Non-canonical $N_2O$ production pathways under low oxygen

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Aquatic systems are a key source of the greenhouse gas nitrous oxide ($N_2O$), generating up to 35% of global $N_2O$ emissions. Yet, little is known about the microorganisms and the partitioning of pathways that mediate $N_2O$ production across oxygen and nutrient gradients. We dissected the contributions of denitrification and nitrification to $N_2O$ production in the oxygen minimum zone of the Eastern Tropical North Pacific (ETNP) using both $^{15}$N-labeled substrates and $^{18}O_2$. Production of $^{15}$N$_2$O from $^{15}$NO$_3^-$ additions, but not from $^{15}$NH$_4^+$ additions, suggested denitrification as the source of $N_2O$ within both the oxycline and the deep chlorophyll maximum.

However, the data suggested that microbes reduced the $^{15}$NO$_2^-$ via $^{15}$NO$_3^-$ to $^{15}$N$_2$O in an atypical “closed” pathway without freely exchangeable intermediates. Surprisingly, no variability in the $N_2O$ production rate via this pathway was observed over a manipulated oxygen range of 0.1 to 15 µM. This stands in contrast to previous work that observed inhibition of $N_2O$ production via canonical denitrification at nanomolar oxygen concentrations. Interestingly, experiments labelled with $^{18}O_2$ showed incorporation of $^{18}O$ into $N_2O$. Such incorporation would be expected in $N_2O$ from hydroxylamine oxidation by ammonium oxidizers, but the lack of $^{15}$N incorporation from $^{15}$NH$_2^+$ in parallel incubations does not support this, which suggests that an alternate mode of $N_2O$ production is at play. Multiple pathways of $N_2O$ production were also indicated by metatranscriptomic data showing transcripts encoding proteins of both aerobic and anaerobic $N_2O$ production. In summary, the apparent patterns observed in the ETNP did not match those predicted based on current hypotheses of how $N_2O$ is produced in low-oxygen environments. Further elucidation of these non-canonical pathways and the organisms involved is important for understanding the factors controlling $N_2O$ emissions from aquatic systems.