Geophysical Research Abstracts
Vol. 18, EGU2016-17630, 2016
EGU General Assembly 2016

Hydrologic and biologic influences on stream network nutrient concentrations: Interactions of hydrologic turnover and concentration-dependent nutrient uptake

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Stream networks lie in a crucial landscape position between terrestrial ecosystems and downstream water bodies. As such, whether inferring terrestrial watershed processes from watershed outlet nutrient signals or predicting the effect of observed terrestrial processes on stream nutrient signals, it is requisite to understand how stream networks can modulate terrestrial nutrient inputs. To date integrated understanding and modeling of physical and biological influences on nutrient concentrations at the stream network scale have been limited. However, watershed scale groundwater – surface water exchange (hydrologic turnover), concentration-variable biological uptake, and the interaction between the two can strongly modify stream water nutrient concentrations. Stream water and associated nutrients are lost to and replaced from groundwater with distinct nutrient concentrations while in-stream nutrients can also be retained by biological processes at rates that vary with concentration. We developed an empirically based network scale model to simulate the interaction between hydrologic turnover and concentration-dependent nutrient uptake across stream networks. Exchange and uptake parameters were measured using conservative and nutrient tracer addition experiments in the Bull Trout Watershed, central Idaho. We found that the interaction of hydrologic turnover and concentration-dependent uptake combined to modify and subsequently stabilize in-stream concentrations, with specific concentrations dependent on the magnitude of hydrologic turnover, groundwater concentrations, and the shape of nutrient uptake kinetic curves. We additionally found that by varying these physical and biological parameters within measured ranges we were able to generate a spectrum of stream network concentration distributions representing a continuum of shifting magnitudes of physical and biological influences on in-stream concentrations. These findings elucidate the important and variable role of physical and biological processes in both modifying and stabilizing nutrient concentrations and emphasize the crucial role stream networks play in transporting and modulating nutrients to downstream ecosystems or receiving water bodies.