Linkages among Geophysical Facies, Microbial Composition, Biogeochemical Rates, and Seasonal Hydrology in the Hyporheic Zone

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The hyporheic zone is a critical ecosystem transition that links terrestrial, aquatic, and subsurface domains. To understand connections among physical, microbial, and biogeochemical components of the hyporheic zone, we obtained approximate 0.5 m freeze-cores along the Columbia River in the Hanford 300 Area and performed geologic, molecular, and microbial assays. Relationships among these data types were assessed using multivariate statistics; mud and sand content were found to be the primary drivers of microbial community attributes (in particular, of nitrite and carbon oxidizers). Microbial community analysis revealed an abundance of nitrifying Archaea (*Thaumarchaea*) and an absence of nitrifying Bacteria. Network analysis revealed significant negative correlations between sand content and some statistical modules of microbial taxa, perhaps indicating the importance of pore water residence time on community composition. A similar set of microbial modules was positively correlated with total organic carbon. One such module that also positively correlated with aerobic metabolic rates was dominated by *Thaumarchaea* and *Nitrospira*, suggesting that ammonia oxidation--instead of respiration--was the dominant aerobic process at the time of sample collection. We further examined temporal changes in hyporheic microbial community structure and activity through repeated sampling of attached and pore water microbial communities across a spatial gradient. We found that microbial communities remained distinct in river, hyporheic, and inland zones across seasonal variation in hydrologic mixing conditions. One factor that resulted in distinct communities across the three zones was temperature-driven increases in microbial species richness in the hyporheic zone. We employed a combination of null modeling and multivariate statistics to show that the relative importance of ecological selection and dispersal varied across environments (e.g., pore water vs. attached) and across geographic zones. Our results also indicated that while selection imposed short-term constraints on microbial community structure, hyporheic sediment communities did not respond to short-term hydrologic variation. Importantly, we demonstrated that the influence of selective pressures varied with phylogenetic affiliation, which may have been responsible for seasonal increases in *Thaumarchaea* and aerobic activity. Taken together, our results elucidate spatiotemporal shifts in the composition and activity of hyporheic microbial communities across sedimentary geochemical gradients as well seasonal gradients in pore water environments that correlate with the contribution of *Thaumarchaea* to aerobic processes.