EAGER report

The award was granted to investigate geologic contributions of carbon to subterranean food webs in the aquifers underlying gravel-bed river floodplains. The secondary objectives of the grant were to expand understanding of the river hyporheic zone and to contribute to research on the biology of macroinvertebrates surviving in these extreme systems. We identified multiple floodplains in Colorado with potential for this discovery, collected preliminary samples, and over the course of the grant found detailed evidence of ancient contributions of carbon to a riverine food web at one site in particular: Cement Creek. Here, we found evidence that ancient carbon delivered from deep in the earth contributed to modern primary and secondary producer biomass.

The Cement Creek floodplain overlayed a shale formation at the upstream end and intersected multiple fault lines at the downstream end. A warm spring output delivered water from deeper in the earth to the floodplain surface along the fault line, and this was evidenced by a travertine formation likely tens to hundreds of thousands of years old. Travertine is formed by the precipitation of carbonates out of solution when the CO2-rich groundwater reaches a lower pressure environment and where algae also contributes to the removal of CO2 from solution.

We installed and sampled 7 wells at this site. From these wells, we collected water samples for cation and anion analysis (nutrients), measured dissolved gas content (CO2 and CH4), measured isotopic ratios and radiocarbon ages of organic matter, and identified and studied the isotopic ratios of macroinvertebrates. We also collected corresponding samples from surface water, including at the warm springs. We used these measurements to understand the age of carbon contributing to modern production.

When we began the study, we predicted that the shale and warm spring would contribute ancient methane to the subterranean food web. However, the true situation was far more complex and our investigation highlighted a critical flaw in our assumption that rivers are fueled by modern day photosynthetic production. 1. Some of the invertebrate biomass contained carbon dated to >10,000 years BP, reflecting a mixture of ancient and modern carbon. 2. The methane contribution was not obvious, with invertebrates showing the 13C depletion characteristic of non-photosynthetic carbon but not depleted enough to serve as definitive evidence of a methane contribution. Instead, these findings demonstrated that alternative methods of carbon fixation (ammonia oxidation, sulfur oxidation, and methane oxidation) were all potential candidates for food web contributions (DelVecchia et al. in prep). The 13C signatures could be used to infer and model these contributions, and as far as we know, no literature or modeling framework has been used to explicitly model this – instead, as a field, we have tended to conclude that any depletion of 13C signatures indicates a methane contribution.

These main findings are groundbreaking in the field of freshwater ecology for highlighting a critical assumption and limitation to our current river conceptualization. In addition to these main results, DelVecchia led a conceptual review of the hyporheic zone in non-perennial systems, extending the findings of Cement Creek to a broader framework on how river hydrology, biogeochemistry, and biology differs once water is underground (DelVecchia et al. 2022). DelVecchia similarly contributed this perspective on hyporheic ecology to multiple reviews ((Zimmer et al. 2020, Krabbenhoft et al. 2022) while she was supported as a research scientist on the grant. DelVecchia and Stanford furthermore contributed to work led by Rachel Malison on the hypoxia and anoxia tolerance of subterranean macroinvertebrates, adaptations which facilitate their access to resources dependent on an oxic-anoxic interface, such as the ammonia, sulfur, and methane oxidation (Malison et al. 2020a, 2020b). Finally, DelVecchia contributed to a synthesis of hyporheic ecology and the use of methane derived carbon led by Stanford (Stanford et al. 2024).

The award also led to multiple training and development opportunities. DelVecchia was supported as a research scientist on the grant, giving her the grant administration, project execution, and lab development training that supported her hire as an assistant professor at UNC Chapel Hill in 2022. She trained three paid research assistants over the course of the award, two of which were undergraduate students.

Finally, the award supported the teaching of river floodplain ecology to many community members and stakeholders in Colorado. At the start of the grant, DelVecchia discussed the work with many property owners in Colorado, and worked with state fish hatcheries to sample their water systems. In this process, she gave approximately five presentations of the work’s objectives and ongoing results, and provided water quality information to the Roaring Judy State Fish Hatchery. In addition, she worked with an addition undergraduate at UNC to create a publicly accessible summary of the work (https://amandadelvecchia.weebly.com/cement-creeks-ancient-c.html). She also presented the work to the Society for Freshwater Science, at Rocky Mountain Biological Laboratory, Virginia Tech, UNC Greensboro, Dartmouth, UNC Chapel Hill, and the University of New Mexico. Lastly, she has used the findings of the work to support two additional NSF proposal submissions thus far, and is in prep on an additional submission which was spurred by her discussion of the work at the award-supported attendance at the Association for Limnology and Oceanography meeting in 2023.

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