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Physical, Resource Supply, and Biological Controls on Nutrient Processing Along the River Continuum

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Excess nutrient loading has negatively impacted the ecology of ~90% of the streams in the US and the ecosystem services these streams provide, with estimated damages to US surface and groundwater system over of 100 billion dollar per year. Thus, there is a strong need to develop methods to predict the transport, uptake, and export of nutrients along fluvial networks and their cumulative effects on surface and groundwater quality. Our project is developing a data-driven, mechanistic understanding of critical factors that largely control nutrient uptake and export: 1) interactions between transport-related processes (mass- transfer to metabolically active zones), 2) resource supply dynamics (nutrient concentrations, stoichiometric constraints, etc.), and 3) biological controls (microbial community structure and function), and how these key factors drive nutrient uptake along a river continuum. This work is designed to address current knowledge gaps in understanding lotic nutrient dynamics that include a paucity of data for high order streams, a lack of studies assessing stoichiometric controls on nutrient uptake due to a traditional focus on solute-specific analyses (e.g., nitrogen only), and a scarcity of data that links microbial diversity and function with nutrient uptake dynamics along fluvial networks. Resolving these limitations will promote scientifically based restoration projects to reduce the burden of eutrophication costs. To meet our goals, we are pursuing three specific research objectives: RO1) Investigate how changes in river sediment texture control mass-transfer to metabolically active zones, colonizable surface area, and biological nutrient uptake along the river continuum; RO2) Investigate nutrient uptake kinetics along the river continuum considering limiting vs. non-limiting (i.e., stoichiometrically balanced) conditions, and labile vs. recalcitrant organic matter sources; and RO3) Investigate differences in microbial diversity, community structure, and genomic potential along the river continuum and how differences interact with resource supply to impose fundamental controls on nutrient uptake.

We are performing our research in a river continuum that spans four orders of magnitude in mean annual discharge (10^0–10^3 L/s), more than 2000 m in altitude, and more than 500 km of stream longitude. We incubated novel hollow-core columns filled with native and standardized sediments at each of the eight stream orders along the continuum for three months. The columns will be transported to the lab where tracer experiments will be performed under standardized flow conditions. Conducting the experiments with the two sediment types will provide the information necessary to determine how transport, normalized (by colonization and surface area) nutrient uptake rates, and variation in the biological community interact to influence nutrient uptake along the river continuum. Additionally, two resource supply injections will be performed on each of the columns: an only nitrate addition, followed by a stoichiometrically 'balanced' 106C:16N:1P addition. The stoichiometrically balanced injections will provide information necessary to determine how limitations for a given resource may impact nutrient uptake scaling in streams.

Our research seeks to depart from the status quo of focusing on solute-specific, site-specific nutrient uptake analyses, which have resulted in unscalable frameworks, to incorporate a more holistic, stoichiometrically and microbially based, data-driven mechanistic understanding of nutrient uptake and export along fluvial networks.