Does particulate organic carbon in the hyporheic zone drive stream metabolism?

Buried particulate organic C fuels heterotrophic metabolism in the hyporheic zone of a montane headwater stream

Citation Serchan, S. P., Wondzell, S. M., Haggerty, R., Pennington, R., Feris, F., Sanfilippo, A., Tonina, D., & Reeder, W. J. (2024). Buried particulate organic C fuels heterotrophic metabolism in the hyporheic zone of a montane headwater stream. *Freshwater Science*, 43(3), 288-306. https://doi.org/10.1086/731772

Is particulate organic carbon in the hyporheic zone more important for stream metabolism than stream-sourced dissolved organic carbon? In streams the hyporheic zone is the portion of subsurface sediments beneath and adjacent to streams where surface flow enters the subsurface and reemerges into surface flow downstream. This zone is an important area for carbon metabolism and cycling in streams. The researchers investigated whether heterotrophic metabolism in the hyporheic zone was fueled to a greater extent by dissolved organic carbon from surface-sourced flow or by particulate organic carbon that was buried or sediment-bound.

Were water and respiration characteristics similar between the well network and the mesocosms?

- Water temperatures were similar from all well sites and stream samples on each sample date. In mesocosms, water temperature was similar from the inlet to the outlet during winter-spring but in summer-autumn water temperatures increased with travel time by up to 5°C.
- In general, for both the well network and the mesocosms, dissolved O_2 concentrations decreased with travel time and dissolved inorganic carbon (DIC) concentrations increased, while dissolved organic carbon (DOC) concentrations changed little. The decreases in DOC were smaller than the increases in DIC.

Did the respiration reaction rates differ between the well network and the mesocosms? Did they differ seasonally?

- The reaction rate for consumption of O_2, k_{O2}, varied seasonally in the mesocosms but did not vary seasonally in the well network. In both the wet and dry seasons, the k_{O2} was higher in the mesocosms than in the well network.
- The reaction rate for production of DIC, k_{DIC}, varied seasonal in the mesocosms but not in the well network. In the dry season, mean k_{DIC} did not differ between mesocosms and the well network, but the range was larger in the mesocosms. In the wet season, mean k_{DIC} was higher in the well network than in the mesocosms.

What factors were related to respiration reaction rates for O_2 and dissolved inorganic carbon?

- Both the k_{O2} and the k_{DIC} increased with temperature in the mesocosms, with a stronger relationship for the k_{O2}. The k_{DIC} increased slightly with inlet DOC concentration in the mesocosms and well network and k_{DIC} was strongly related to time since sediment packing in the mesocosms.

What was the magnitude of change for O2, DIC, and DOC in the mesocosms? Did the magnitude of change vary seasonally?

- Within the closed systems of the mesocosms, mean ΔO_2 was -0.076 mM, mean ΔDIC was 0.0388mM, and mean ΔDOC was -0.008 mM. The amount of O_2 used was at least 2 times more than the ΔDOC on all sample dates.
- The magnitudes of ΔO_2 and ΔDIC were larger in the summer-autumn than in the winter-spring. The magnitude of ΔDOC did not differ seasonally.

Could the net change in dissolved organic carbon explain the changes in O_2 or dissolved inorganic carbon?

- The reduction in O_2 and production of dissolved inorganic carbon could not be well explained by either the input dissolved organic carbon concentration or by the net reduction in dissolved organic carbon within the mesocosms.

Does this provide evidence that sediment-bound particulate organic carbon is important for respiration?

- The fact that input dissolved organic carbon and ΔDOC could not fully explain the consumption of O_2 and production of dissolved inorganic carbon, provide evidence for the idea that buried or sediment-bound particulate organic carbon is a major source of carbon for hyporheic respiration in this system.
- The linear relationships between travel time and both O_2 consumption and DIC production suggest that aerobic respiration rates in the hyporheic zone are controlled by the processes generating bio-available dissolved organic carbon from buried and sediment-bound particulate organic carbon.

What factors influence carbon cycling and exchange in stream networks? Can mesocosms be used to study these relationships effectively?

- The concentration of dissolved organic carbon in a stream likely depends on temperature, respiration rates, hyporheic transport times, and inputs from groundwater and organic matter fall. Therefore, stream-sourced dissolved organic carbon may be more important for respiration during winter-spring.
- The mesocosms do not exactly replicate the hyporheic zone of the stream, but are a reasonable platform to study the biogeochemical processing of organic carbon in the hyporheic zone.

Research Approach/Methods

- The researchers built 6 hyporheic mesocosms on the bank downstream of a stream well network. Each mesocosm was 2-m long with a 20.3-cm internal diameter. The end caps were grooved to distribute the water into laminar flow and then direct it back into one outlet flow.
- They filled the mesocosms with a mix of fine gravel, sand, and finer textured mineral sediment that they collected from a bedload trap basin downstream of the study area, mixed, and sequentially packed to distribute sediment variation across mesocosms.
- To maintain a temperature similar to the hyporheic zone, the researchers enclosed the mesocosms in an insulated aluminum box, used copper tubing to pipe streamwater past the mesocosms, and placed heat cables to keep it from freezing in winter.

- They pumped water into a head box above the mesocosms to provide upward vertical flow through each mesocosm. They maintained flow rates through the mesocosms as close as possible to 48 mL/min. The mean flow velocity was 0.19 m/h, which closely matched in-stream well observations.
- The authors collected in-stream data at 11 well network sites. At each they measured water elevation, pH, temperature, dissolved O_2, and EC. They pumped each well, let it refill overnight, then collected filtered and unfiltered water samples from the well and the stream nearby.
- The researchers collected the same data from water flowing through the mesocosms using built-in ports at the inlet, mid-point, and outlet of each setup. They categorized samples as summer-autumn or winter-spring to capture low- and high-flow seasons.
- The authors used zero-order kinetic reactions to model the consumption of O_2 and the production of dissolved inorganic carbon with travel time. They tested whether inlet concentrations of dissolved organic carbon, water temperature, time since packing, and season influenced respiration rate.
- They also estimated the amount of hyporheic metabolism in the mesocosms that could be explained by net loss of dissolved organic carbon.

Keywords hyporheic, mesocosm, aerobic respiration, dissolved organic carbon, DOC, particulate organic carbon, POC, headwater stream

Images

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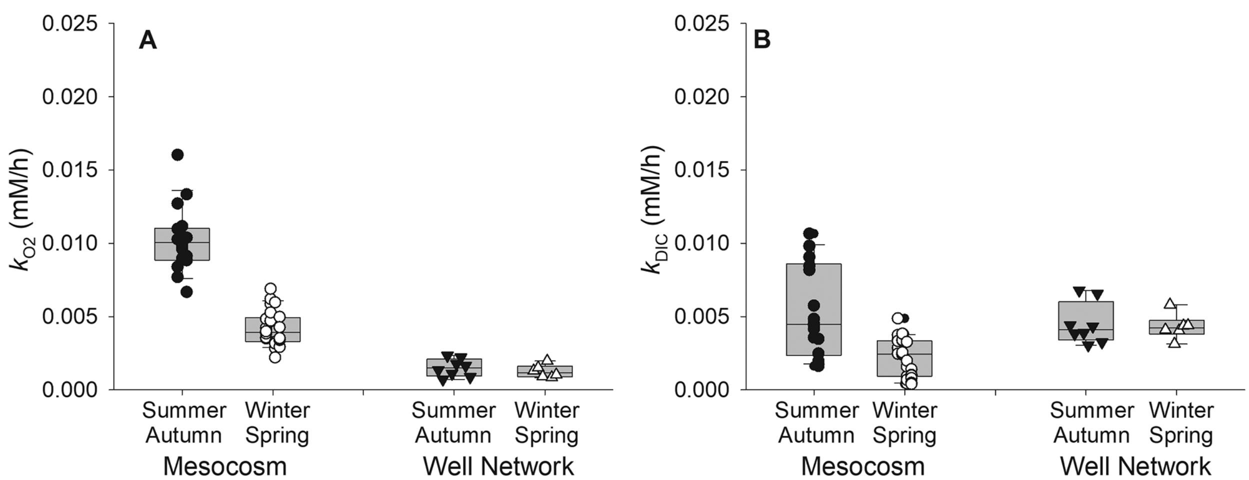

Figure 4 in Serchan et al. 2024. Comparison of zero-order reaction rates for the consumption of dissolved O2 (kO2) (A) and the production of dissolved inorganic C (kDIC) (B) between the mesocosms and the well network and between seasons (summer–autumn and winter–spring) at the H. J. Andrews Experimental Forest in Oregon, USA. Data points (circles and triangles) for all individual measurements are plotted on top of box and whisker graphs showing the median, quartiles, and the 10th and 90th percentiles (whiskers).

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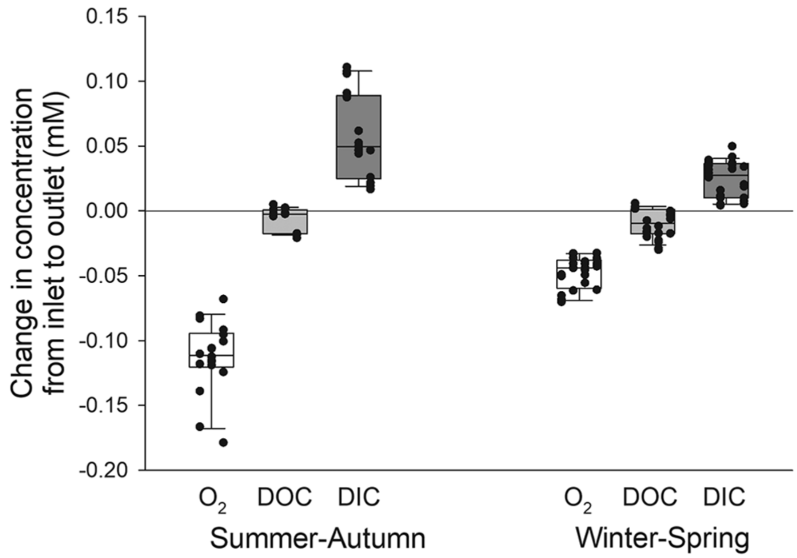

Figure 7 in Serchan et al. 2024. Change in concentration of dissolved O2 (ΔO2), stream-sourced dissolved organic C (ΔDOC) and dissolved inorganic C (ΔDIC) along 2-m-long flow paths through the hyporheic mesocosms, contrasting the summer–autumn and winter–spring seasons at the H. J. Andrews Experimental Forest in Oregon, USA. Negative values indicate consumption, whereas positive values indicate production. Bars show the median and 25th and 75th percentiles; whiskers show the 10th and 90th percentiles. The data from each mesocosm is plotted over the boxplot. Points are jittered along the x-axis to separate each sampling date.

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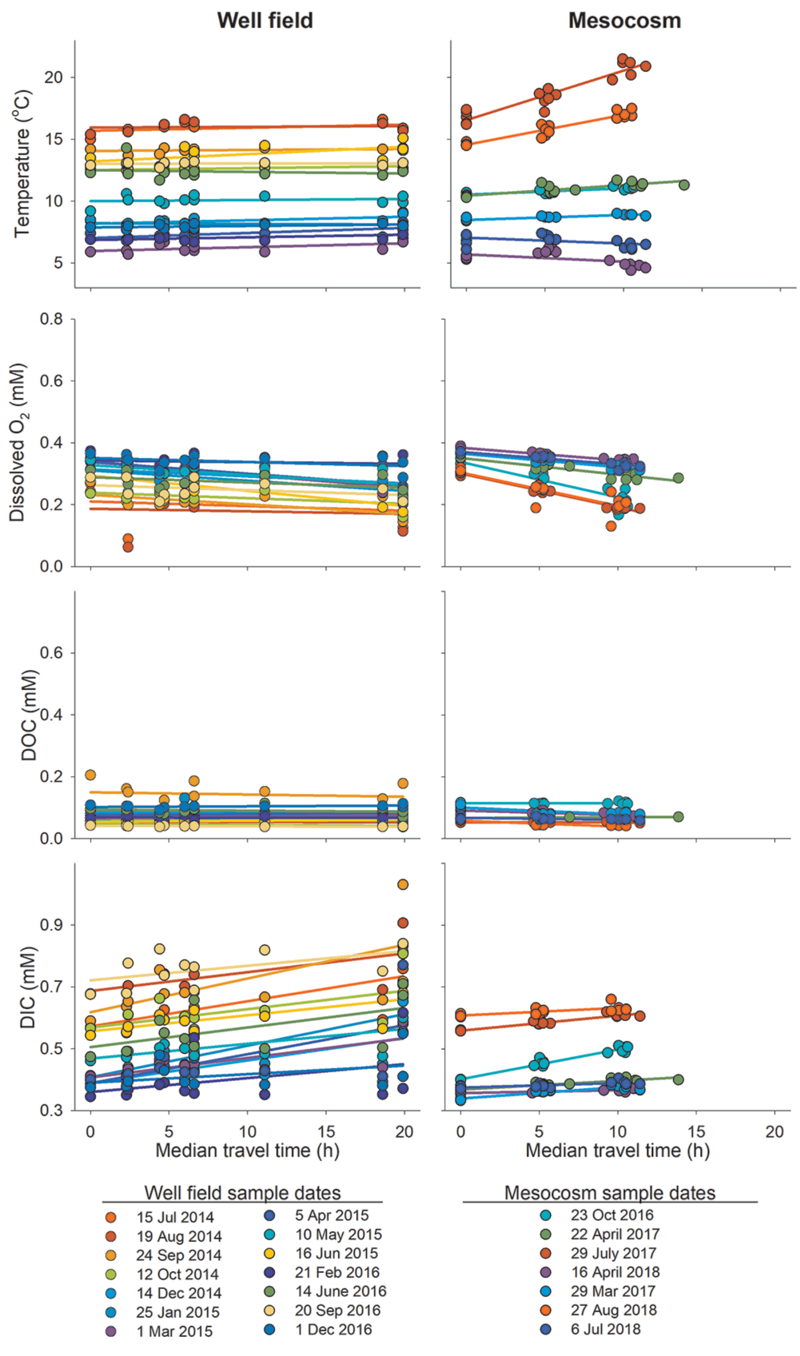

Figure 3 in Serchan et al. 2024. Patterns of water temperature, dissolved O2, dissolved organic C (DOC), and dissolved inorganic C (DIC) vs median travel time for the well field and the mesocosms at the H. J. Andrews Experimental Forest in Oregon, USA. Colors denote approximate water temperature at the time of sampling: reds are warmest, and blues and purples are coldest.