

Does salt marsh function as a coastal filter for nutrient additions from land?

Joanna L. Nelson

PhD Candidate, University of California, Santa Cruz, and Graduate Research Fellow,
NOAA/NERR

Questions:

- 1) Does salt marsh function as a coastal filter for anthropogenic nutrient additions from land?
- 2) How do salt marshes, mudflats, and water quality interact with respect to nutrient loading, particularly nitrogen loading? (For example, if there are more salt marshes, will that improve water quality by improving nutrient concentrations, clarifying water and making more suitable conditions for eelgrass?)
- 3) Is wetland/marsh filtration a process we should depend on, or one that probably won't play a significant role for Elkhorn Slough?

Background and Methods

Eutrophication and sea-level rise will affect salt marsh extent and functioning, living marine resources, and delivery of ecosystem services in estuaries. I investigate the role of threatened salt marsh habitats as a “coastal filter” that improves water quality of runoff into the ocean through microbial denitrification. The estuarine ecosystem service of nitrogen pollution reduction is important; eutrophication (excessive nutrients leading to algal blooms, subsequent die-offs, and hypoxic conditions) is the leading environmental problem in US coastal waters. Sea level rise is predicted to diminish the distribution of salt marsh relative to bare mudflats, through marsh drowning. I compare denitrification rates in vegetated sediments and mudflats and record plant nitrogen uptake in order to map the ability of a central California estuary to buffer rising nitrogen loading over the next century. I achieve this via a) literature review of denitrification rates in marsh and mudflat in temperate regions; b) a manipulative field experiment in Elkhorn Slough National Estuarine Research Reserve (ESNERR), California, in which I followed plant species diversity, above- and belowground net primary production, and tissue nitrogen in response to manipulated tidal height and nitrogen fertilization. The field experiment allows me to document nitrogen uptake by salt marsh vegetation as it is adversely impacted by a range of simulated sea-levels.

I created a two-by-three factorial experiment: Relative sea level (RSL) and addition of nitrogen (N).

| | |
|--|-------------|
| No change in experimental sea level | no N +N |
| + RSL (lower marsh plot) Two levels: lower 30 cm lower 10 cm | no N + N |
| - RSL (raise marsh plot 10cm) | no N + N |

I established 27 1x1-m marsh plots in Coyote Marsh, within the Research Reserve. I assigned plots to three blocks and, in a completely randomized design, included the following factors (1) marsh height – 4 levels, (2) nitrate addition – 2 levels. To manipulate marsh height, I removed all vegetation

including intact roots, altered sediment depth beneath the vegetation layer (depending on the treatment), and replaced the vegetation layer. To alter N levels, I added ammonium nitrate (NH_4NO_3) to designated plots by adding 15 gN m^{-2} every two weeks for a total of $300 \text{ gN m}^{-2} \text{ yr}^{-1}$ (the form of N, and an amount, used in conventional agriculture in the watershed). The four halophyte species found in the experimental plots are: the dominant pickleweed, *Sarcocornia pacifica*, *Jaumea carnosa*, *Frankenia salina*, and *Distichlis spicata*. To assess plant biomass and tissue nitrogen, I harvested a $10 \times 50 \text{ cm}$ swath of aboveground biomass in July and November 2008, and April, July and November 2009. In addition, I took sediment cores to assess root biomass in July and November 2009.

Results and Conclusions

1) Literature review comparing denitrification in vegetated sediments and bare mudflat

Published studies comparing denitrification in temperate vegetated sediments (including salt marsh) and mudflats ($n=6$, lab and field studies) show higher rates in vegetated sediments (Figure 1). Vegetated sediments – a mix of submerged and emergent vegetation – removed 10-100% of nitrate, while mudflats removed 0-40% of nitrate. No published studies address this comparison on the US Pacific Coast.

2) Field experiment in Coyote Marsh, Elkhorn Slough, quantifying salt marsh plant uptake of nitrogen

In the manipulative field experiment in Coyote Marsh, Elkhorn Slough, a notable result is the capacity of salt marsh plants to take up experimentally-added nitrogen above and beyond the *high* background levels of nitrogen already found in Slough tidewater. Nitrogen continued to be a limiting nutrient – halophyte biomass increased significantly with fertilization at the middle elevations of -10cm and 0cm (Figure 2, showing two harvests). The highest sea-level treatment (-30cm elevation) led to rapid decreases in plant biomass, and to the death of all vegetation after 15 months of the experiment: plants continued to take up excess nitrogen as long as they were alive. The +10-cm elevation, a proxy for sedimentation outpacing sea level, typically did not show differences between fertilized and control plots, with the exception of July 2009 where raised, fertilized plots had the highest biomass. In contrast with aboveground N-uptake results, root biomass did not show a strong response to experimental N additions in July 2009. Plants in fertilized plots retain the most nitrogen in tissues.

Winter biomass was greatest in plots raised 10 cm with inorganic N addition: but all winter biomasses were at least threefold smaller than summer. These results a) suggest that marsh plants have a significant ability to continue to take up excess nitrogen, in summer and in winter, but that seasonality matters; and b) underscore the importance of a potential threshold at which nitrogen is no longer a limiting nutrient and plant uptake is diminished.

3) Pilot measurements of denitrification rates in Coyote Marsh, Elkhorn Slough

In two consecutive night-time sampling sessions in August (August 17 -18, 2009), I found that denitrification fluxes in fertilized treatment plots (-30cm and -10cm elevation) ranged from 219 to 597 micromoles $\text{N}_2 \text{ hr}^{-1} \text{ m}^{-2}$. In contrast, I found lower rates in control plots (no added nitrogen, also -30cm and -10cm elevation), ranging from 125 to 397 micromoles $\text{N}_2 \text{ hr}^{-1} \text{ m}^{-2}$, suggesting that long-term fertilization contributed to source pools for denitrification fluxes.

An average of all August denitrification rates, 297 micromoles $\text{N}_2 \text{ hr}^{-1} \text{ m}^{-2}$, translates to a diel rate of 7 micromoles $\text{N}_2 \text{ m}^{-2} \text{ day}^{-1}$, indicating that denitrification could play a significant role in the Slough's consumption of incoming nitrate (K.Johnson, pers. comm.).

Figure 1: Comparison of denitrification rates in vegetated and bare sediments from a literature review

Percent reduction in N and P by vegetated sediments

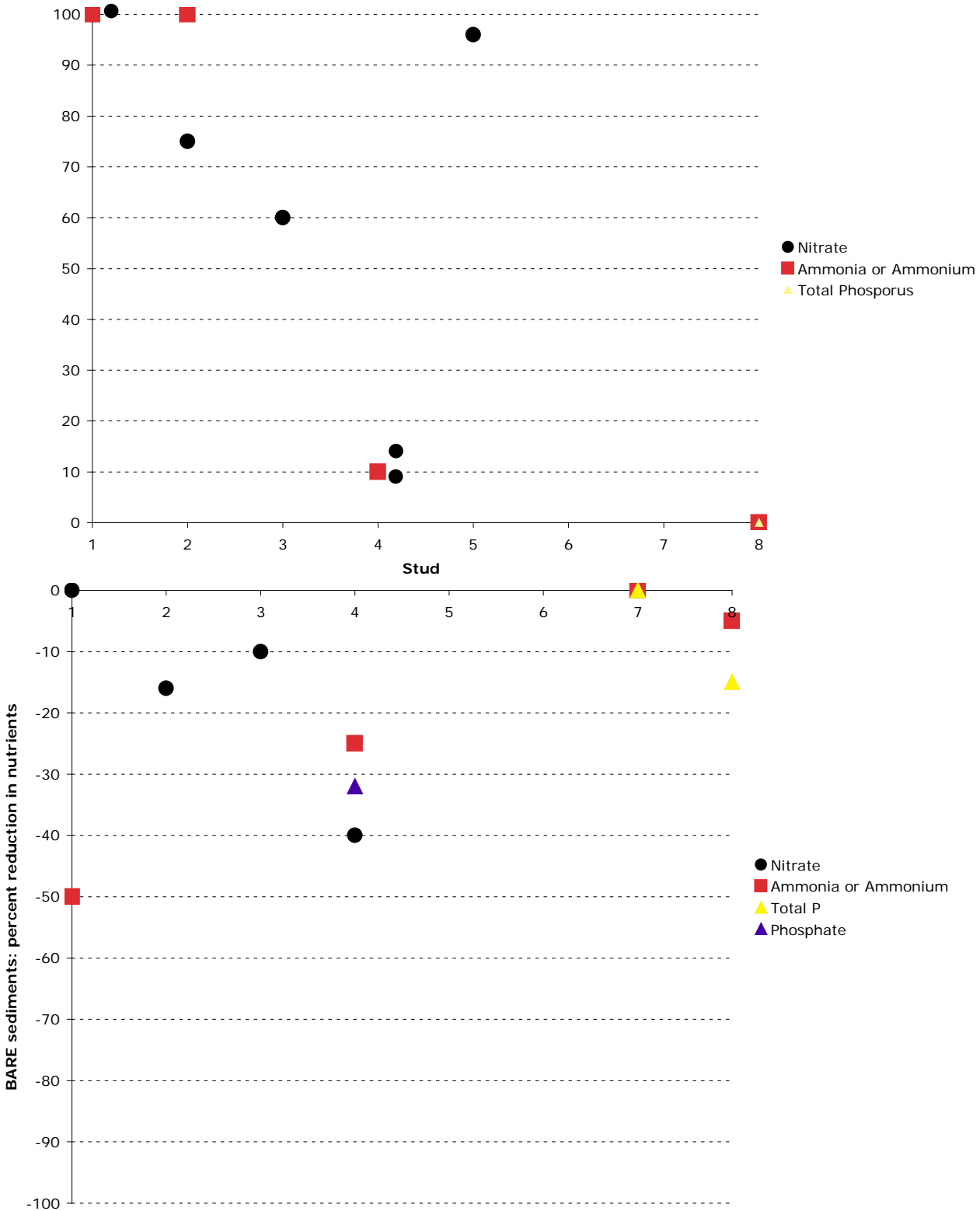


Figure 1 caption continued: **Field studies** (n=3): Salt marsh, Rhode Island, US; Salt marsh, Spain; eelgrass, cordgrass, and rushes (subtidal to intertidal), Portugal (Davis et al. 2004, Alvarez-Rogel et al. 2006, and Lillebo et al. 2006). **Chambers** incubated in a laboratory (n=3): Subtidal vegetation – redhead grass and eelgrass – collected from field samples in Chesapeake Bay, US; estuarine mesocosms, Rhode Island, US (Caffrey and Kemp 1990, Caffrey and Kemp 1992, and Nowicki and Oviatt 1990).

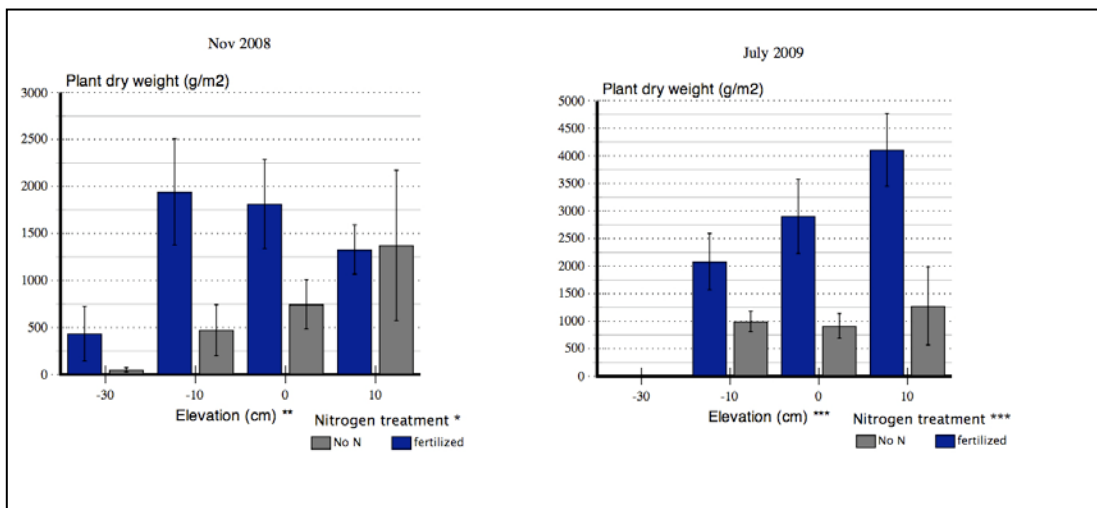


Figure 2. Difference in biomass between fertilized and unfertilized plots at different elevations (a proxy for sea-level rise) in the field manipulative experiment at Coyote Marsh, Elkhorn Slough. A) November 2008, after the summer peak growing season: both elevation and N-addition have a strong effect, where fertilized plots, at most sea levels, show an increase in biomass. B) July 2009, peak growing season in the second year of the experiment: all plants in the highest-sea-level simulation (-30cm elevation) have died; the effect of both factors, fertilization and elevation, is strong, with the highest biomass yet recorded. Note the different scale of the y axis from November. Salt-tolerant plants continue to be N-limited, responding to fertilization even against a high background N load. Error bars represent +/- 1 SE. Statistical significance levels: * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

Cited literature

Alvarez-Rogel, J., F. J. Jimenez-Carceles, and C. E. Nicolas. 2006. Phosphorus and nitrogen content in the water of a coastal wetland in the Mar Menor Lagoon (SE Spain): Relationships with effluents from urban and agricultural areas. *Water, Air and Soil Pollution* 173: 21-38.

Caffrey, J. M. and W. M. Kemp. 1990. Nitrogen cycling in sediments with submerged macrophytes: Microbial transformations and inorganic pools associated with estuarine populations of *Potamogeton perfoliatus* L. and *Zostera marina*. *Marine Ecology Progress Series* 66:147–160.

Caffrey, J. M. and W. M. Kemp. 1992. Influence of the submersed plant, *Potamogeton perfoliatus* L., on nitrogen cycling in estuarine sediments. *Limnology and Oceanography* 37:1483–1495.

Davis, J. L., B. Nowicki, and C. Wigand. 2004. Denitrification in fringing salt marshes of Narragansett Bay, Rhode Island. *Wetlands* 24: 870-878.

Lillebo, A. I., M. R. Flindt, M. A. Pardal, and J. C. Marques. 2006. The effect of *Zostera noltii*, *Spartina maritima* and *Scirpus maritimus* on sediment pore-water profiles in a temperate intertidal estuary. *Hydrobiologia* 555: 175-183.

Nowicki, B. L., and C. A. Oviatt. 1990. Are estuaries traps for anthropogenic nutrients? Evidence from estuarine mesocosms. *Marine Ecology Progress Series* 66: 131-146.