Investigating Mechanisms of Ocean Alkalinity Enhancement in Estuarine Sediments

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Introduction:

What is the problem?

- Increasing CO_2 emissions in the atmosphere is causing climate change and ocean acidification (OA).
- These OA conditions are more acidic and corrosive to the shells of calcifying organisms such as clams, oysters, etc.[1]
- Ocean alkalinity refers to the ocean's capacity to buffer changes in acidity by neutralizing acids like CO_2.
- On geological timescales, rock weathering and erosion transports dissolved alkaline substances to the ocean increasing its alkalinity.[2]
  - However, these processes are too slow to keep up with current rates of CO_2 emissions.

What is sediment buffering?

- A method to mitigate OA effects on calcifiers inhabiting intertidal sediments by rapidly enhancing ocean alkalinity via dissolving alkaline minerals[3,4]
- Estuarine sediments are rich in naturally occurring metabolic CO_2, creating a system that helps dissolve the minerals far faster than any other parts of the ocean.

Study Site and Minerals:

Idaho Flats in Yaquina Bay estuary near Newport, OR, USA

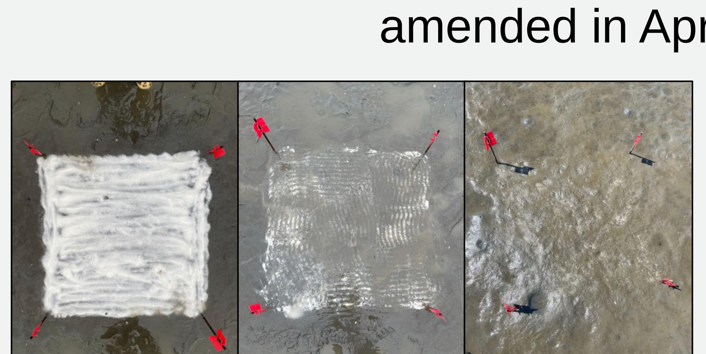
What minerals do we use?

- Calcite, Dolomite, and crushed Pacific Oyster (*Crassostrea gigas*) Shell at 8% and 16% w/w amounts
- 2 control treatments (disturbed and true control)

Amending the sediment:

Three sites in Idaho Flats, OR:

- March–August 2022, Site A and B (24 0.25 m^2 plots at each site, all treatments replicated in three rows, amended in September 2021)
- April–June 2023, Site C (four 1 m^2 plots, deeper in estuary, calcite only, amended in April 2023)



Minerals are raked in the upper 2 cm of sediment

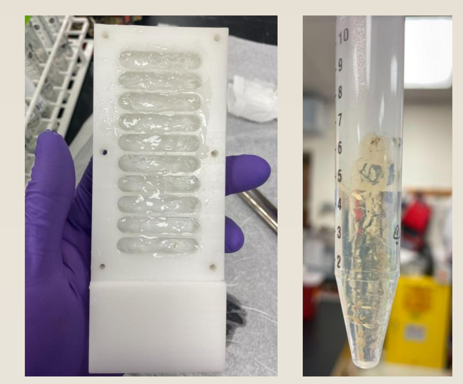
Objectives and Methods:

Why are we interested in this?

- Defining limitations and understanding the mechanisms of sediment buffering given the vastly different outcomes from past efforts within the scientific community.

Methods of sediment sampling:

Porewater Peepers



Records porewater alkalinity during weekly or biweekly deployments

Sediment Cores

Collected from field plots to measure sediment carbonate and organic content, oxygen consumption rates, and permeability

Results:

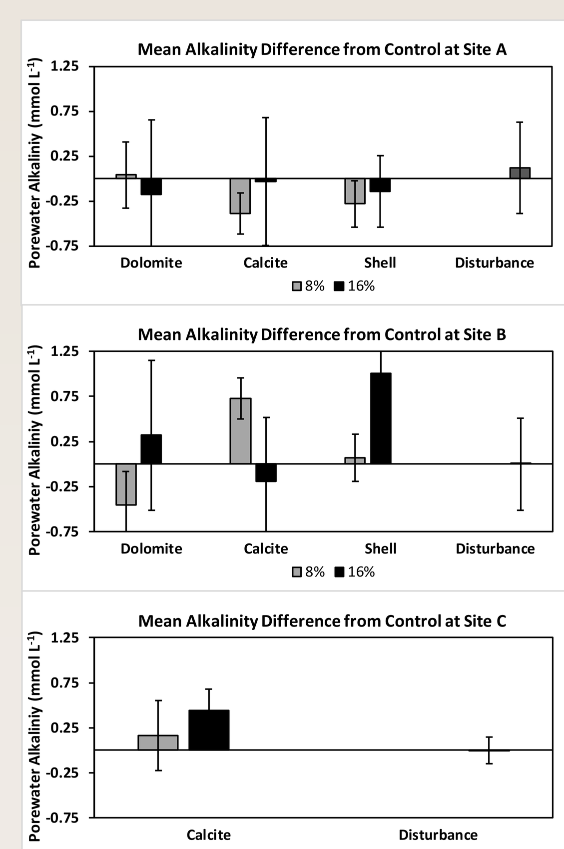


Figure 1: Mean sediment porewater alkalinity difference from control across all mineral treatments and sites.

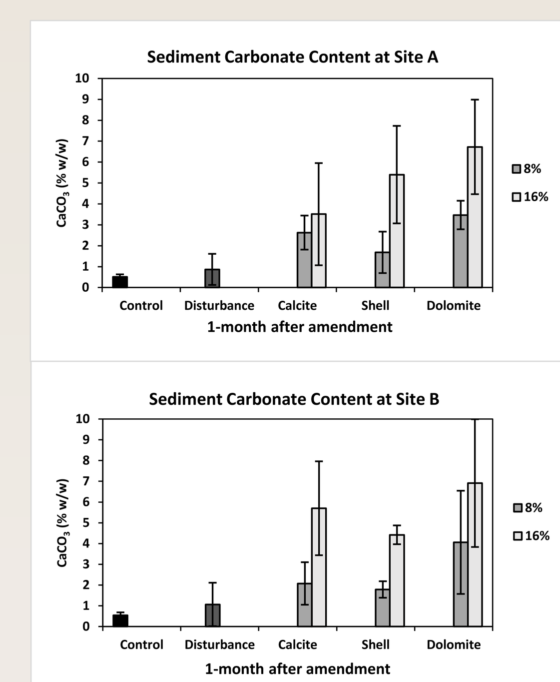


Figure 2: Sediment particulate inorganic carbon (PIC) measured across all treatments one month after amendment at Site A and B in 2022.

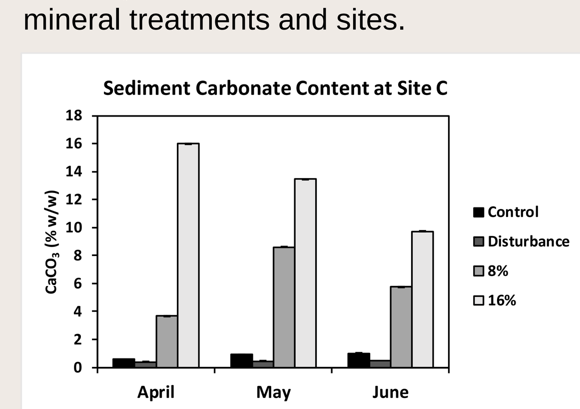


Figure 3: Sediment particulate inorganic carbon (PIC) measured monthly across all treatments at Site C in 2023.

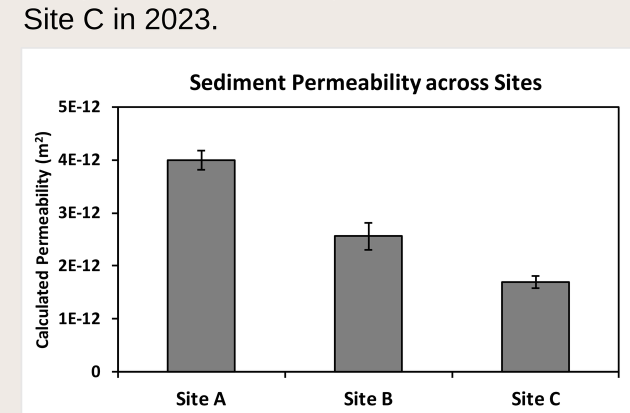


Figure 5: Sediment permeability measured across all sites for control treatments.

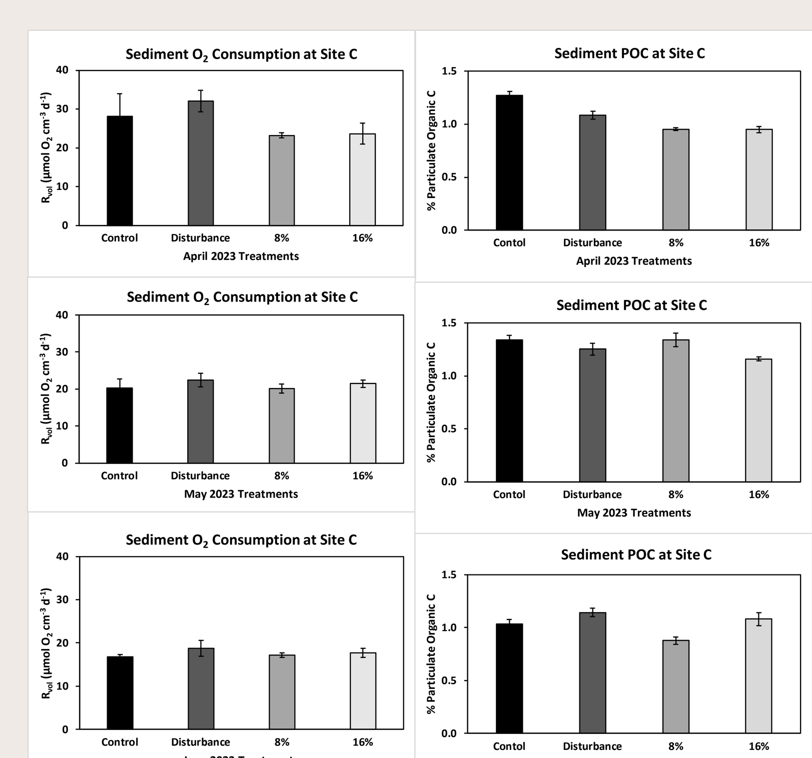


Figure 4: Sediment oxygen consumption rates (R_{vol}) and particulate organic carbon (POC) measured monthly at Site C in 2023.

Discussion and Conclusions:

Summary of Alkalinity Analyses:

- Inconsistent effects of sediment amendments were observed in Site A and B, whereas at Site C, calcite increased porewater alkalinity as expected (Figure 1).
  - The standard deviation across deployments and plots were typically larger than measured amendment effects at Site A and B
  - Site A's amendments, on average, appeared no different from control.
  - Average porewater alkalinity at Site B and C increased by ~10% across all plots due to amendments.

Site-specific Findings:

- ≥ 50% of carbonate was lost at Site A and B after the first month of amendment (Figure 2).
  - This brings attention to constraining factors that influence carbonate transport out of sites.
- A gradual loss of carbonate was observed over the 3-month experiment at Site C (Figure 3).
- At Site C, an initial decrease in sediment metabolism was measured in amended plots that eventually subsided within a month (Figure 4).
- Site C was ~60% lower in permeability than Site A, and ~30% lower than Site B (Figure 5).
  - Sediment permeability may play a key role in controlling whether porewater alkalinity is retained in amended sediments or largely flushed out via tidal drainage

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References:

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