Salt marsh metabolism and carbon accumulation: Effects of location and fertilization

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Introduction

Salt marshes are thought to have high carbon (C) sequestration rates and store a globally significant pool of C. However, C sequestration rates are heterogeneous, changing with elevation, dominant plant species, and distance from the creek channel as well as with external forcing such as anthropogenic nitrogen (N) loading. In net autotrophic marshes gross primary production (GPP) of the dominant macrophyte exceeds community (plant and microbe) respiration (R). When R exceeds GPP, marshes are a source of C to the atmosphere (i.e. net heterotrophic). Net heterotrophic marshes generally require input of sediment OC in order to accumulate C; however, lateral export of C as dissolved inorganic or organic C (DIC, DOC) to adjacent creeks may represent a significant loss. Location may be an important factor affecting C sequestration as flushing by creek water and prolonged inundation may influence the accumulation of dissolved pore-water compounds such as sulfide (H_2S), known to interact with C cycling. Anthropogenic N loading to marshes has been observed to increase above-ground biomass and rates of sediment C trapping; however, it may also increase net heterotrophy by stimulating plant and microbial R.

Background

Salt marsh carbon (C) accumulation

- Net community production (NCP) = R - GPP
- Net autotrophic marsh: GPP>R; negative NCP; net uptake of CO_2
- Net heterotrophic marsh: R>GPP; positive NCP; net source of CO_2 to atmosphere and adjacent tidal waters
- Net ecosystem metabolism (NEM) = NCP spatially extrapolated to marsh
- Sediment input contributes OC
- Lateral export of DIC and POC through both tidal water and groundwater

Effects of Location

- Physical factors such as creek water flushing and hydroperiod vary with location
  - Flushing varies with proximity to tidal creeks
  - Hydroperiod varies with marsh elevation, water level, and tidal amplitude.
- Flushing influences the accumulation of pore-water H_2S and nutrients such as NH_4^+, DIC, and DOC
- Long hydroperiods affect redox conditions and, as a result, plant growth.
- H_2S accumulation interacts with C cycling by inhibiting *Spartina alterniflora* N uptake, potentially influencing the balance of R and GPP

Effects of Fertilization

- Typically increases above-ground biomass (AGB)
- Greater AGB has been observed to increase sediment trapping
- May stimulate both plant and sediment microbial R, shifting marsh toward net heterotrophy

Objective of Study

Determine net accumulation of OC in an *S. alterniflora* salt marsh as a function of:

1. location (edge vs. interior)
2. fertilization
3. hydroperiod
4. sediment OC input

Figure 1: Map of sites (Freeman and Traps marsh) within Camp Lejeune Marine Corps Base, NC

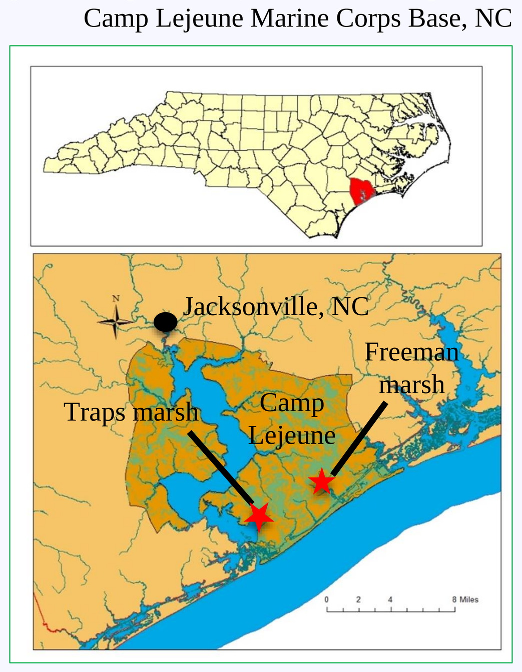
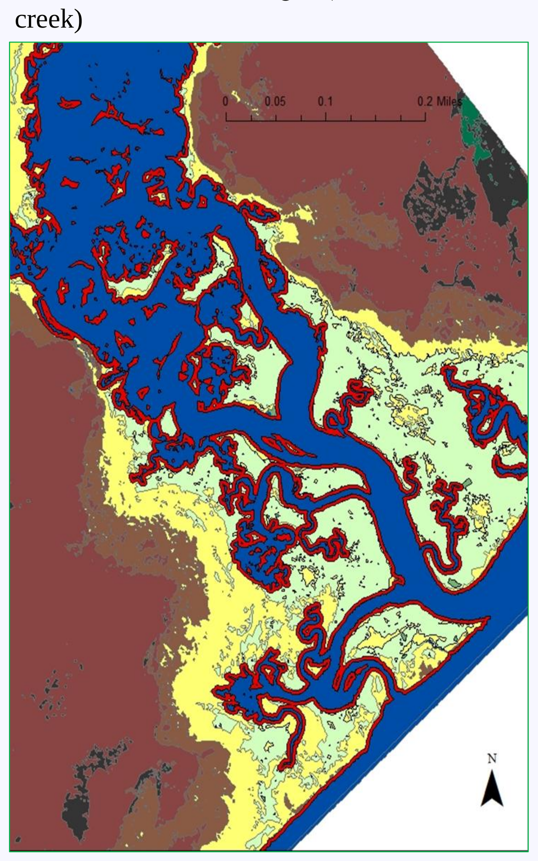


Figure 2: Freeman Creek interior marsh area (green and yellow) and edge marsh area (red): About a third of *S. alterniflora* low marsh habitat in Freeman Creek is "edge" (within 5 m of a tidal creek)



Measurements and Methods

Sites (see Fig. 1):

Freeman: a *S. alterniflora* marsh located adjacent to the Intracoastal Waterway near the New River Estuary in North Carolina.

Traps: a *S. alterniflora* marsh with lower tidal amplitude but greater hydroperiod than Freeman.

Experimental Design:

- Edge (within 5 m of creek; Fig. 2) and interior comparison at Freeman
- 3 fertilized, 3 control 0.9 x 0.9 m plots at each site (Fig. 3)
- Piezometers and collars with drain holes in each plot (Fig. 4)
- Seasonal fertilization:
  - 30 mol N yr^{-1} as NH_4NO_3
  - 15 mol P yr^{-1} as P_2O_5

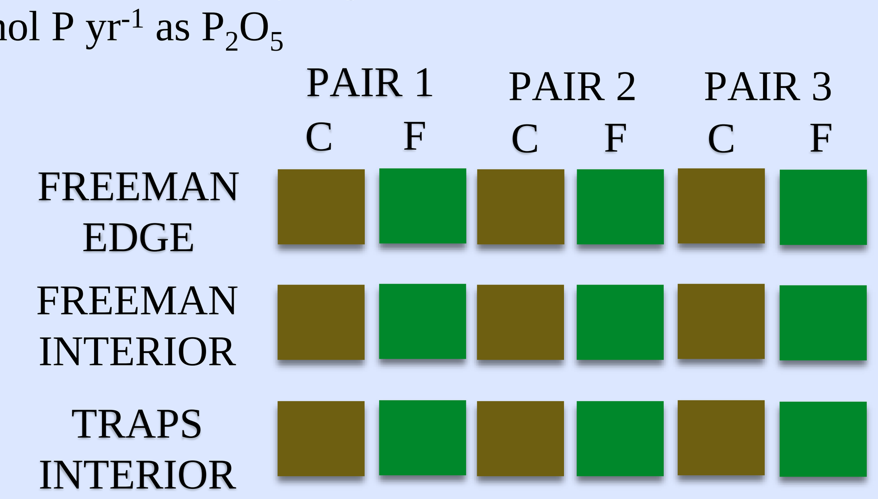


Figure 3: Experimental design with three control (C, brown) and fertilized (F, green) plot pairs in each of three locations

Figure 4: Plot with collar and piezometers

Figure 5: Chamber system for *in situ* CO_2 flux analysis

Seasonal Measurements:

- Pore-water H_2S, NH_4^+, DIC, and DOC
- CO_2 flux in dark and three light levels using static chambers (Fig. 5)
- R and GPP scaled to respective seasons using Q_{10} and photosynthesis-irradiance curves
- Compared extrapolated flux with available Freeman Creek eddy covariance tower results (Fig. 6)
- Sediment C input based on marker horizon data and predictive model (E. Herbert).
- Groundwater export of DIC and DOC based on discharge and GW concentrations; tidal export based on water volume at slack flood and concentrations.

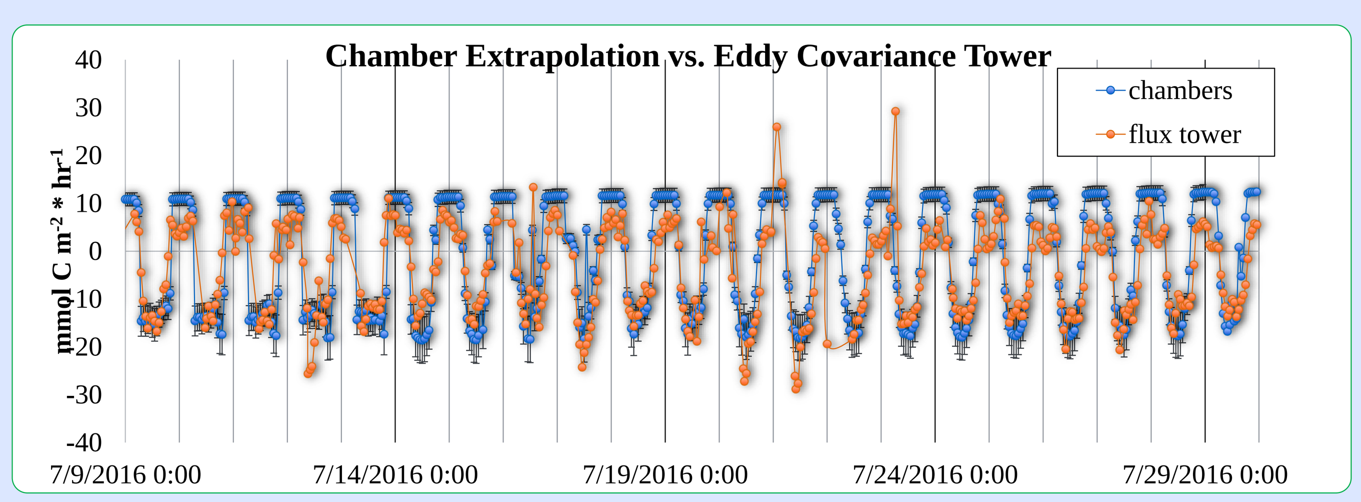
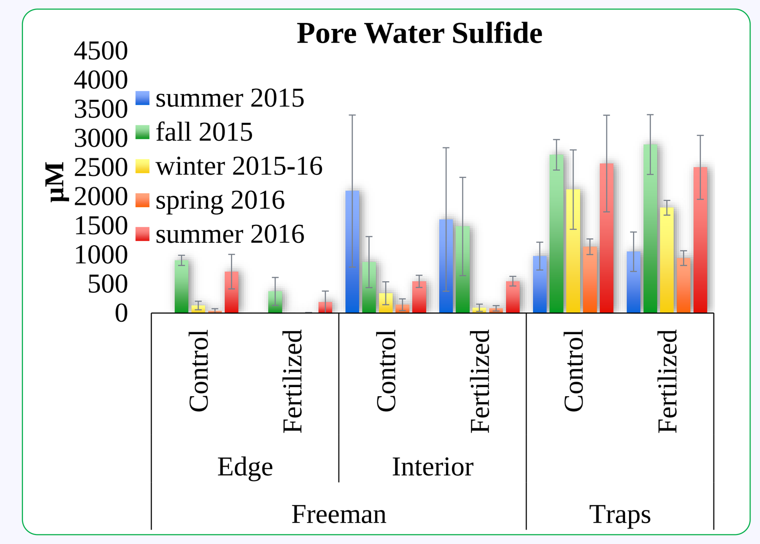
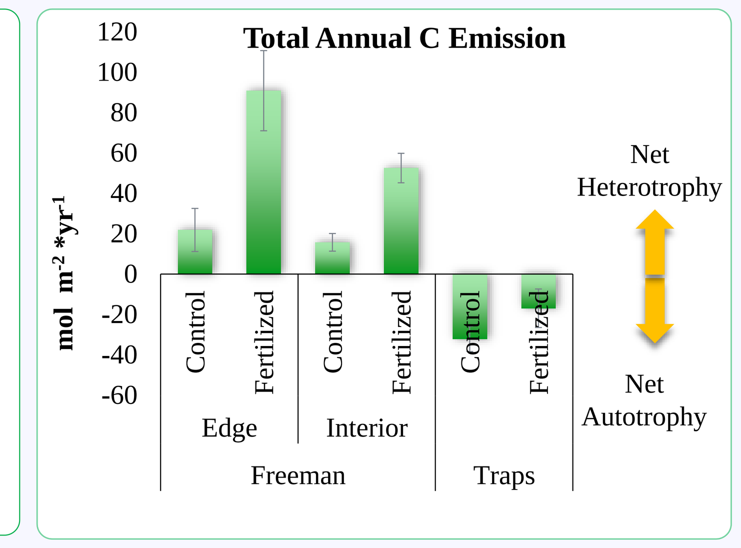


Figure 6: C fluxes from Freeman interior control plots extrapolated to range of days July 9-29 and graphed alongside Freeman eddy covariance tower data. Interior plots were within footprint of tower.

Results



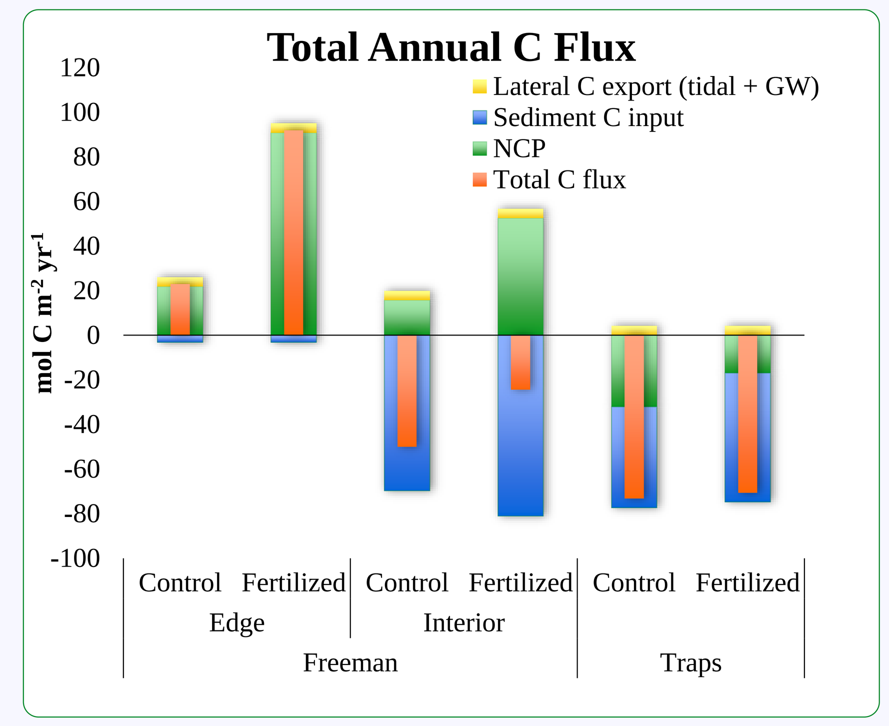


Pore-water analytes differ with location

- H_2S, NH_4^+, and DOC lower on edge; higher at Traps

Trophic status varies with location

- Freeman is net heterotrophic but Traps is net autotrophic on an annual basis
- Fertilization causes shift toward net heterotrophy in every location



Salt Marsh C Sources and Sinks

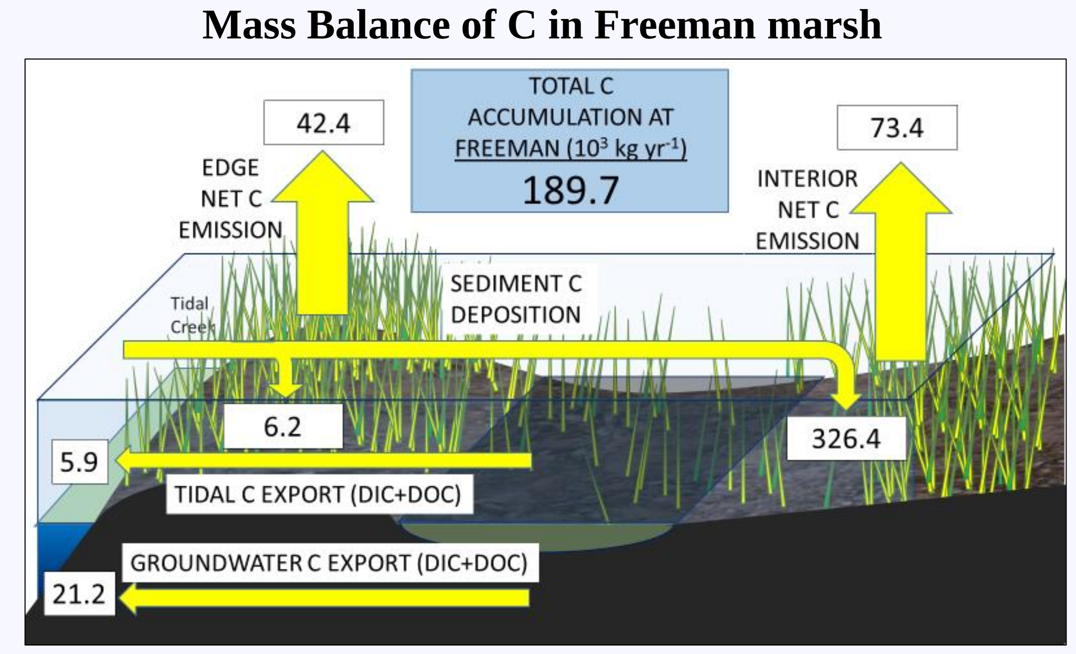
- Lateral C export represents a minor loss
- NCP and sediment C input are the two major drivers of C accumulation
- A net heterotrophic marsh requires sediment OC input to accumulate C

Significance of Edge Marsh

- Fertilization had greatest effect on the edge
- NEM of Freeman marsh is ~10-20% greater when edge effect is included

Net Ecosystem Metabolism (10^5 Kg C yr^{-1})	Calculated without edge effect	Calculated with edge effect	% difference
Control	1.04	1.16	11.4
Fertilized	3.47	4.21	21.4
% difference:	234.1	263.8	

Mass Balance of C in Freeman marsh



(Total C accumulation overestimated at 331 x 10^3 kg yr^{-1} if edge differences not accounted for)

Conclusions

- Salt marsh trophic status varies with location
- Fertilization shifts marsh toward net heterotrophy in all three locations
- Lateral C export to the creek was a minor loss; thus, sediment C input and NCP largely determine C accumulation in these marshes
- Sediment input is vital to the sustainability and C accumulation of net heterotrophic marshes
- In marshes with a significant proportion of marsh edge, edge differences must be considered when assessing NEM and C accumulation

Acknowledgements

Iris Anderson and lab: Jen Stanhope, Ashley Smyth, and Hunter Walker

NOAA Morehead City: Carolyn Currin, Nathan McTigue, Jenny Davis, Luke Snedaker

BK Song and lab: Miguel Semedo, Ann Arfken, Jess Lisa, Sam Fortin, Michele Cochran

Scott Neubauer, VCU

Mark Brush, Sara Blachman, Scott Ensign, Sam Lake, Ellen Herbert, Matt Kirwan, Kelley Uhlig, Shanna Williamson, Anne Giblin (MBL)

Many other VIMS students, staff, faculty, and volunteers

This research was conducted under the Defense Coastal/Estuarine Research Program (DCERP), funded by the Strategic Environmental Research and Development Program (SERDP). Views, opinions, and/or findings contained in this poster are those of the author(s) and should not be construed as an official U.S. Department of Defense position.