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Gaseous carbon balance for a small boreal lake following artificially increased DOC loading

Hannu Nykänen (1), Sari Peura (2), Paula Kankaala (3), and Roger Jones (2)

(1) University of Jyväskylä, Jyväskylä, Finland (Hannu.K.Nykanen@jyu.fi), (2) University of Jyväskylä, Jyväskylä, Finland, (3) University of Eastern Finland, Joensuu, Finland

Lakes constitute a globally significant source of greenhouse gases carbon dioxide (CO_2) and methane (CH_4) to the atmosphere. Most lakes are now known to be net sources of CO_2 to the atmosphere due to mineralization of allochthonous organic carbon from the catchment outweighing net autochtonous carbon production and retention in the lake. Predicted changes in precipitation and hydrological patterns may change carbon input from catchment area. In this study possible effects of artificially increased organic carbon input on a lake carbon cycle were evaluated.

The studied lake, Alinen Mustajärvi, is a small, oligotrophic, mesohumic headwater lake located in a boreal coniferous forest area in southern Finland. Because of its sheltered position and high concentration of allochthonous humic substances, the lake is normally steeply stratified with respect to temperature and oxygen. The lake is covered by ice for 5–6 months each year and is partially meromictic. The natural epilimnetic DOC concentration of the lake is around 11 mg C l^{-1}. Dissolved organic carbon concentration in the epilimnion was increased by adding carbon as cane sugar. The goal was to increase the amount of labile DOC available for heterotrophic bacteria without affecting the light climate for autotrophic phytoplankton. Cane sugar was chosen because, as well as increasing DOC availability, its isotopic signature is typical of C4 plant and thus markedly different from that of local C3 plants, allowing the added DOC to act as an isotopic tracer in the lake carbon fluxes. The year 2007 served as a control year, while during the ice-free periods (May to October) of 2008 and 2009 66 kg of cane sugar was added monthly, thus adding 22 g C $m^{-2}$to the epilimnion annually. This amount was calculated to produce an approximately 2 mg l^{-1} rise in the DOC concentration in the epilimnion, intended to raise labile DOC concentration from around the first quartile level for boreal lakes to that in lakes around the third quartile level (Henriksen *et al*. 1998). During 2010 sugar addition ceased and recovery of the lake was monitored.

CH_4 and DIC concentrations and their stable isotopic composition were measured at the deepest point of the lake from 1 m intervals. Fluxes of CH_4 and CO_2 from the lake surface to the atmosphere were estimated with boundary layer diffusion equations presented by Phelps *et al.* 1998 and Cole and Caraco 1998. Amount of CH_4 oxidized was estimated from vertical CH_4 and DIC stable isotope measurements and by comparing differences between observed concentrations and CH_4potentially transported by turbulent diffusion between different vertical layers in the lake (Kankaala *et al.* 2006). Community respiration and primary and bacterial production were measured from the euphotic zone. Concentrations of nutrients, Chlorophyll a, DOC and POC were measured from composite samples from the meta-, epi- and hypolimnion as well as the biomass of bacteria, phytoplankton and zooplankton. δ^{13}C and δ^{15}N of dissolved and particulate organic matter (DOM, POM) and zooplankton were analyzed from composite samples from the meta-, epi- and hypolimnion.

Results from stable isotope analyses indicate that the added cane sugar was effectively used in specific lake processes, while changes in estimated CH_4 and CO_2 fluxes suggest that the additional carbon loading had an effect on overall lake metabolism.

References

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