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Enhanced N_2 fixation in the North Atlantic Subtropical Gyre through the Holocene

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Low-latitude regions are the primary loci of marine N_2 fixation which dominates the input of bioavailable nitrogen. Constraining the evolution of marine N_2 fixation during the Holocene is fundamental to understanding the feedback mechanisms governing oceanic nutrient and carbon cycles under warm climate conditions. However, existing low-latitude nitrogen isotope records are predominantly derived from marginal seas, leaving a critical gap in Holocene records from the core regions of open-ocean nitrogen fixation. Here, we present Holocene records of deep-sea coral-bound $\delta^{15}N$ from the North Atlantic Subtropical Gyre (NASG). Because surface waters in the NASG are characterized by complete nitrate consumption, the continuous decreasing trend observed in our $\delta^{15}N$ records reflects enhanced N_2 fixation throughout the Holocene. This trend aligns with regional foraminiferal nitrogen isotope records, supporting the hypothesis that increased shelf sedimentary denitrification lowered the nitrogen-to-phosphorus ratio of the nutrient supply, thereby stimulating open-ocean N_2 fixation. Notably, the overall Holocene trend in low-latitude N_2 fixation exhibits broad similarities to $\delta^{15}N$ variations observed in the high-latitude Southern Ocean. We suggest this reflects a global-scale coupling, where enhanced low-latitude N_2 fixation replenished nitrogen deficits driven by sedimentary denitrification, thereby reducing the mean $\delta^{15}N$ of the global marine nitrate reservoir.