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Groundwater flow diminishes nitrate processing in the hyporheic zone of streams

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Modeling and experimental studies demonstrate that ambient groundwater reduces hyporheic exchange, but the implications of this observation for stream N-cycling is not yet clear. We utilized a simple process-based model (the Pumping and Streamline Segregation or PASS model) to evaluate N- cycling over two scales of hyporheic exchange (fluvial ripples and riffle-pool sequences), ten ambient groundwater and streamflow scenarios (five gaining and losing conditions and two stream discharges), and three biogeochemical settings (identified based on a principal component analysis of previously published measurements in streams throughout the United States). Model-data comparisons indicate that our model provides realistic estimates for direct denitrification of stream nitrate, but overpredicts nitrification and coupled nitrification-denitrification. Riffle-pool sequences are responsible for most of the N-processing, despite the fact that fluvial ripples generate 3–11 times more hyporheic exchange flux. Across all scenarios, hyporheic exchange flux and the Damkohler Number emerge as primary controls on stream N-cycling; the former regulates trafficking of nutrients and oxygen across the sediment-water interface, while the latter quantifies the relative rates of organic carbon mineralization and advective transport in streambed sediments. Vertical groundwater flux modulates both of these master variables in ways that tend to diminish stream N-cycling. Thus, anthropogenic perturbations of ambient groundwater flows (e.g., by urbanization, agricultural activities, groundwater mining, and/or climate change) may compromise some of the key ecosystem services provided by streams.