Coupled Microbial-Biogeochemical Responses to Groundwater-Surface Water Mixing

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The zone of groundwater-surface water mixing—the subsurface interaction zone (SIZ)—is an important component to the functioning of integrated surface/subsurface ecosystems. Due to the mixing of complementary electron donors and acceptors, the SIZ is a biogeochemical hotspot with significant influence over material transformation, the cycling of C and N, and the fate of contaminants. Relatively little is known, however, about the microbial communities that drive biogeochemical reactions in the SIZ. This is a broad knowledge gap that must be filled to link microbial ecology with hydro-biogeochemical models. To better understand SIZ microbial communities and their responses to changing biogeochemical conditions we used the Hanford site 300 Area as a model system to perform field investigations in the near-shore hyporheic zone (~ 1m below the Columbia River) and across the broader SIZ (~50-100m from the Columbia River shoreline). Hyporheic microbial communities showed elevated biomass and aerobic respiration rates in times of groundwater-surface water mixing, but this was not true of microbial communities in the broader SIZ. The collective results imply that mixing introduces labile carbon to the hyporheic, but organic carbon introduced to the broader SIZ is more recalcitrant. A sharp decline in dissolved oxygen during mixing in the hyporheic zone, but not in the broader SIZ, further supports this inference. A preliminary laboratory experiment suggested that river water itself is not the labile carbon source, leading to the hypothesis that labile carbon is transported into the hyporheic zone from riverbed sediments. Application of ecological theory to the dynamics of microbial community composition revealed that a unique selective environment emerges during times of mixing in the hyporheic zone and that microbial community dynamics in groundwater or surface water are relatively stochastic. Microbial taxa that showed significant shifts in relative abundance during mixing were associated with the ability to oxidize a broad range of organic compounds. This suggests that a generalist strategy—in terms of electron donor usage—is selected for during mixing in the hyporheic zone. These results are currently being integrated with hydro-biogeochemical modeling with the aim of improving predictions of SIZ biogeochemical function as hydrodynamics respond to variations in the hydrologic cycle. Field investigations are also being extended to couple microbial ecology to identified sediment facies to enable spatial predictions of microbial community properties relevant to SIZ biogeochemical function.