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Riparian buffers mitigate downstream effects of clear-cutting on instream metabolic rates

Maria Myrstener[1, 3], Larry A. Greenberg[2], William Lidberg[1] and Lenka Kuglerová[1]*

[1]Department of Forest Ecology and Management, Swedish University of Agricultural Sciences, Umeå, Sweden

[2]Department of Environmental and Life Sciences, Karlstad University, Karlstad, Sweden

[3]Present address: Department of Fish, wildlife and environmental studies, Swedish University of Agricultural Sciences, Umeå, Sweden

[*]Corresponding author: Maria Myrstener (mariamyrstener@gmail.com)

METHODS FOR METABOLISM DATA

2.3 Biofilm metabolism

Local biofilm metabolism was estimated using ceramic tiles (4.8x2.3 cm) for GPP and wood tiles (made of birch veneers, 5x2 cm) for community respiration (CR). Two different tiles, ceramic and wood, were used because autotrophs (periphytic algae) often dominate inorganic surfaces (tiles), while heterotrophic organisms (bacteria and fungi) favor organic substrates (Myrstener et al., 2018). At each stream location (upstream, within clear-cut, 50 m and 100 m downstream), four ceramic and four wood tiles were deployed for 21 days, once in July and once in August. After retrieval, tiles were stored at 4 °C and incubated in the lab within 24 h of collection for estimates of GPP and CR. Incubations were conducted by adding one tile each to a 50 mL tube and filling them with oxygen saturated stream water. The water used in the incubation was collected from the same locations as the tiles with no modifications other than bubbling with air to saturation. Dissolved oxygen saturation (YSI ProDO, USA) was measured pre- and post-incubation and the instrument was calibrated each morning before the experiment started. Ceramic tiles were incubated for 3 h in light chambers at 12 °C for estimation of autotrophic oxygen production, and both ceramic and wood tiles were incubated for

3h in dark chambers (12 °C) for estimation of total oxygen consumption. We chose 12 °C for all incubations as a way of standardizing conditions between streams and because this was the average temperature of all streams during the study. We also chose the same temperature for all streams so that the GPP and CR represent the biomass growth over the whole deployment, rather than being influenced by the differences in temperature during the incubations. An additional three blanks (stream water only), treated the same way as the tiles, were used to correct for any water column changes in dissolved oxygen. Metabolic rates were calculated as the difference in dissolved oxygen between start and finish of incubations, correcting for any dissolved oxygen change in the blanks, and presented as per surface area (g O_2 cm^{-2} hr^{-1}). GPP was calculated for ceramic tiles as the mass of oxygen produced during light incubation plus oxygen consumed during dark incubation. We calculated CR as the mass of oxygen consumed during dark incubation of wood tiles.

2.4 Whole stream metabolism

Whole stream metabolism was modeled for the upstream, clear-cut and 100 m downstream locations in three of the streams (streams 3, 7 and 8) during ca 90 days from mid-July to early October. We chose those streams to represent both wide and narrow buffers (Fig. 1B-D and Table 1). We also chose streams that lacked substantial inputs of water from ditches or ground water ~200 m upstream of the logger sites because this disrupts the oxygen signal. At each stream, we recorded dissolved oxygen at 10-minute intervals using miniDOT loggers (Precision Measurement Engineering Inc., USA). Oxygen loggers were calibrated before and after deployment using 100 % oxygen saturation and 0-5 % oxygen saturation. There was no notable drift during deployment. Metabolism was estimated at these locations using the single-station diel oxygen method where GPP and ecosystem respiration (ER) were estimated using Bayesian inverse modelling (Hall & Hotchkiss, 2017). We used our time series data for dissolved oxygen, dissolved oxygen saturation (DOsat), water temperature, light (from lux loggers), together with a modelled gas exchange rate coefficient (K) and stream depth (z). The main equation for GPP and ER was:

Δdissolved oxygen/Δt=(GPP-ER)/z+K(DOsat-dissolved oxygen)

where the change in oxygen over time (O_2 m^{-3}) equals all oxygen produced by photosynthesis (GPP, g O_2 m^{-2} d^{-1}) minus all oxygen consumed by respiration of both autotrophs and heterotrophs (ER, g O_2 m^{-2} d^{-1}), and the rate of gas exchange between the water and air (K, d^{-1}). We modelled three parameters (GPP, ER and K) but with daily priors (the starting point from which the model predicts a parameter) for Ks based on nighttime regression analysis and discharge-K relationships (following Rocher-Ros et al., 2020). Finally, we filtered data for erroneous model days by using the mean average error between the observed and the modelled DO concentrations. All days with a mean average error larger than 0.25 were removed. All remaining days were visually inspected to further exclude erroneous model estimates as the model can be poor, even if the model has a small error, if GPP is very low. Following these guidelines, we removed 25 % of analyzed days across all streams. We are aware that the footprint of the downstream oxygen loggers might incorporate signals from the water of upstream locations. These are, however, headwater streams with multiple waterfalls per reach that completely mix (and thereby oxygenate) the water, causing short oxygen turnover lengths. Still, we tested for correlations in metabolic rates between loggers and this was highest for ER in stream 8 (r^2=0.37). With that, we are certain that our estimates of whole stream GPP and ER to a large degree represent metabolic rates, which are produced in the represented location (i.e. good separation between upstream, clear-cut and downstream locations). There may have been a modest downstream transport of oxygen in stream 8, the stream with the highest correlation between ER in the clear-cut and downstream site, but this effect is not expected to be large enough to affect the direction of change between logger locations. ER in this location was also highly autocorrelated (r^2 = 0.5, $p<0.01$), as daily values of ER depended on the previous day's ER, for at least three days (lag3). This indicates low daily variability in ER, and therefore we would expect some correlation between locations even without any overlap in logger footprint.