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Measuring and modeling physical and biological contributions to nutrient retention across a stream network: Implications for watershed scale nitrogen export

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There has been growing interest in elucidating controls on downstream transport of nutrients to receiving bodies from both basic and applied scientific perspectives. However, reach scale understanding of nutrient retention has been limited and scaling these processes across stream networks represents an even greater challenge. We quantified reach scale physical (hydrological) and biological (uptake) retention of nitrate-nitrogen and scaled these relationships from reach to channel network extents. Physical retention occurs due to hydrologic loss of water (and associated solutes) from the stream to the groundwater system, which in turn slows the downstream transport of nutrients. Biological retention occurs due to nutrient uptake and is a concentration dependent process. We used tracer experiments to quantify both biological and physical retention dynamics across a range of stream scales, hydrogeomorphic settings, landscape positions, and experimental nutrient concentrations in a mountain stream network. We observed that physical retention was an important, if not dominant, form of nutrient retention across the network. Additionally, we found strong variability in uptake kinetic curves across the stream network and rapid increases in nutrient uptake over modest concentration ranges within a given stream reach. From these data we developed and parameterized a network scale nutrient export model that incorporates physical retention due to gross hydrologic loss, concentration dependent uptake kinetics, variable hydrologic loading, and channel network geometry. This approach allowed us to quantify the spatial evolution of stream network nutrient biogeochemistry. We suggest that stream network nutrient export models can help elucidate linkages between ecosystem processes and stream reach biogeochemistry and their manifestation at the watershed scale.