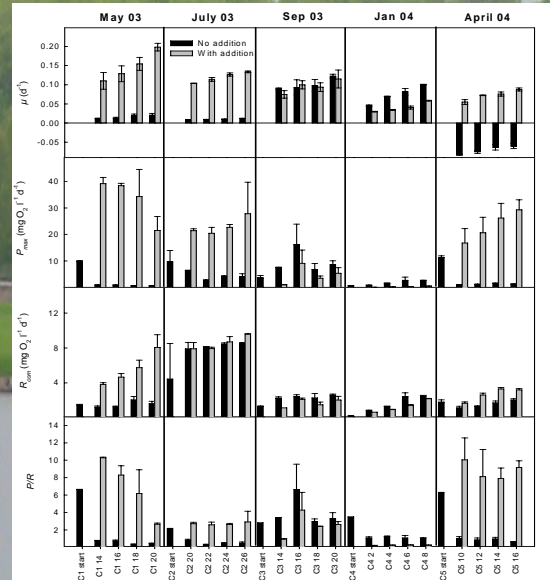


Figure 3. Specific growth rate (μ), maximum photosynthesis - P_{max} , community respiration - R_{com} and ratio of photosynthesis and respiration - P_{max}/R_{com} . Parameters were determined for lake water acclimated different temperatures with and without nutrient addition. For each campaign (C1, C2, C3, C4 and C5) samples were taken at the start of the acclimation period and after 1 to 2 weeks of growth at ambient, +2, +4 and +6°C. Growth temperatures are indicated by the last number. Error bars are 1 SD, (n = 2). Ambient nutrient concentrations were high in September and January.

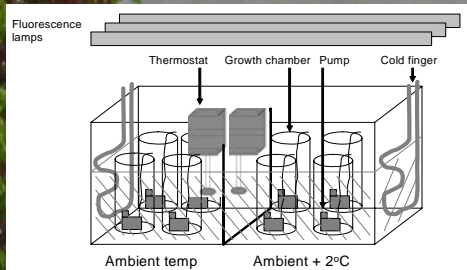


Figure 1 Front view of the temperature controlled aquaria in which lake water was allowed to acclimate to different temperatures with and without nutrient addition. The aquaria were divided into two parts in which temperature was controlled by a cold finger and a thermostat with a pump. Only the setup for ambient and ambient + 2°C is shown.

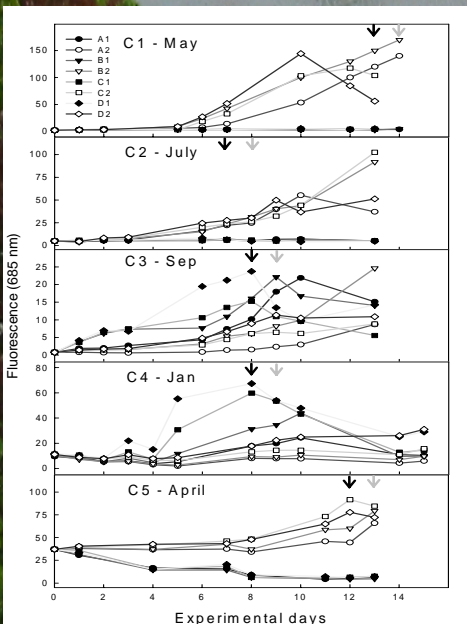


Figure 2 Biomass development as determined by fluorescence of Chl a at 685 nm in acclimation experiments. Arrows indicate time of sampling for photosynthesis and respiration. Black arrows represent growth chambers +4 and -6°C and grey arrows chambers grown at ambient temperature and +2°C. Closed and open symbols indicate growth chambers without and with nutrient addition, respectively (n = 2). All chambers with nutrients added experienced exponential algal growth and most eventually went into a stationary growth phase. During September and January campaigns of higher initial nutrient concentrations relative to demands the effect of nutrient addition did not appear until after 8 to 10 days. At this point chambers with nutrients added continued to support exponential growth while those without nutrients became stationary.

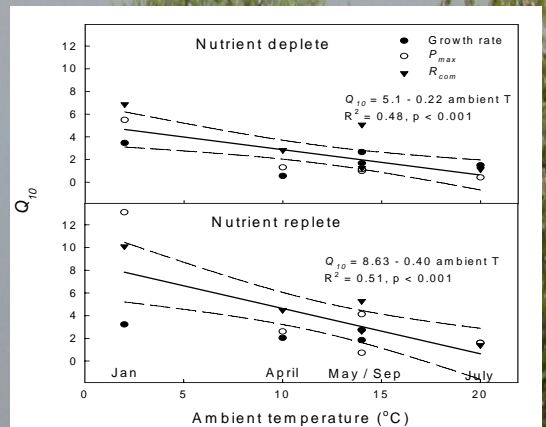


Figure 4. Q_{10} of nutrient deplete and nutrient replete cultures, plotted as a function of ambient temperature in five acclimation experiments. Data represents Q_{10} values for phytoplankton growth rate, maximum photosynthesis (P_{max}) and respiration (R_{com}). Solid lines were found by linear regression and dashed lines represent the 95% confidence limits of the regression model. Q_{10} depended on the ambient temperature and on nutrient availability.

Ecological implications of rising temperatures

Long-term changes in the balance between production and respiration are known to occur not only as a response to changes in temperature but also to changes in nutrient loading, allochthonous input and food web structure. The potential importance of temperature-induced changes on ecosystem metabolism will therefore depend upon several basic structural and functional properties of the lake ecosystem. Shallow eutrophic lakes, characterized by high nutrient availability, large annual and daily changes in temperature, such as Frederiksberg Slotssø sampled here, will certainly display a strong temperature dependence of metabolic balances. Larger and more oligotrophic lakes with long periods of stratification and low nutrient availability will, on the other hand, be less affected by temperature changes but highly controlled by nutrient input.

Besides the possible annual changes in metabolic balances, a temperature rise of up to 6°C in a future climate scenario will certainly facilitate an earlier spring bloom and alter the species composition of the phytoplankton assemblage, according to their temperature optima. In temperate lakes we should therefore anticipate a longer summer period of cyanobacterial dominance. Finally, the mere fact that algal cells and algal communities acclimate to warmer temperatures suggests that phytoplankton productivity and ecosystem functioning will respond less dramatically to global warming than might be anticipated from extrapolations of simple batch experiments. Future research could therefore benefit from comparative studies of lake metabolism across nutrient regimes and latitudes of different climate.