Supporting information materials and methods

Vertical profiles of scalar irradiance in the photosynthetically active radiation (PAR) region (400 -700 nm; E0) were measured using a spherical irradiance sensor (BioSpherical instruments) attached to a 10 channel CTD profiler (WRW620. RBR Ltd., Canada). The sensor was lowered at a rate of approximately 20 cm s-1 with a sampling rate of 6 Hz. In order to correct for temporal changes in irradiance caused by for example wave action and clouds during the CTD cast, we regressed the log-transformed E0 against depth (z) for each ten sampling point (i.e. sliding windows). The vertical attenuation coefficient for scalar PAR (K0PAR) was then estimated by taking the median of the distribution of these slopes.

Measurements of concentrations of total phosphorus (TP), total organic carbon (TOC) and total nitrogen (TN) were carried out both at the Norwegian Institute for Water Research (NIVA) and at the University of Oslo (UiO). Regressions between the measurements at the two laboratories showed no systematic differences (TP: *R*2 = 0.77, residual standard error (*RSE*) = 2.27 µg l-1; TOC: *R*2 = 0.99, *RSE* = 0.25 mg l-1; TN: *R*2 = 0.91, *RSE* = 81 µg l-1) and the averages of the results were used in the subsequent analysis. DOC was calculated as the difference between the total organic carbon (TOC) and particulate organic carbon (POC). TOC was measured by infrared CO2 detection after catalytic high temperature combustion (Shimadzu TOC-VWP analyser (UiO), or Phoenix 8000 TOC-TC analyser (NIVA)).
POC was measured on an elemental analyser (Flash EA 1112 NC, Thermo Fisher Scientific, Waltham, Massachusetts, USA) through rapid combustion in pure oxygen of particulates captured on a pre-combusted GF/C-filter. The major part (> 95 %) of the TOC was in dissolved form (DOC). At UiO, TOC was measured together with total inorganic carbon (TIC). TP was measured on an auto-analyser as phosphate after wet oxidation with peroxodisulfate. The two labs measured TN in different ways. UiO measured TN on unfiltered samples by detecting nitrogen monoxide by chemiluminescence using a TNM-1 unit attached to the Shimadzu TOC-VWP analyser, and NIVA measured TN through detection of nitrate after wet oxidation with peroxodisulfate in a segmented flow auto-analyser.
For gas analyses, water from the composite water sample (integrated from 0 to 5 m depth) was gently let into 120 ml glass serum vials without bubbling. The samples were fixed with 0.2% HgCl and sealed with gas-tight butyl rubber stoppers (see Yang et al. (2015) for details). Prior to analysis, the vials were stored dark and cold (4 ºC). In order to prepare a 20-30 ml headspace, a gentle helium pressure (needle valve) was applied to the top of the bottle volume replacing ca. 40 ml of sample with pure He, before venting the bottles to 1 atmosphere. Equilibration between liquid and headspace was achieved by shaking the bottles horizontally at 150 rpm for 2 h at room temperature. Headspace concentrations of CO2 and O2 were determined by automated gas chromatography (GC; Model 7890A, Agilent, CA, USA).

In brief, the bio-optical model calculating area specific primary production (PPA) is based on estimating the in vivo rate of light absorption by phytoplankton, and subsequently electron transport rates (ETRs) through photosystem II (PSII) using information about the light-dependent quantum yield of the PSII photochemistry. ETR can further be converted to a rate of gross carbon fixation by assuming an appropriate value for the quantum yield of CO2 fixation (Kromkamp and Forster, 2003, Suggett et al., 2010). While the method could be sensitive to phytoplankton community composition, it has gained increased interest over the last two decades because it offers a fast and inexpensive way of obtaining PPA estimates (see Thrane et al (2014) for details). A comparison of this method and empirical estimates for PPA in boreal lakes demonstrated good accordance (Thrane et al., 2014). The method is thus a feasible tool for assessment of primary production across a large number of sites. It also avoids many of the pitfalls of 14C-bottle incubation, which in any case could not have been applied in this kind of synoptic survey.

CO2 flux

We used Fick’s law of diffusion to calculate the water-air flux of CO2 (Fnet; mmol m-2 d-1) from lake surface CO2 concentrations.:

$F\_{net}=k\_{CO2}∆\_{CO2}$ (1)

where kCO2 (m d-1) is the CO2 gas exchange coefficient at a given temperature and ∆CO2 (mmol m-3) is the CO2 deficit from concentrations at equilibrium with the atmosphere, obtained using Henry’s law. kCO2 was estimated for each lake using the gas transfer velocity (m d-1) for a gas-temperature combination with a Schmidt number of 600 (k600; CO2 at 20 °C) according to Jähne et al. (1987):

$k\_{CO2}=k\_{600}\left(\frac{Sc\_{CO2}}{600}\right)^{-x}$ (2)

where x = 2/3 if wind speed ≤ 3ms-1 and x = 0.5 if wind speed > 3m s-1, Sc is the temperature dependent Schmidt number for CO2. k600 is estimated from the wind speed according to Cole and Caraco (1998):

$k\_{600}=2.07+0.215 U\_{10}^{1.7}$ (3)

Hourly wind speed data at 10 m above ground (U10 in equation 9) at all 75 lakes were extracted from the Norwegian Reanalysis Archive (NORA10) and aggregated into July-August means.

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