Nutrient enrichment alters the carbon storage function of a New England salt marsh

Emily Geoghegan1,2, Joshua Caplan1,2, Francine Leech1, Paige Weber1, Caitlin Bauer1,3, Thomas Mozdzer1
1Bryn Mawr College, Bryn Mawr, PA; 2Temple University, Ambler, PA; 3Villanova University, Villanova, PA

Background

Coastal wetlands are among the most productive ecosystems on Earth and are responsible for numerous ecosystem services such as flood protection, water filtration, and carbon (C) sequestration.

Several manipulative studies have evaluated empirically how global change factors like nutrient enrichment could influence blue carbon processes at the ecosystem scale.

A prior study (Deegan et al. 2012, Nature 490:388-392) suggested that chronic nutrient pollution at our study site can reduce belowground productivity, and induce eco-geomorphic feedbacks that induce creek bank instability and conversion to mudflats.

Nitrogen (N) can stimulate primary production and theoretical net ecosystem exchange (NEE) and gross primary productivity (GPP).

However, N also stimulates activity of anaerobic bacteria (increasing ecosystem respiration (R_e)), which is a pressing need to understand how landscape-level pollution affects C. Runoff, R_e, and NEE and influences ecosystem C dynamics.

Methods

TIDE Project = long-term nutrient enrichment experiment in MA that studies two creeks, Sweeney Creek (N-enriched with NO_3 from May-October from 2004-2016) and West Creek (reference control) Sweeney Creek was enriched to ~70-100 µM NO_3, which is ~4-5x that of the reference creek (West Creek).

Fluxes of greenhouse gases (GHS) CO_2 and CH_4 were measured using static, gas-tight chambers placed in low marsh S. alterniflora stands from June-August in 2015 and 2016.

On sampling periods, we measured GHS concentrations in chamber headspace via a portable Greenhouse Gas Analyzer (LI-8300, LI-COR, Inc., Lincoln, NE, USA) under light & dark conditions (Figure 3a,b); while recording ambient air temp, soil temp, and photosynthetic active radiation (PAR).

- Generated NEE light response curves for both treatments by supplementing the dataset with fluxes measured under medium and low light (i.e., using one or two mesh shade cloths, respectively).
- Aboveground biomass (AGB) and belowground biomass (BGB) within each flux collar was destructively sampled after flux measurements, dried, and weighed.
- Mixed-effects linear models determined how strongly N enrichment influenced C fluxes and S. alterniflora biomass.

Results

We found that N enrichment increased ecosystem respiration (R_e) by 8-65%, gross primary productivity (GPP) by 67-113%, and aboveground biomass by 77-179%. However, nitrogen had no effect on net ecosystem exchange (NEE), methane emissions, or belowground biomass. Our estimate of net C flux throughout the growing season (May 1 – September 1, 2016) indicated that the reference marsh released 355 g C m^-2 y^-1 into the atmosphere, while the N enriched marsh released 1062 g C m^-2 y^-1, given its greater R_e rates but similar NEE rates. The total ecosystem C budgets are fairly high compared to previous findings, but will likely decrease when we have adjusted our model to include soil temperatures. However, the relative difference will remain the same once we adjust our model, given the differences in R_e between the two creeks.

Discussion

- BY stimulating R_e but not GPP, N-fertilization could transform this and similar salt marshes from well-established C sinks into weak sinks or even sources of atmospheric C.
- While our study did not differentiate between soil and plant respiration, the similar levels of belowground biomass in our study (Figure 4) suggest that changes in R_e are likely due to N altered soil microbial activity.
- Given the established role of soil organic matter in maintaining surface elevation, losses of soil C through accelerated R_e may decrease soil surface elevation.
- Affected marshes and would be more susceptible to sea level rise and marsh bank collapse could accelerate, creating a positive feedback.
- Unless coastal N management improves, wetlands such as this may export carbon stores, there is a pressing need to understand how landscape-level pollution affects C. Runoff, R_e, and NEE and influences ecosystem C dynamics.

Conclusions

Our results suggest that increased N input to tidal salt marshes could weaken their C storage function through enhanced respiration of sequestered C. In some cases, marshes that were net C sinks may reverse to become C sources.

Acknowledgements

We thank David Behringer, Amanda Davis, Ian Cracle, and Linda Deegan for field, logistical, and technical assistance. Funding for this project was provided by the National Science Foundation (award DEB-1354124 to T.J.M, award DEB-1719621 to the TIDE project), and awards DEB-1637630 & DEB-1238212 to the PIE-LTER) and awards DEB-1354124 & DEB-1719621 to the TIDE project, and awards DEB-1637630 & DEB-1238212 to the PIE-LTER) and was further supported by start-up funds from Bryn Mawr College to T.J.M.