

Denitrification Process Rates Along a Gradient of Salt Marsh Health

Goals and Background

Salt marshes are essential for providing ecosystem services, specifically in the removal of nitrogen. The process of eliminating nitrogen is crucial for preserving water quality and preventing the occurrence of eutrophication in coastal habitats. Salt marshes function as natural filtration systems, employing denitrification and other processes to eliminate excess nitrogen from the water (Craft et al., 1999). This experiment evaluated the influence of historical ditching and distance from both expanding and stable ponds on soil net potential denitrification rates at two salt marsh sites (Great Bay Boulevard and Edwin B. Forsythe National Wildlife Refuge). We hypothesized that potential denitrification rates would be lower in ditched sites compared to unditched sites due to the altered hydrological conditions caused by drainage ditches, which may lead to reduced soil moisture and increased oxygen availability due to ditching, both critical factors influencing denitrification processes (Nyman et al., n.d.). The aim was to determine whether site characteristics such as ditching could predict nitrogen removal capacity, thereby informing targeted restoration efforts to maintain this important ecosystem service (Ooi et al., 2022).

Methods

Soil sampling was conducted along three transects extending from each pond across the four site types: Forsythe ditched, Forsythe unditched, Great Bay ditched, and Great Bay unditched. Unditched sites were characterized by stable ponds, while ditched sites are characterized by expanding ponds. Along each transect, two vegetation plots were established—one in the “Inner” band (1–5 meters) and the other in the “Outer” band (11–20 meters) from the edge of each pond. These plots were utilized for taking metrics such as bearing capacity and percent cover. Denitrification samples were collected within 1 meter adjacent to these vegetation plots. Soil samples were collected within specific bands. A 5 cm x 5 cm x 5 cm deep soil cube was extracted from the top layer of salt marsh soil and any above-ground plant tissue was removed. The soil cube was bagged in a ziplock bag and kept in a cooler on ice until they could be returned to the laboratory and refrigerated. Samples were processed within 24 hours of collection. For each pond, samples collected from the Inner band across the three transects were thoroughly mixed to create a composite sample representing the Inner band for that pond. Similarly, samples collected from the Outer band across the three transects were combined to create a composite sample representing the Outer band for that pond. A composite sampling approach was used to address spatial heterogeneity within each site while maintaining a manageable sample load. Subsequently, the homogenized samples underwent incubation using the acetylene block assay (Sørensen, 1978) to measure net potential denitrification rates. 5 g of soil were placed in 50-mL Erlenmeyer flasks containing 10 mL of salinity-adjusted artificial seawater with 2000 $\mu\text{mol L}^{-1}$ N as nitrate (Schutte et al., 2020). Flasks were purged with pure nitrogen gas and supplemented with 5 mL of acetylene to inhibit nitrous oxide (N_2O) conversion to nitrogen gas (N_2). Incubation occurred at room temperature (21°C), with headspace subsamples collected at 0.5, 1, 2, and 4 hours. Gas samples were injected into nitrogen-purged 10-mL vials and analyzed for N_2O concentrations using a gas chromatograph (Shimadzu

GC-2030) with an electron capture detector and headspace autosampler. Net potential denitrification rates were calculated from the linear increase in N_2O concentrations over time and corrected for the dry mass of the soil incubated.

Results

There were significant differences in net potential denitrification rates between the four site types investigated here (Kruskal-Wallis test, $p = 0.006$) with Forsythe ditched being significantly different from the other three site types (Dunn's test, $p < 0.045$) and the other three site types not different from one another (Dunn's test, $p > 0.5$). The median rate of $5500 \text{ nmol N gdw}^{-1} \text{ day}^{-1}$ (Inter Quartile Range (IQR) = $4810\text{--}7290 \text{ nmol N gdw}^{-1} \text{ day}^{-1}$) at Forsythe ditched sites was much higher than the median rate of $1390 \text{ nmol N gdw}^{-1} \text{ day}^{-1}$ (IQR = $821\text{--}3040 \text{ nmol N gdw}^{-1} \text{ day}^{-1}$). Ooi et al. (2022) measured a lower mean denitrification rate of $663 \text{ nmol N gdw}^{-1} \text{ day}^{-1}$ (95% CI = $425\text{--}903 \text{ nmol N gdw}^{-1} \text{ day}^{-1}$) across 20 Connecticut salt marshes. These rates are most similar to those measured at the Forsythe unditched and Great Bay sites. Mean net potential denitrification rates were higher in the Outer band than they were in the Inner band across all four site types (Figure 2), but these differences were not significant (Dunn's test, $p = 1$), likely due to high variation between the three samples within each sample group. Since there were no differences in net potential denitrification rates between the Forsythe ditched, GBB ditched, and GBB unditched site types, these data were pooled together to compare rates between the Inner and Outer bands (Figure 3). Even with the larger sample size in each group ($n = 9$), there were no significant differences in net potential denitrification rates between samples collected within 5 meters of a pond edge and those collected 10–15 meters from a pond edge (Wilcoxon test, $p = 0.55$). While ditching and pond stability did not have any discernable influence on denitrification potential as expected, these data demonstrate that denitrification was active across all marsh types regardless of ditching, distance from pond, or pond type. Notably, even marshes adjacent to expanding pond edges exhibited active denitrification potential, indicating that they are still capable of facilitating the nitrogen removal ecosystem service provided by salt marshes. Therefore, denitrification potential may be robust across vegetated portions of highly dynamic salt marsh landscapes, even in areas that are perceived to be low in quality or prone to loss.

Figures:

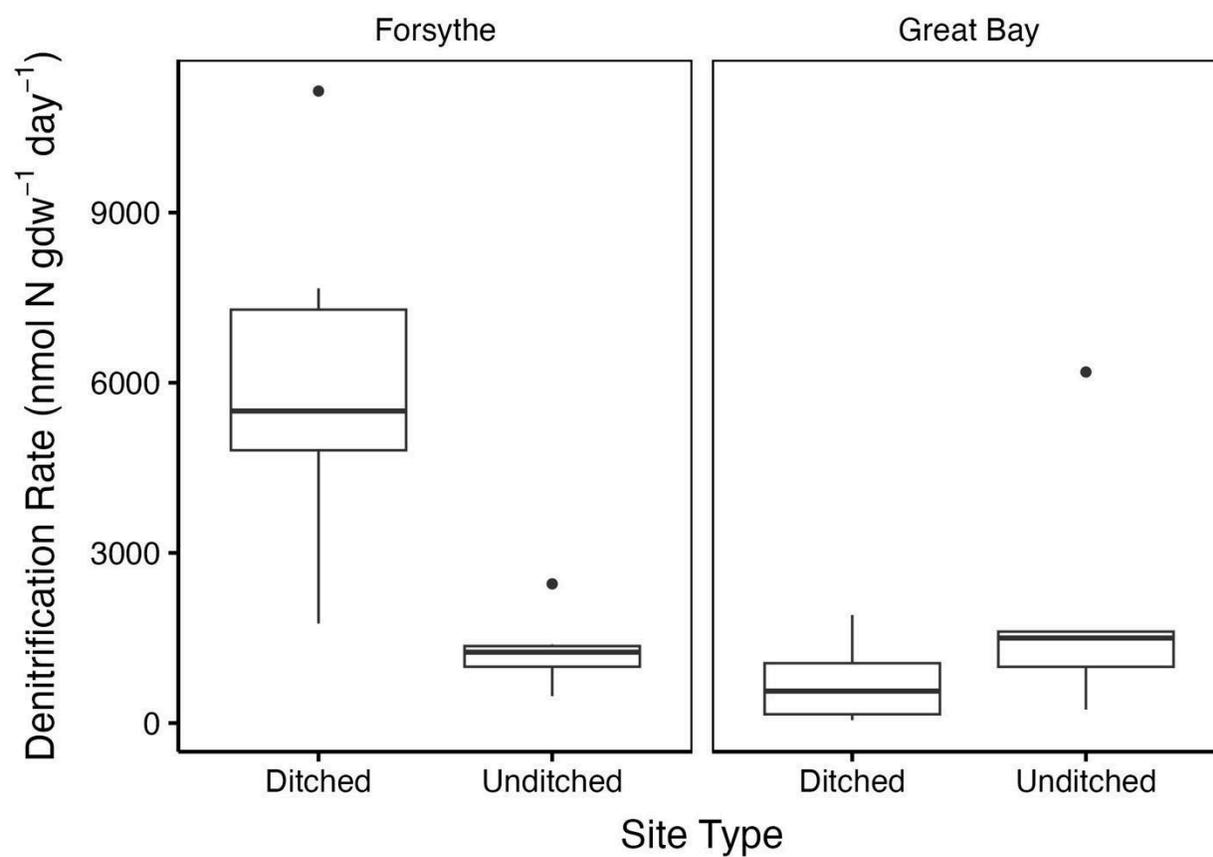


Figure 1. Box plot showing net potential denitrification rates across four salt marsh types: Forsythe ditched, Forsythe unditched, Great Bay ditched, and Great Bay unditched.

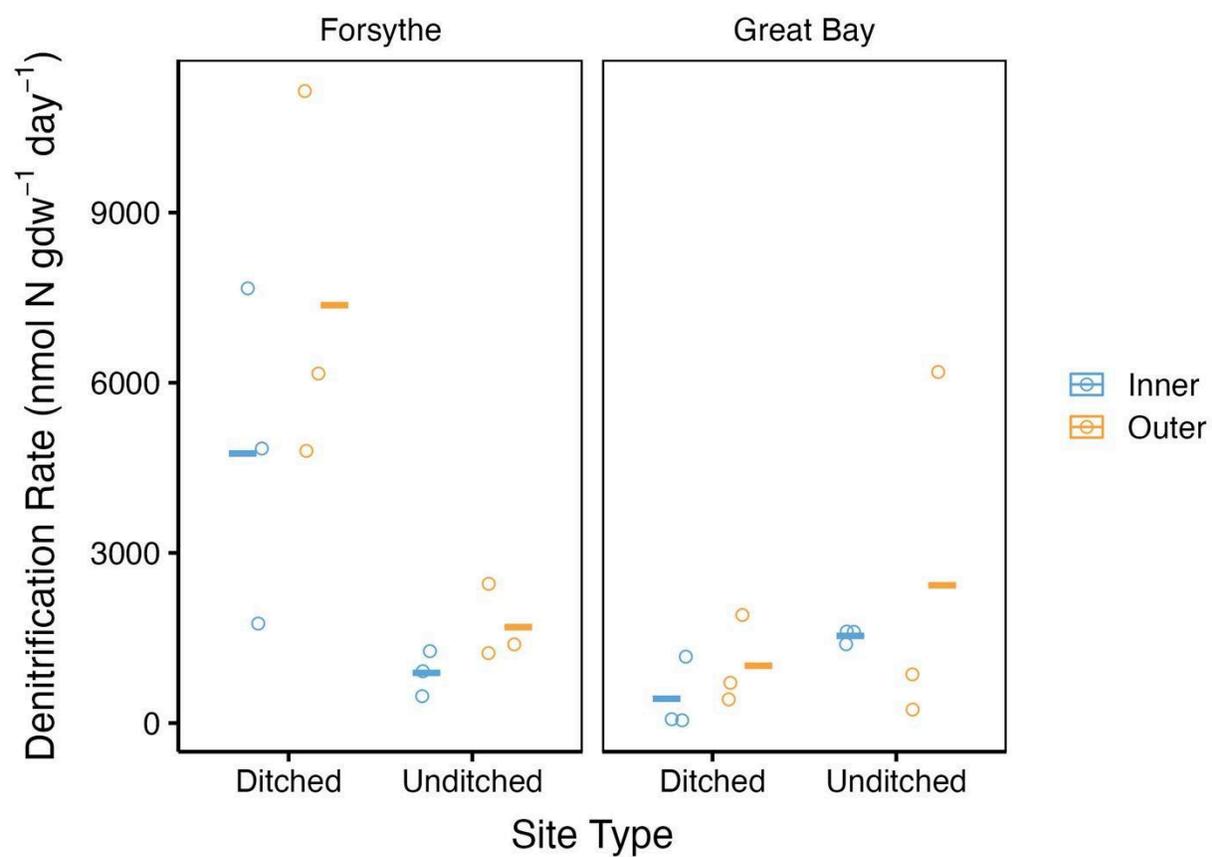


Figure 2. Circles represent each individual measurement, and bars represent the mean value of all measurements from the respective site types (Forsythe unditched, Great Bay ditched, Great Bay unditched, and Forsythe ditched).

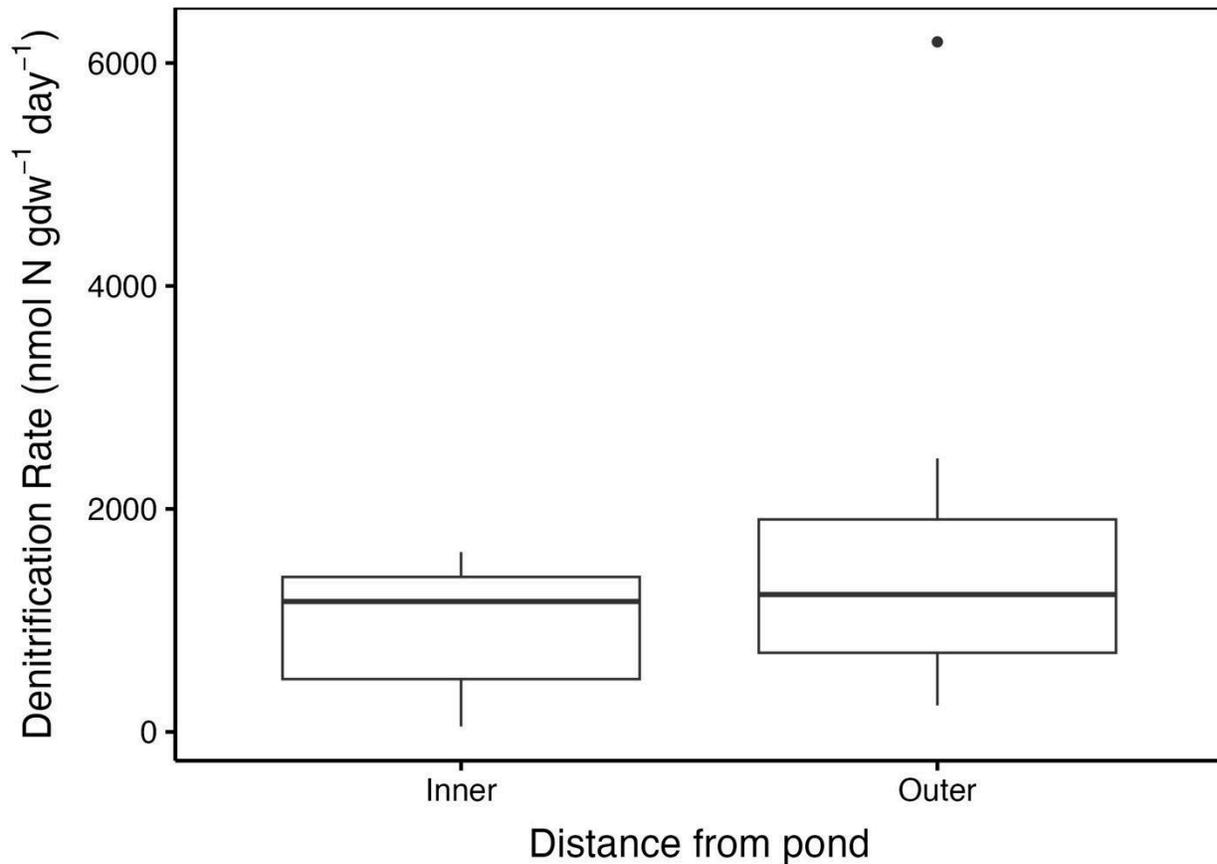


Figure 3. Potential denitrification rates across Great Bay (GBB) sites, with Forsythe ditched marshes removed and grouped by the Inner and Outer bands.

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