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Combining empirical and modelling approaches to assess the role of in-stream net uptake on inorganic nitrogen export from catchments

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Streams are integrative recipients of nutrient exports from terrestrial ecosystems as well as highly reactive ecosystems with a significant capacity to transform and retain dissolved inorganic nitrogen (DIN) during downstream transport. However, the relevance of in-stream DIN cycling at the whole-catchment scale is still poorly understood due to the constraints associated with upscaling empirical data obtained mostly at the reach scale to larger spatial scales, and also because our current knowledge on the temporal variation of in-stream DIN uptake is still limited. Modeling approaches accounting for N dynamics in catchments increasingly incorporate rates of in-stream DIN uptake as a potential mechanism to help understanding whole-ecosystem N cycling, yet consideration of temporal variation of DIN uptake rates in these models is still an ongoing challenge. The aim of this study was to investigate the temporal variation of in-stream net DIN uptake (nitrate + ammonium) and its potential to regulate catchment DIN export under base flow conditions. To do so, we first estimated empirically whole-reach net DIN uptake rates (U_{DIN}) that integrate both uptake (assimilation, denitrification, adsorption) and release (mineralization, desorption) processes by analyzing monthly longitudinal profiles (n = 45) of DIN concentration in two headwater streams. We assessed the potential contribution of in-stream N cycling to catchment DIN export with two independent approaches: (i) we scaled-up the empirical estimates of U_{DIN} by using a fluvial network model (empirical approach) and, (ii) we used the observed natural range of U_{DIN} to run the INCA model, one of the few dynamic catchment models with an in-stream bioreactive compartment (modelling approach).The empirical data set showed that in-stream uptake and release did not offset each other (DIN uptake $\neq$ DIN release) in 48% of the dates, and that positive net DIN uptake ($U_{DIN} > 0$) occurred mostly in autumn. Our empirical approach suggested that in-stream processes during base flow conditions could reduce catchment DIN export by 19-52%. The consideration of temporal variation of U_{DIN} contributed to 2/3 of this amount. Model results supported our empirical results; however, simulated in-stream DIN retention was lower than estimated empirically, partially due to the low variation of the simulated in-stream uptake within the model. Our empirical data set illustrates that U_{DIN} varies widely intra- and inter-annually in headwater streams and both, the empirical and modelling approaches highlight that in-stream net uptake can substantially regulate DIN export from catchments under base flow conditions.