Revisiting the blueprints for blue carbon:

is salt marsh sediment organic carbon a source of emissions after wetland loss?

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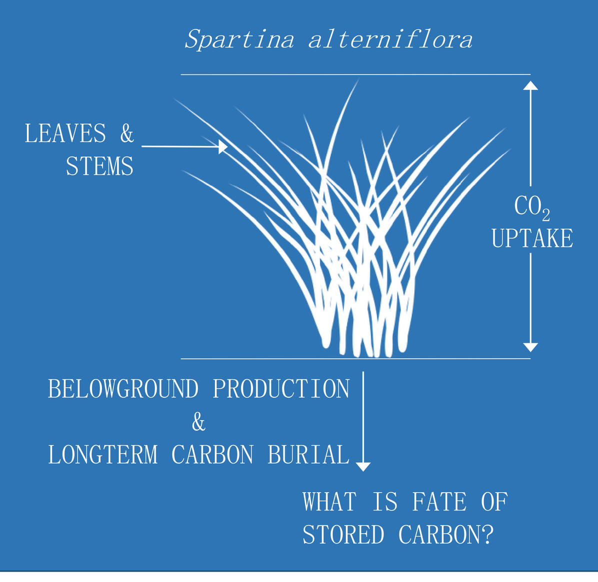


Introduction

Salt marshes have enormous potential to bury and store organic carbon in sediment for centuries to millennia. However, little is known about the fate of this carbon pool after degradation events, particularly erosion that would unbury and expose it to aerobic and photo-oxidizing environments in tidal creeks. Currently, estimates in the literature span from 25% to 100% oxidation of preserved organic carbon in wetlands upon degradation[1] (e.g., land-use change or erosion), but few experimental data exist to substantiate this potential range. Therefore, we devised an experimental approach to provide empirical data that better constrains possible ranges of potential CO_2 emissions from eroded wetlands.

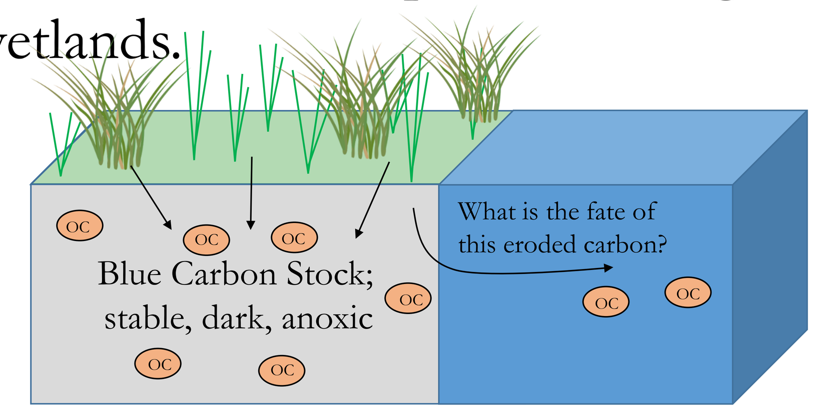
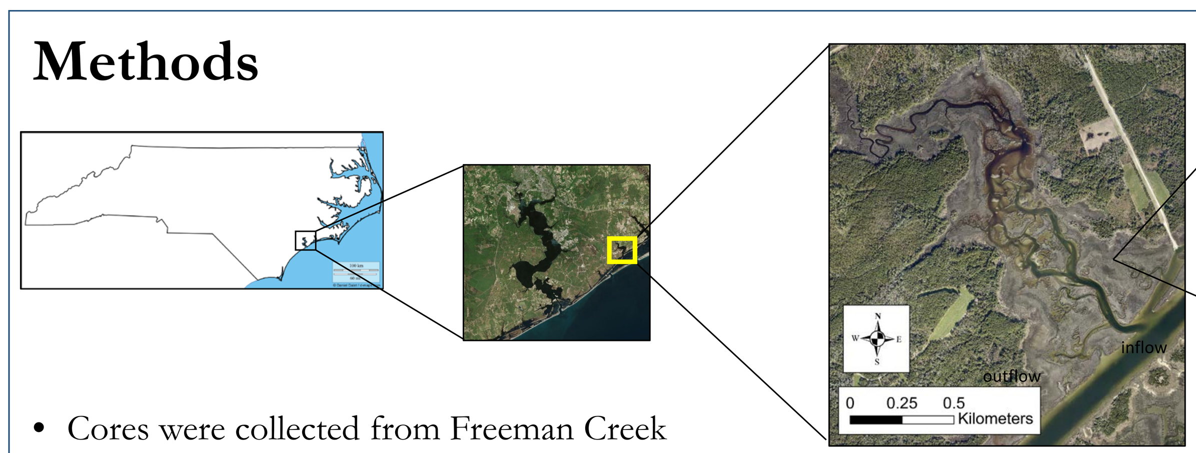
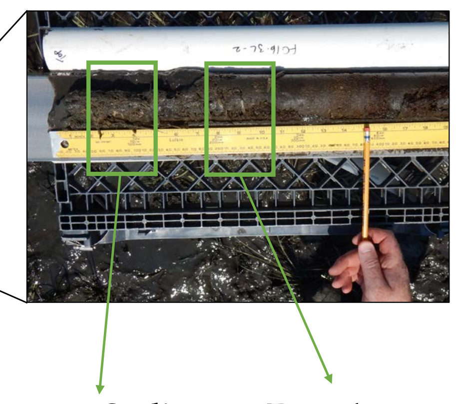


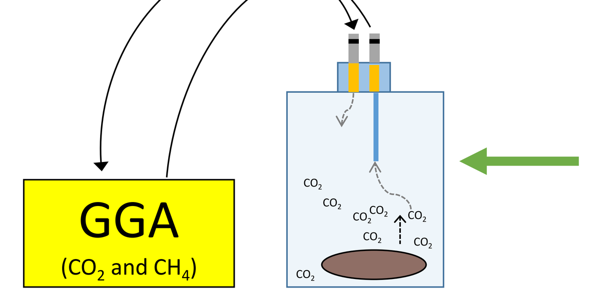
Fig. 1. Conceptual schematic outlining overall question.

Methods





- Cores were collected from Freeman Creek (New River Estuary, NC) by hand with a Russian peat corer.
- Sediment was collected from two depth horizons and incubated at 20 and 30 °C for 161 days in creek water inoculum (S=32).
- Decomposition was quantified by measuring CO_2 and CH_4 production with a greenhouse gas analyzer (GGA; Los Gatos, Inc.)



Sediment Depth

Temperature	Shallow	Deep
20 °C	n=3	n=3
30 °C	n=3	n=3

Definitions

$$Q_{10} = \frac{Rate\ at\ 30°C}{Rate\ at\ 20°C}$$

Q_{10} describes the temperature sensitivity of a rate. A higher Q_{10} indicates more temperature sensitivity.

$$Q_{10-q} = \frac{Time\ required\ for\ 1\%\ to\ decompose\ at\ 20°C}{Time\ required\ for\ 1\%\ to\ decompose\ at\ 30°C}$$

Q_{10-q} standardizes Q_{10} to substrate quality as it changes during an experiment. An increase in Q_{10-q} indicates substrate quality affects respiration rate more than temperature[2].

$$\ln k_2 = -\frac{E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right) + \ln k_1$$

Activation energy (E_a) can be thought of as the biochemical resistance of a substrate to catalysis[3].

Results & Discussion

Table 1. Characteristics of the two sediment horizons incubated during the 161 day experiment.

Sediment Horizon	Depth (cm)	^{14}C Age* (cal BP)	OC Content (%)	C:N (mol:mol)	Q_{10}	Activation Energy (kJ mol^{-1})	Decomposition Rate (mmol C mol C^{-1} yr^{-1})
Shallow	5 – 10	110±35	11.9±0.2	22.9±0.8	2.0	49.7	230±3
Deep	20 – 25	320±35	9.5±0.1	21.4±0.4	2.2	58.8	168±2

*estimated from a linear age-depth model: a sample of OC from 92 cm was aged at 1290±15 cal BP, or 14 yrs cm^{-1}. However, younger OC from the root zone was captured at the shallow depth.

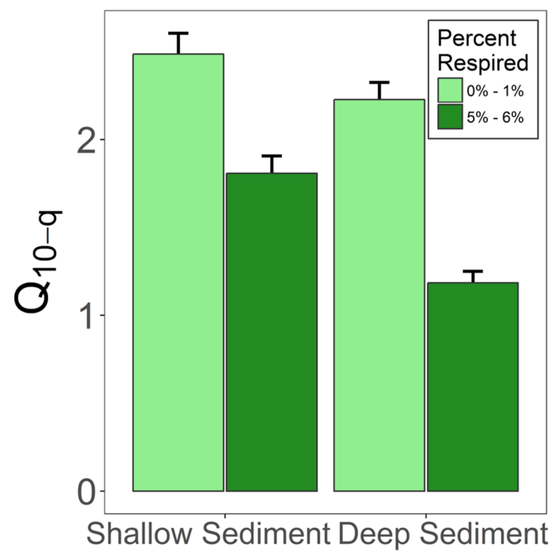


Fig 3. Comparison of Q_{10-q} for the 1[st] and 5[th] percent of carbon loss

Over the duration of this experiment, Q_{10-q} did not increase; thus, temperature was the most important driver of decomposition, as reflected in linear decomposition rates.

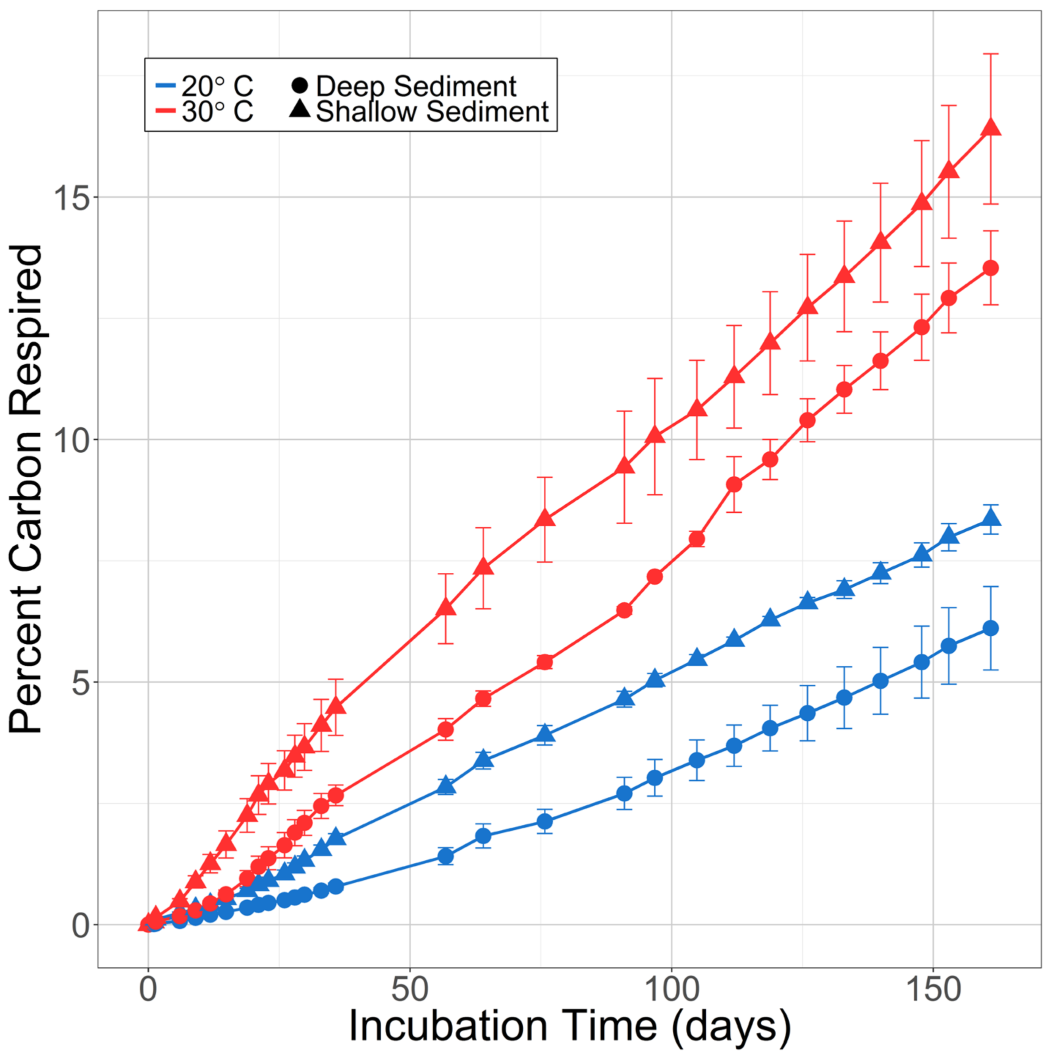


Fig 2. Decomposition rates for shallow and deep sediment at 20 and 30 °C.

- Decomposition rates were linear over the 161 day experiment.
- CH_4 production was negligible at 3-4 orders of magnitude less than CO_2 production.
- Although shallow sediment decomposed faster than its deep counterpart, decomposition rates for both depth horizons exhibited temperature sensitivity.
- Deep sediment is more resistant to remineralization, but the reaction is more sensitive to temperature, as predicted by the Carbon-Quality Temperature hypothesis[2,4].
- Therefore, relatively stable organic matter will exhibit enhanced decomposition as temperature increases.

- Using monitoring data, creek temperature was converted to annual decomposition rates using Arrhenius kinetics (Table 1).
- These average rates (16.8 – 23.0%) constrain previous estimates of 25-100% OC remineralization[1].

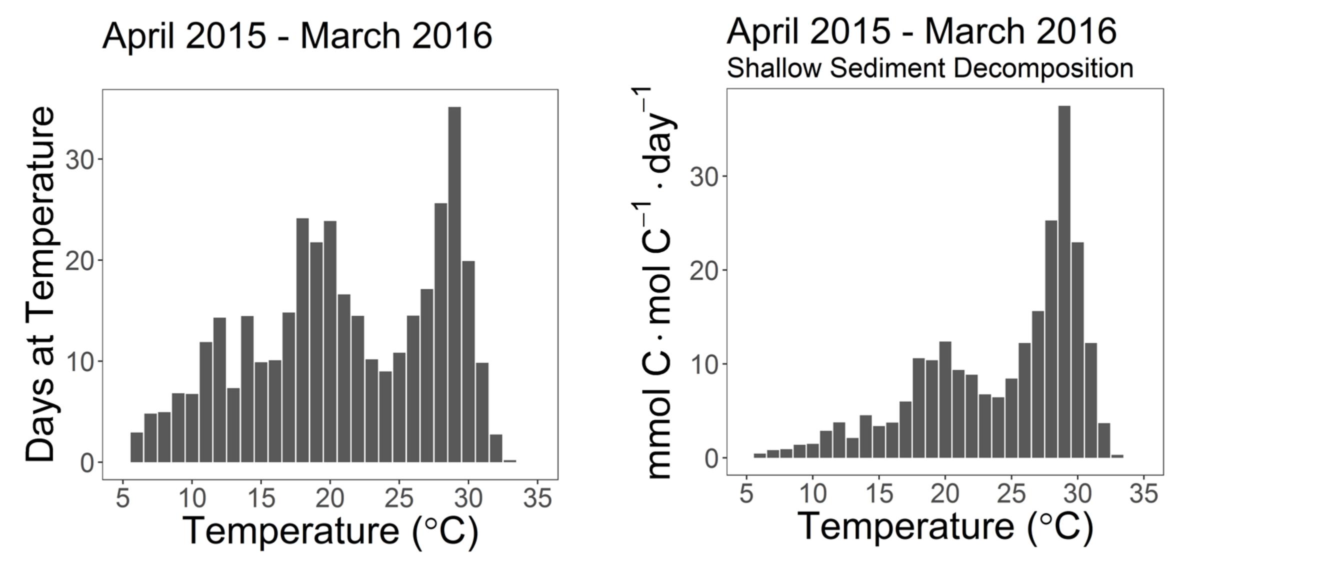


Fig. 4. (Left) Annual temperature profile for the study site. (Right) Decomposition rates integrated over time at each temperature.

Implications

Table 2. Updated calculations of potential carbon emissions.

	Global Salt Marsh Extent (Mha)	Marsh Area Loss Rate (% yr^{-1})	Sediment Carbon Decomposition Rate (% yr^{-1})	At-risk Carbon Stock in Top 1 m of Marsh* (Mg C ha^{-1})	Carbon Emissions** (Pg CO_2 yr^{-1})
Pendleton et al. 2012	2.2 – 40	1.0 – 2.0	25 – 100	65 – 259	0.02 – 0.24
This study	19 – 40	1.0 – 2.0	17 – 23	41 – 60	0.05 – 0.13

*Sediment Carbon Decomposition Rate x 259 Mg C ha^{-1} (mean stock for above-ground biomass and top $1m^{1,5,6}$)
**1 g C = 3.67 g CO_2; the non-parametric 90% confidence interval is presented as a range

This study updates the range of potential emissions from wetland loss by:

- Improving the minimum global salt marsh extent from new data[7,8]
- Narrowing the sediment carbon decomposition rate through empirical research

The "salt marsh carbon pump" effectively stores CO_2 since long-term net carbon accumulation stockpiles refractory OC that resists rapid decomposition, although the enzymatic kinetics of its breakdown is temperature sensitive.

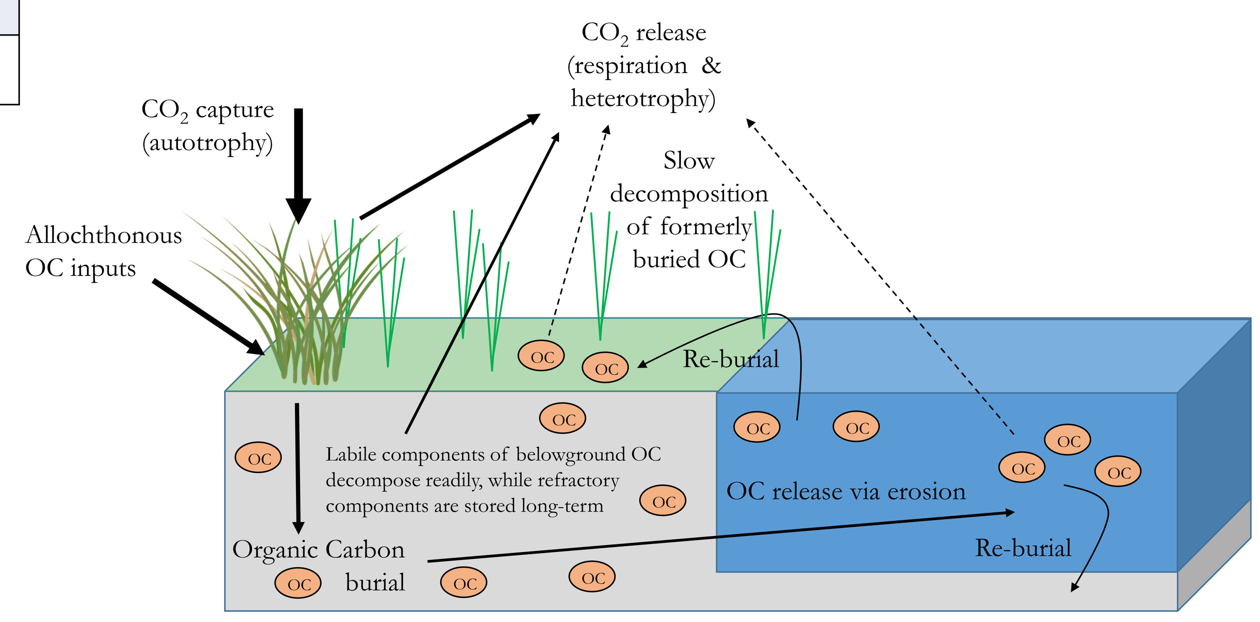


Fig. 5. Conceptual schematic of the salt marsh carbon pump. Upon marsh erosion, OC that has passed through the pump resists rapid decomposition and is likely reburied before it completely remineralizes.

References & Acknowledgments

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