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Universal and Rapid Recovery of Sedimentary Nitrous Oxide Consumption under Oxygenation Perturbation

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Coastal zones are global hotspots of nitrous oxide (N_2O) emissions, yet the resilience of sedimentary N_2O consumption, a critical ecosystem service for climate mitigation, remains poorly understood under frequent anthropogenic oxygen disturbances. Here, we investigated the capacity and recovery kinetics of N_2O consumption across a land–estuary continuum, including aquaculture ponds, mangroves, tidal mudflats, and estuarine sediments. By integrating flux incubations, kinetic modelling, and metagenomic analysis, we quantified how alternating oxygenation regulates the balance between N_2O production and consumption. Incubation experiments revealed that sediments rapidly regained N_2O consumption capacity after anoxia was re-established, shifting from net sources to net sinks within 10–24 hours (≤30 h). This rapid functional recovery occurred across all sediment types despite marked differences in microbial community composition, eutrophication status, and oxygen exposure duration. A flux-constrained kinetic model further demonstrated that N_2O consumption is a broadly maintained ecosystem function across diverse coastal environments. Metagenomic analyses provided mechanistic insight into this resilience. The N_2O reductase gene (*nosZ*) was widespread across sites. Although total *nosZ* abundance showed only weak correlations with specific consumption rates, 71 bacterial species spanning 16 classes contributed to the N_2O sink. *Pseudomonadota*, particularly *Beta-*, *Gamma-*, and *Alphaproteobacteria*, dominated the genetic contribution along the continuum. Despite substantial community turnover from land to estuary, N_2O consumption remained functionally conserved, ensuring robust reduction under dynamic redox fluctuations. Conservative upscaling based on kinetic parameters suggests that global coastal sediments may remove 0.39 ± 0.14 Tg N_2O–N annually, offsetting approximately 12–28% of coastal N_2O emissions. By linking molecular ecology with geochemical flux measurements, this study reveals coastal sediments as resilient and rapidly recovering N_2O sinks following oxygen perturbations, an underrepresented component in coastal greenhouse gas budgets.