Assessing the Dynamic Resilience of Newly Established Salt Marshes to Wave-Induced Stress Over Time

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INTRODUCTION

Restoration of coastal salt marshes has become progressively more common as the ecosystem services provided by these systems, including flood protection and shoreline stabilization, have been acknowledged. Recent examples in Canada include a marsh restoration in Boundary Bay (British Columbia) and a managed realignment at Belcher Street (Nova Scotia) (van Proosdij et al., 2023).

These restorations can be challenging due to limited available data characterizing the performance of similar projects, especially in a Canadian context (Vouk et al., 2021). The first two years of marsh establishment tends to be particularly important as young marshes are especially prone to damage by storms and suboptimal water quality, and do not provide the same level of performance as an established marsh.

Most models for wave attenuation by vegetation idealize plants as rigid cylinders or require input regarding a range of plant morphology variables (stem width, plant density, plant height, etc.) that are often assumed constant. These simplifying assumptions are not always valid, particularly in strongly seasonal climates like those in Canada, where plant morphological parameters vary significantly throughout the year. Maza et al. (2022) showed that wave attenuation by vegetation is strongly controlled by the aboveground biomass and incorporated this methodology into SWAN (Maza et al., 2023). Zhang and Nepf (2021) showed that plant stiffness also has an influence on wave attenuation.

To date, most laboratory-based live vegetation experiments have used transplanted natural marshes (Möller et al., 2006; Maza et al., 2022), which are representative of established marsh conditions. However, seasonal fluctuations in biomass and the reduced density of newly established (constructed) marshes compared to their natural counterparts (Tempest et al., 2015) can potentially result in significant variability in performance. There is a pressing need to understand the performance of newly established marshes to better characterize short-term benefits and ensure the long-term viability of these restoration efforts.

OBJECTIVES

This study is one of the first to examine the wave attenuation and erosion resistance performance of a newly established salt marsh over its initial growing period. The objectives of this study are:

1) Link the wave attenuation and erosion protection function of Canadian salt marsh vegetation species to plant morphology.
2) Examine the seasonal variation of marsh performance.

The goal is to develop an improved understanding of young marsh performance to aid planning and design, including any temporary mitigation measures that may be needed during marsh establishment.

METHODOLOGY

The experiments were performed in the outdoor large wave flume (120 m × 5 m × 5 m) at INRS, Quebec City, Canada. A marsh platform of sediment was built (d_{50} = 0.20 mm) based on an idealized cross-section of a salt marsh in the Chignecto Isthmus in Nova Scotia, Canada (Figure 1). The slope was instrumented with acoustic and capacitance-type wave gauges to measure wave transformation, as well as several Acoustic Doppler Velocimeters (ADV) and an Acoustic Doppler Current Profiler (ADCP) to measure wave-induced velocities. Optical backscatter sensors (OBS) were placed in three profiles along the slope to measure suspended sediment load.

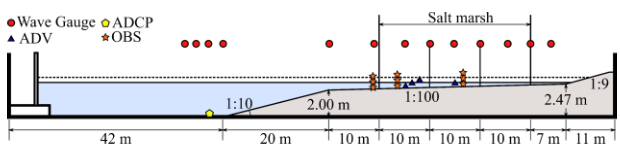

Figure 1. Experimental Setup in large wave canal.

The experimental protocol consisted of a series of twelve tests varying the wave height (H_s = 0.15 m, 0.20 m, and 0.25 m), wave period (T_p = 2 s and 4 s), and water depth (h = 2.50 m and 2.75 m). Experiments were performed for a duration of 1200 waves. The test series was performed once without vegetation (bare soil) to establish a reference case.

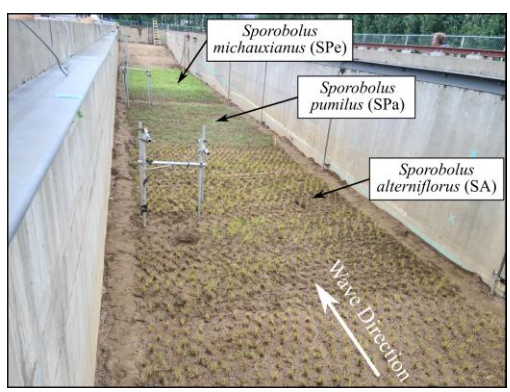

Figure 2. Salt marsh after the initial planting.

Three plant species native to Atlantic Canada were planted on the marsh platform representing the high marsh (*Sporobolus michauxianus*), mid-marsh (*Sporobolus pumilus*), and low marsh (*Sporobolus alterniflorus*). The plants were grown in a greenhouse from March to June and were transplanted into the wave flume in late June as plugs (Figure 2). The plants were provided with a small amount of fertilizer after the second week of planting. The plants were left to establish for one month with the low marsh being inundated for approximately six hours per day. The high marsh and mid-marsh were watered daily.

The plants were then exposed to waves every second week, following the test series described above. Between test weeks, the biomechanical properties of the plants were measured including biomass, elastic modulus, and plant morphology.

RESULTS

Aboveground biomass of each of the species increased over the first six weeks after planting and gradually declined afterwards. The most prominent biomass loss was observed in the leaves of all three species, whereas minimal stem loss was observed. *Sporobolus michauxianus* was the only species to exhibit significant stem breakage. Elastic moduli of the plants gradually increased through the experimental test series.

Figure 3 shows the results of one test condition over the first seven weeks of testing. The primary y-axis shows the wave transformation over the slope based on analysis of the wave gauges for each of the test weeks compared with the bare soil case. The secondary y-axis shows the average profile throughout the experimental campaign.

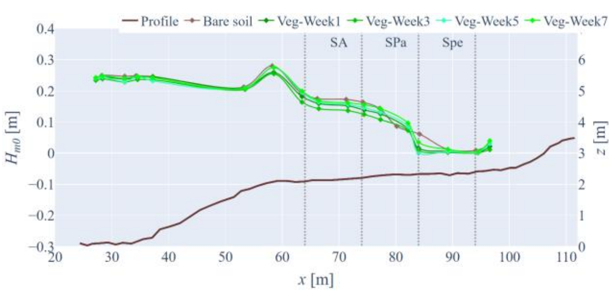

Figure 3. Wave transformation over the salt marsh platform for test series (H_s = 0.25 m, T_p = 4 s, h = 2.50 m). Tests with green coloring represent tests with vegetation, red coloring indicates bare soil. The location of the saltmarsh is delineated with the grey dotted lines.

The wave attenuation generally matched the findings of Maza et al. (2022) with more energy dissipation observed with higher biomass. No significant difference in wave attenuation by species was observed, though this was difficult to interpret because of the differences in submergence depth between the species.

Limited sediment transport was observed throughout the experiments. However, by the end of the test series, the plants at the seaward marsh edge were noticeably buried. This suggests some deposition occurred, but the thickness of accumulated sediment was lower than the measurement threshold of the total station.

DISCUSSION AND CONCLUSIONS

The first two years of a newly established salt marsh is critical in determining its survival and longevity. This study looks at the short-term evolution of a newly planted marsh in controlled conditions. The results generally followed the results of Maza et al. (2022) with increased aboveground biomass contributing to greater wave attenuation, providing a good estimation of marsh performance. This study will be continued into Fall 2023 and Spring 2024 to monitor marsh performance and health over a year cycle. The results from this study can be used to estimate marsh performance while also inform opportunities for mitigation measures to protect young marshes.

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