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Effect of Salinity on the Fate of Inorganic Nitrogen in Sediments of the Parker River Estuary, Massachusetts

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Sediments are a major site controlling the cycling and availability of nitrogen in estuaries (1). In sediments, inorganic nitrogen (*ie.,* ammonium, nitrate, nitrite) can diffuse to overlying water, be adsorbed onto sediments, or be denitrified (2). Previous studies have suggested that the fate of nitrogen in sediments may be influenced by salinity (3). High cation concentrations in salt water may decrease ammonium adsorption onto sediments by occupying cation exchange sites, increasing the relative amounts of free to exchangeable (adsorbed) ammonium in the sediments (3). Because primary productivity in many estuarine systems is nitrogen limited (4) and the salinity structure of estuaries can vary substantially over time, it is necessary to study the importance of this possible "salt effect."

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We examined the effects of salinity on sediment nitrogen cycling, including the ratio of free to exchangeable ammonium in sediments, inorganic nitrogen fluxes across the sediment-water interface, and denitrification. Twenty sediment cores (6.5 cm in diameter and 12 cm deep) were collected from the upper reaches of the Parker River Estuary (PRE), Massachusetts, where salinity varies from 0 to 18 ppt annually (Fig. 1a). Overlying water in 10 cores was replaced with seawater (32 ppt). The remaining 10 cores were held at an ambient salinity (0.7 ppt). To estimate denitrification, half of the high-salinity and low-salinity cores were incubated with anoxic overlying water. Under this condition, nitrification and subsequent denitrification are halted; therefore total inorganic nitrogen accumulated in the sediments and the overlying water could be compared between oxic and anoxic treatments to estimate denitrification. This estimate assumes that rates of nitrogen remineralization are similar under oxic and anoxic conditions.

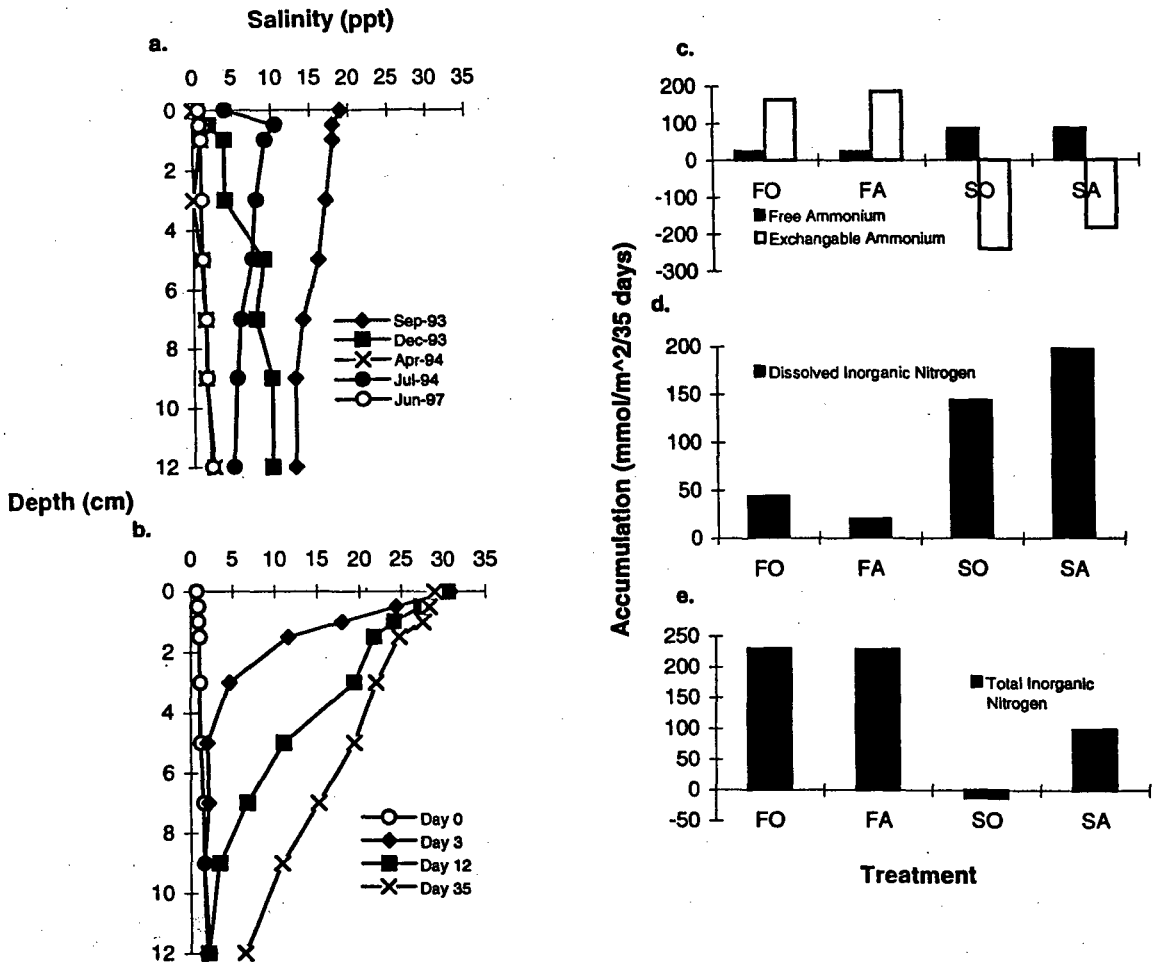

Figure 1. *(a) Salinity profiles typical for the Parker River Estuary site over a year. Open symbol reflects the profile of the initial untreated core analyzed during this study. (b) Average salinity profiles for salt-water treatments during the experiment. (c) Accumulation or loss of free and exchangeable ammonium in sediments during the 35-day incubation. (d) Accumulation of dissolved inorganic nitrogen in the overlying water during the 35-day incubation. (e) Accumulation or loss of total inorganic nitrogen in sediments and overlying water during the 35-day incubation. Abbreviations: FO = fresh oxic, FA = fresh anoxic, SO = salt oxic, and SA = salt anoxic.*

For all cores, the overlying water was changed every 3 to 7 days and sampled for ammonium and nitrate/nitrite. At intervals throughout the 35-day study, one core from each treatment was sectioned into 2-cm intervals (three untreated cores were analyzed on day 0 for baseline analysis). Free and exchangeable ammonium concentrations and chloride concentrations were analyzed in each sediment section. The concentrations of free ammonium, exchangeable ammonium, and dissolved inorganic nitrogen fluxes (ammonium and nitrate/nitrite) to the overlying water were individually summed at each sampling time, and then subtracted from their initial baseline concentrations. These results represented the total change in free and exchangeable ammonium in the sediments and the total amount of dissolved inorganic nitrogen (DIN) fluxed to the overlying water over the course of the study.

Throughout the experiment, the fresh-water chloride profiles remained similar to the initial profile, or Day 0 (Fig. 1b). The chloride profiles of the salt-water treatments indicated salt intrusion with depth over time (Fig. 1b). By the end of the investigation, there was a greater accumulation of free ammonium in the salt-water treatments than in the fresh-water treatments (Fig. 1c). In addition, the salt-water treatments experienced a net loss of exchangeable ammonium, while the fresh-water treatments gained exchangeable ammonium (Fig. 1c). Also, by the end of the study, the total amount of DIN released to the overlying water was much greater in the salt-water treatments (Fig. 1d). Summing fluxes to the overlying water and sediment stocks (Fig. 1c + Fig. 1d), the overall increase in total inorganic nitrogen was greater in fresh-water treatments than in salt-water treatments (Fig. 1e). The lower response in the salt-water anoxic treatment may be due to decreased metabolism produced by salinity shock at the outset of the experiment (4).

We were not able to perform statistical analyses on the summed data (Fig. 1c, d, and e) because only one core from each treatment was analyzed at each time point. However, for individual time points, the rate of DIN flux to the overlying

water was significantly greater in the salt-water treatments than in the fresh-water treatments ($P < .05$, t-test) (data not shown). Also, the ratio of free to exchangeable ammonium at the end of the study was significantly greater in the salt-water treatments ($P < .01$, t-test) (data not shown). This suggests that salt intrusion significantly affects nitrogen cycling in estuarine sediments and that differences between the fresh-water treatments and salt-water treatments in Figure 1c, d, and e are real.

There was no notable difference in the amount of total inorganic nitrogen between the fresh-water oxic treatments and the fresh-water anoxic treatments (Fig. 1e). There was a difference between the salt-water treatments: a net inorganic nitrogen gain in the anoxic sediments and a net loss in the oxic sediments (Fig. 1e). Although this difference could not be statistically evaluated, it appears that denitrification was more important in the salt-water treatments than in the fresh-water treatments. These results are contrary to those of Seitzinger *et al.* (5), who suggested that denitrification is greater in fresh water. Future study should include direct, repeated measurements of denitrification, to better understand differences in the effects of the variation of salinity on denitrification.

The results of this study suggest that salinity had a major influence on the distribution and fate of nitrogen remineralized in benthic sediments. The "salt effect" that we observed appeared to be an increase in the ratio of free to exchangeable ammonium, which supports observations of Gardner *et al.* (3). In addition, a subsequent effect of increased salinity appeared to be an increased DIN flux to the overlying water. This result is consistent with previous observations in the Parker River Estuary where ammonium fluxes were unusually high (relative to sediment remineralization) when porewater experienced large increases in salinity during the summer. Therefore, it appears that this high ammonium flux represented not only current remineralization, but also ammonium originally stored on the sediment exchange complex.

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Literature Cited

1. **Nixon, S. W. 1981.** Pp. 111–137 in *Estuaries and Nutrients.* B. Neilson and L. Cronin, eds. Humana, Clifton, NJ.
2. **Mackin, J. E., and R. C. Aller. 1984.** *Limnol. Oceanogr.* **29:** 250–257.
3. **Gardner, W. S., S. P. Seitzinger, and J. M. Malczyk. 1991.** *Estuaries* **14:** 157–166.
4. **Ryther, J. H., and W. M. Dunstan. 1971.** *Science* **171:** 1008–1013.
5. **Seitzinger, S. P., W. S. Gardner, and A. K. Spratt. 1991.** *Estuaries* **14:** 167–174.