Integrating Microbial Ecology with Hydro-Biogeochemistry

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As an integrated Science Focus Area (SFA) the PNNL SBR-SFA works to understand how water-cycle-driven hydrodynamics interact with fundamental biogeochemical and ecological processes across scales. Research activities focus on the zone of groundwater-surface water mixing (the subsurface interaction zone, SIZ) due strong a strong influence of this zone on contaminant release to surface waters and C/N cycling. The PNNL SFA will ultimately encode knowledge of SIZ processes in a multiscale modeling framework that forecasts system responses and feedbacks to environmental change. A challenge in the development of such a modeling framework is the need for deeper knowledge of interactions among microbial communities, major ecological factors, hydrodynamics, and biogeochemical processes. Significant advances in our understanding of these interactions have been achieved within the PNNL SFA through development of new ecological modeling frameworks and by using the Hanford 300 Area "coupled to the adjacent Columbia River" as a model system of SIZ dynamics. Relative to pre-existing approaches, our ecological modeling frameworks greatly improve understanding of factors that govern microbial communities through space and time. We find that dominant ecological factors vary across geologic formations, with selection-based processes dominating microbial communities in a fine-grained geologic formation and dispersal-effects dominating in a coarse-grained formation. We also find substantial spatial variation in the relative influences of ecological factors and reveal environmental features that may cause these variations. By further extending our modeling framework beyond community composition we show that high dispersal rates homogenize the metabolic potential of microbial communities through space, time, and across a broad range of groundwater-surface water mixing conditions. Simulation modeling predicts that this situation "where high dispersal rates govern microbial communities" causes a decline in biogeochemical rates, relative to the rates expected when selection is dominant. Integrated spatiotemporal monitoring of the SIZ nonetheless reveals that groundwater-surface water mixing causes an increase in microbial metabolism that strongly influences both carbon cycling and contaminant (nitrate) dynamics. To generate a foundation of knowledge needed to develop a predictive multiscale modeling framework, future research activities will explicitly couple spatiotemporal variation in dominant ecological factors with fundamental biogeochemical processes and will elucidate this coupling across scales.