Nitrous oxide emissions under low flow conditions in streams

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Stream low flows resulting from water management and droughts are expected to increase in duration and frequency in most parts of the world due to climate change and increasing human pressure for energy and food production. These changes will influence stream biogeochemistry, streambed morphology and hydraulics, and may also influence the emissions of potent greenhouse gases from streams such as nitrous oxide (N2O). Stream flows well below current summer mean flows are expected to last longer and be more frequent than the present, thus exacerbating predicted responses to climate change as low flows may increase denitrification rates and thus N2O emissions. Here, we analyzed the potential effect of low flows on N2O emissions along two Midwestern US rivers with contrasting land use: the Manistee River (~83% forested) and the Tippecanoe River (~82% agricultural). We combined numerical modeling, empirical data collected during a summer synoptic sampling campaign, stream morphology models, and geostatistical analyses to predict the effect of low flows on N2O emissions with a scaling model based on a Damköhler number. The proposed dimensionless framework allowed us to investigate the effect of different boundary conditions, including chemostatic and chemodynamic conditions, on N2O under flows lower than current summer mean flow conditions. Our results show that while N2O emissions rates (emission per unit area of stream surface) may increase in agricultural watersheds the overall emissions at the watershed scale will decrease regardless of the land use and low flow severity due to the strong reduction in stream surface area. Thus, future low flow conditions will not increase N2O emissions at the fluvial network scale, although stream N2O concentrations may increase in the future, especially in agricultural reaches with high dissolved inorganic nitrogen concentrations.