An Experimental Investigation of The Effects of Seiche Activity on Sulfur-Containing Sediment And Sediment Porewater

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Introduction

- An acceleration in nutrient cycling can occur in locations where periodic inundation allows oxygen penetration deeper into reduced sediments, disturbing the porewater profile and allowing for significant redox reactions.
- Perturbation of redox interfaces and porewater mobilization due to seiche-induced activity in anoxic sediments of freshwater estuaries has not been well studied in relation to nutrient cycling.
- Lake Superior in Duluth, MN experiences seiche on an approximate 8 hr cycle with water level fluctuations reaching approximately 12 cm.
- These fluctuations can reach 12 miles upriver and impact estuarine sediments.

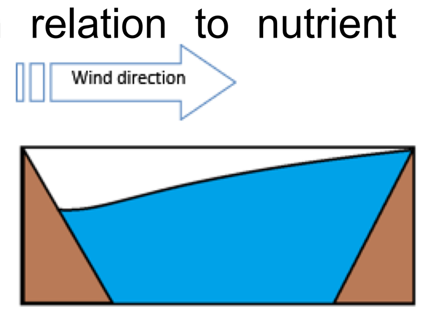

Figure 1: Diagram of seiche initiation.

Objective

- The objective of this research is to study the mobilization of porewater and effect of oxygen intrusion on nutrient sulfur cycling in anoxic sediments subjected to periodic wetting and drying driven by seiche (analogous to the one in Lake Superior) in a laboratory setting.

Methods

- Sediment wedge containing anoxic sediments (1% mud by dry weight to 99% coarse [2 mm] sand by dry weight) was subject to a simulated 8-hour seiche cycle.
- Rhizons positioned in characteristic locations.
- Sediment core samples taken before and after experiment for acid volatile sulfides (AVS) using the Brouwer Diffusion Method.
- Daily surface and pore water samples. Analyzed via ion chromatography.

Figure 2: Photo of sediment wedge in tank. Black tubing is connected to Rhizons within the sediment. (left)

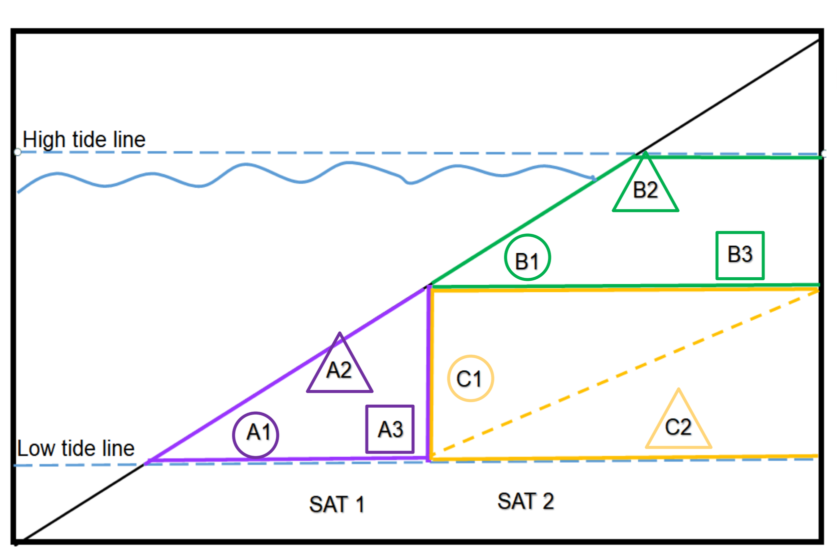

Figure 3: Labeled diagram of wedge setup. Rhizon locations colored and numbered match graphs on poster. (right)

Results

AVS Analysis

Table 1. Average amount of AVS found in the different zones after exposition due to seiche-induce activity

Zone	Average amount of AVS (nmol-S/g-C)	Δ AVS (nmol-S/g-C)	Percentile of AVS oxidized (%)
Dry (Δ)	0.62	6.62	91.41
Splash (O)	2.01	5.23	72.23
Saturated (◇)	4.87	2.37	32.72

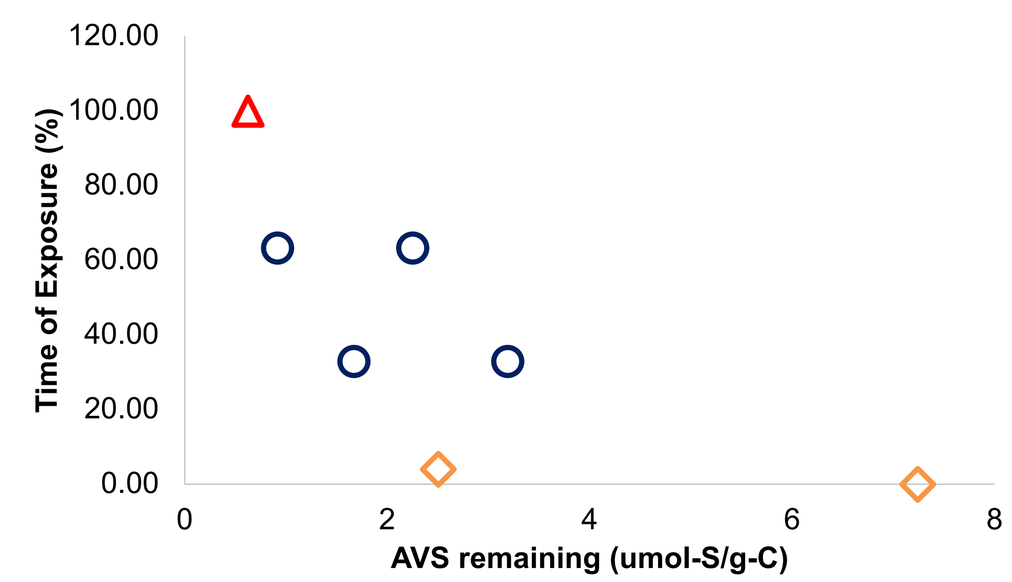

Figure 4. AVS oxidation rate depending on the time of exposure to atmospheric oxygen. The different shapes represent the locations of the zones.

Oxidation Rate Analysis

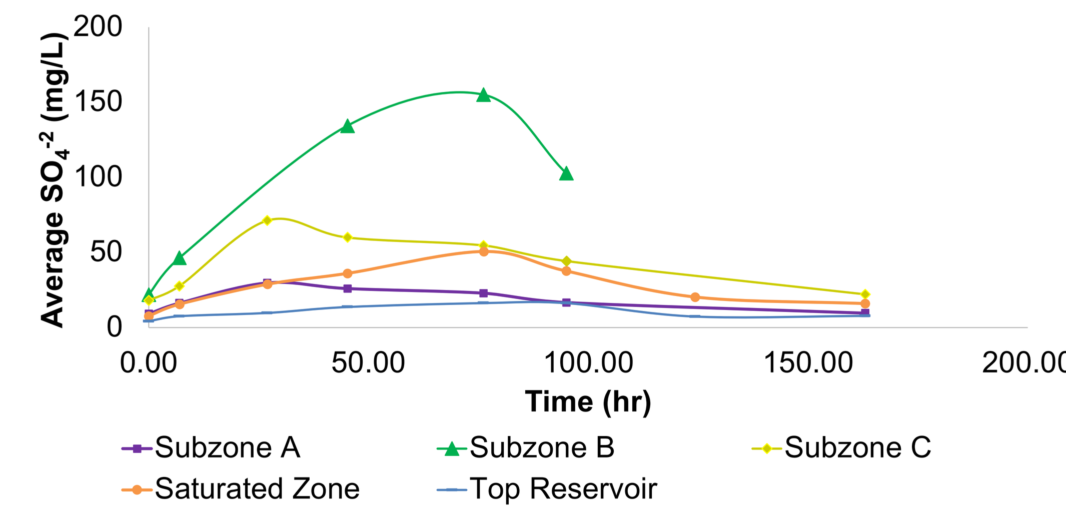

Figure 5. Daily averages of SO_4^{-2} (mg/L) from surface and pore water samples

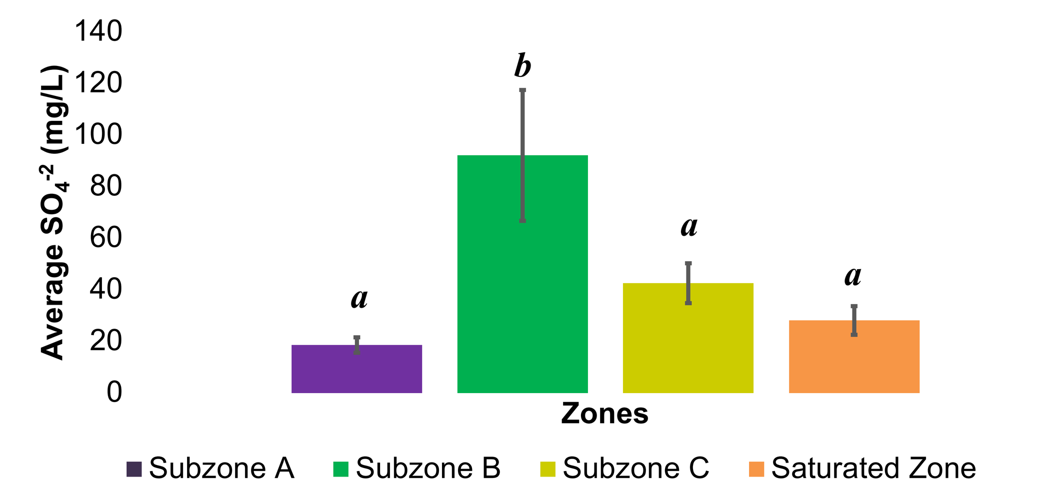

Figure 6. One-Way ANOVA test results for the average porewater SO_4^{-2} concentration (mg/L).

Inundation Frequency

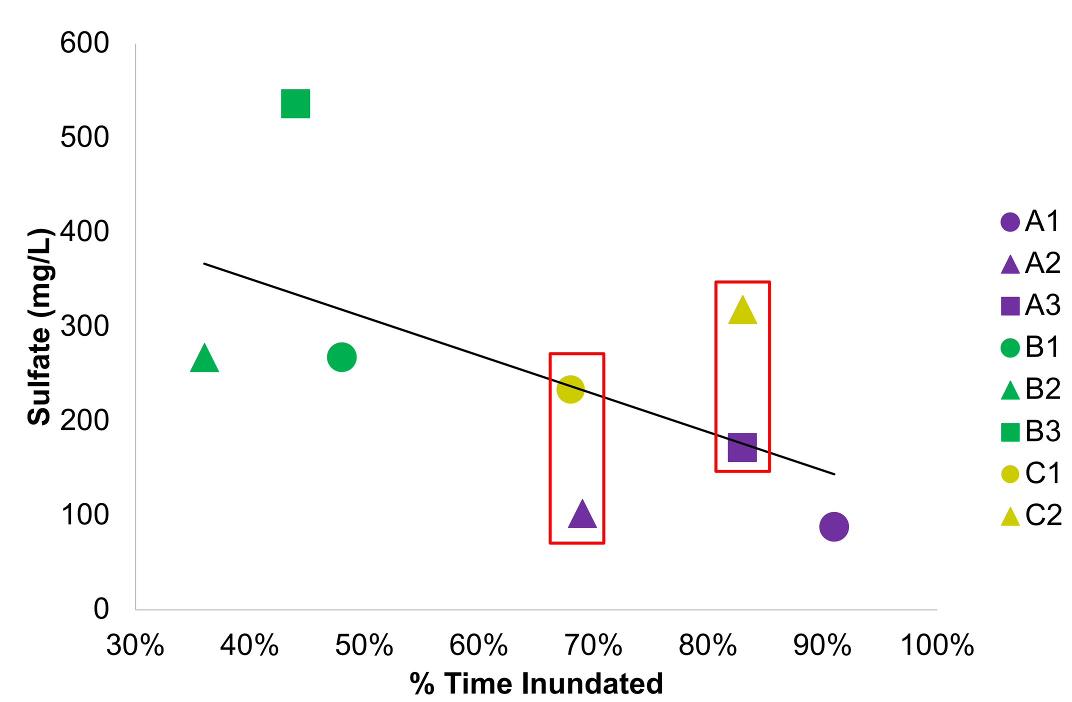

Figure 7. Zones that are less frequently inundated have higher concentrations of sulfate (from more exposure to the atmosphere), but locations with the same inundation frequency have significantly different sulfate concentrations.

Proximity to Sediment-Water Interface

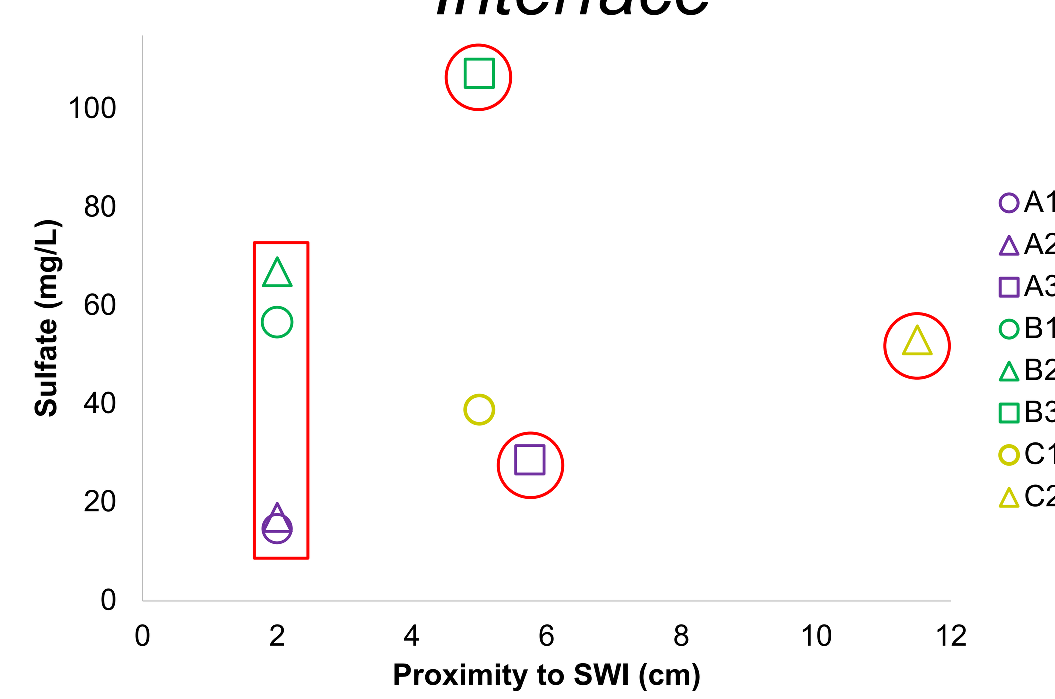

Figure 8. Note higher concentrations of sulfate in rhizons further away from the SWI (circled in red). Also note that locations with the same proximity to the SWI have significantly different concentrations.

Discussion and Conclusion

- This study uses porewater sulfate concentration data over time to assess inundation frequency and proximity to the sediment-water interface (SWI) efficacy in flushing porewater.
- It was found that flushing efficacy depends on a combination of proximity to the SWI, inundation frequency, as well as oxidation rates at each location.
- Findings have the potential to increase knowledge on how redox-driven nutrient cycling behaves in different sediment zones in estuaries regularly impacted by seiche-driven flushing.
- This has implications for how wild rice stands are managed in the St. Louis River estuary as wild rice is finding to be affected by both sulfide and sulfate levels in sediments.

Figure 9. Stand of wild rice along the St. Louis River in northern Minnesota.

- Seiche activity causes constant and periodic oxygen intrusion into sediment; which clearly accelerated sulfur oxidation in our experimental investigation.
- This cyclical hydrological phenomena could participate in the release of metals into the water column by changing sulfur speciation, since exposure to oxygen results in oxidizing conditions that lead to higher levels of SO_4^{-2} and less reduced sulfur that can bind metals strongly.
- There is a possibility of also having the same effect with other elemental-nutrient cycles, increasing the probability of nutrient loads from accelerated carbon mineralization in a dynamic hydrological setting and impacting ecosystem structure .
- The contribution of this study in outlining the potential geochemical implication in near-surface nutrient cycling in riparian areas contributes to a more complete understanding of the seiche's impact to ecosystems.

Acknowledgments

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