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Anthropogenic forcing reorganizes nitrate reduction pathways in tropical coastal sediments: experimental and modeling constraints

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The balance between denitrification (DNIT) and dissimilatory nitrate reduction to ammonium (DNRA) determines whether coastal sediments function as net nitrogen sinks or recycle reactive nitrogen within aquatic systems. Process-level constraints on this partitioning remain limited in tropical environments exposed to localized anthropogenic inputs, where steep redox gradients and high organic loading interact over short spatial scales.

We investigated nitrate reduction dynamics in coastal sediments from Guadeloupe (Caribbean) along anthropogenic gradients in the Moustique River (upstream reference, downstream of a sugarcane distillery discharge, and mangrove reach) and the Canal des Rotours (upstream reference, downstream of a wastewater treatment plant discharge, and mangrove reach). Strictly anoxic batch incubations amended with 500 µM NO_3^- were combined with parallel mineralization controls and pathway-resolved reaction modeling.

Nitrate reduction rates ranged from 0.6 to 3.9 µmol g^{-1} d^{-1} across sites. Sediments directly impacted by effluents inputs exhibited sustained NO_2^- accumulation up to ~140 µM, whereas upstream reference sites displayed substantially lower intermediate build-up. At impacted locations, total dissolved inorganic nitrogen (DIN = NO_3^- + NO_2^- + NH_4^+) transiently increased by up to ~380 µM above initial concentrations, indicating rapid mobilization of reduced nitrogen pools under strongly anoxic conditions.

Mineralization experiments revealed significant NH_4^+ production even without added nitrate (0.03-2.3 µmol g^{-1} d^{-1}), demonstrating the presence of a large, labile nitrogen reservoir. Comparison between nitrate-amended and mineralization incubations indicates that nitrate addition alters redox trajectories and enhances intermediate accumulation rather than simply stimulating background ammonification. Elevated NO_2^- persistence and delayed reduction at effluent-impacted sites identify kinetic bottleneck downstream of nitrate reduction, consistent with incomplete denitrification under highly reducing, organic-rich conditions.

Ongoing isotopic analyses of NO_3^-, NO_2^-, and NH_4^+, integrated within a mass- and isotope-balanced reaction model, will quantify pathway partitioning and constrain the redox controls governing nitrogen retention versus removal. These results demonstrate that anthropogenic point-source inputs reorganize nitrate reduction dynamics over kilometer-scale gradients, with important implications for nitrogen cycling, redox stability, and eutrophication vulnerability in tropical coastal systems.