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Experimental riparian forest gaps and increased sediment loads modify stream metabolic patterns and biofilm composition

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METHODS FOR CHL-a DATA

Study site

We used 12 artificial channels at the Svartberget experimental facility (Laudon et al., 2021) in northern Sweden, 60km west of Umeå. We asked how sandy substrates, decreased riparian shading and nutrient additions affect biofilms (biomass and metabolic rates) and whole ecosystem metabolic rates (Figure 1). We chose to manipulate these three parameters as they represent typical physicochemical changes that follow final felling and site preparation in Sweden and other countries (Kreutzweiser & Capell, 2001; Kuglerová et al., 2021; Marttila et al., 2020). The artificial channels we used are 15m long and 20 cm wide, with flow through water from an adjacent, forest stream. Water depth varied from 3 to 11cm (top to bottom), with a slope of ~0.5cm per meter. Water discharge was constant at 1-2 L s^{-1} and water velocity was 0.1 m s^{-1}. Water to the artificial stream channels is continuously pumped from the forest stream using a bilge pump (Flygt KS 2610) to a 3000 L water collection tank, from which the water is then led to four 1000 L boxes, each feeding three of the channels (Figure 1). The residence time in the boxes is less than 30min. This setup ensures that water is well mixed in the tank and boxes so that all channels have similar water flow (discharge) and inlet chemistry (Appendix S1: Table S1). During the experiment, the channel water had high dissolved organic carbon concentrations, (DOC; 20-30mg L^{-1}), low inorganic nutrient concentrations (average dissolved inorganic nitrogen; DIN=35μg L^{-1} and PO_4^{3-} =4μg L^{-1}) and was cold (average 11ºC), conditions typical for forest streams in the region (Laudon et al., 2021). We ran the experiment for 38 days from 1 August to 7 September 2022, with the tarp used to reduce light installed on August 3rd.

We coupled our chl *α* results from the artificial channel experiment with a snapshot field survey of chl *α* in 9 forest streams, upstream, within and downstream of recent clearcuts, in the county of Västerbotten within 1 h driving distance from the city of Umeå, northern Sweden (Table 1). The site conditions around the streams ranged from young (30-40 years) to mature (60+ years) forests in the upstream and downstream sites to clearcuts. The clearcuts range in buffer width from essentially no buffers (a few individual trees or high stumps) up to 15m wide buffers. Substrate conditions in the surveyed streams varied from no sand present to stream bottoms dominated by fine-grained particles. The sites were clearcut between 2014 and 2020 (Table 1).

Channel experiment set up

We used a 2 x 2 factorial design, with three replicates of each treatment. The two factors were substrate (sand vs stones as bottom substrate) and light (70 % shading tarp or no tarp, Figure 1). The sand (median diameter 0.2mm) and stones (median diameter 8cm) came from a nearby quarry, representing local, natural material, dominated by gneiss and granite. The substrate treatment tests for effects on biofilm growth and metabolism, but it does not test for disturbance effects such as burrowing or scouring because the bottoms were stable throughout the experiment. The sand sediment had no effect on nutrient concentration of the water in the channels (Appendix S1: Table S2) unlike in e.g. Pérez-Calpe et al. (2021). The tarp mimics stream light conditions in a mature forest stand or a wide buffer (>15 m, Chellaiah &

Kuglerová, 2021, Jyväsjärvi et al., 2022). There was no effect of the tarp on water temperature, and the average temperature was 11.0 (±0.06) in the shaded channels and 11.1 (±0.04) in the open channels. This enabled us to test for light effects without any confounding temperature effects, which is hard to achieve in natural streams as the two are closely coupled. For ease of installment and access to the channels, we fixed the tarp over three channels side-by-side instead of fixing it randomly, on individual channels. Nevertheless, each channel is treated as an independent replicate because the set up delivers well mixed water from the same source to each channel separately and the starting conditions for all channels did not differ (see Appendix S1: Table S1 and further below).

Biofilm biomass and species composition in the channels

We estimated biofilm biomass as chl *α* (μg cm^{-2}) once per week, based on ten measurements in each channel. For all chl *α* estimates, we used a BenthoTorch, an *in-situ*, hand-held fluorometric instrument (bbe Moldaenke, Germany). The BenthoTorch estimates chl *α* and distinguishes between diatoms, green algae and cyanobacteria, which often dominate stream biofilms (Allan & Castillo, 2007). Estimates of total chl *α* from a BenthoTorch compare well with conventional spectrophotometric methods when biofilms are relatively thin, as in our situation. However when quantifying community composition, the BenthoTorch have been shown to overestimate the abundance of diatoms (Kahlert & McKie, 2014), yet the instrument performs well in factory calibrations against standards. Still, we only used the community composition results to note presence or absence of green algae in the channels. All statistical analyses used the sum of diatoms, green algae and cyanobacteria (i.e. total chl *α*).

Field survey of chl *α* in streams

During the field survey, we estimated chl *α* on two occasions in each of the nine streams using a BenthoTorch. The first survey was on 1 September and the second was on 19 October, 2022. In the September survey, we had transects in the clearcut part of the stream and in the

October survey we added transects upstream and downstream of the clearcuts to include both open and closed canopy sites. At each site we had six to eight transects, with three measurements taken from the bottom along each transect, for a total of 18-24 measurements per site. In the streams, we measured chl α only from sand and stone substrates so the set-up was not fully random (i.e. avoiding wood, gravel, leaves etc.).