MODELING COLD CLIMATE SALTMARSH EVOLUTION: TOOLS FOR RESTORATION & PREDICTION

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BACKGROUND

Novel approaches to evaluating marsh eco-geomorphic evolution are being developed using mathematical models that incorporate ecological, hydrological, and geomorphologic considerations. Such works have predominantly been implemented for marshes located in the Netherlands (e.g., Gourgue et al., 2022), with a couple case studies in the United States (e.g., Brand et al., 2022) and Australia (Kumbier et al., 2022). Inputs to such models are often highly site-specific and intrinsically tied to geographically variant parameters (species, sediment supply, hydrodynamic context, seasonal effects). Numerical models of marsh eco-geomorphic evolution developed thus far have not been validated for field sites within Canada. Presently, vegetation-based coastal adaptation strategies, including coastal marsh restoration design and erosion risk assessment, are hindered in Canada by a lack of numerical predictive tools that can accurately assess marsh eco-geomorphologic evolution.

OBJECTIVES AND NOVELTY

The objectives of this study were to:

1) Demonstrate the necessity for a detailed eco-geomorphic characterization of saltmarsh sites to inform restoration interventions,
2) Contribute to a database on eco-geomorphic interactions within cold climate marshes, and
3) Develop the first eco-geomorphic numerical tool for marsh restoration and risk assessment in Canada.

The first objective addresses current design practices that limit the success of saltmarsh restoration interventions. The latter objectives address current critical barriers to the application of existing numerical eco-geomorphic models to new geographic regions.

METHODOLOGY

The saltmarsh system considered in this study is located along the Petites-Bergeronnes River, receiving tidal influence from its connection to the St. Lawrence River in Québec, Canada. These marshes have a long history of anthropogenic disturbance, with detrimental impacts from the construction of a private access road and agricultural drainage east of the road (Desrochers et al., 2022). These activities have resulted in the drying of the marsh east of the road, and subsequent conversion to terrestrial habitat. Simultaneously, regions of the marsh that have not been directly disturbed by anthropogenic activities are also exhibiting evidence of instability (edge erosion). The existing loss of marsh habitat due to tidal disconnection, and the potential future loss by edge erosion motivate the present study. In 2021, interventions for restoration were conducted in the form of drainage culvert inversion (Figure 1 - C1, C2), to facilitate the flow of saltwater to the previously drained marshes.

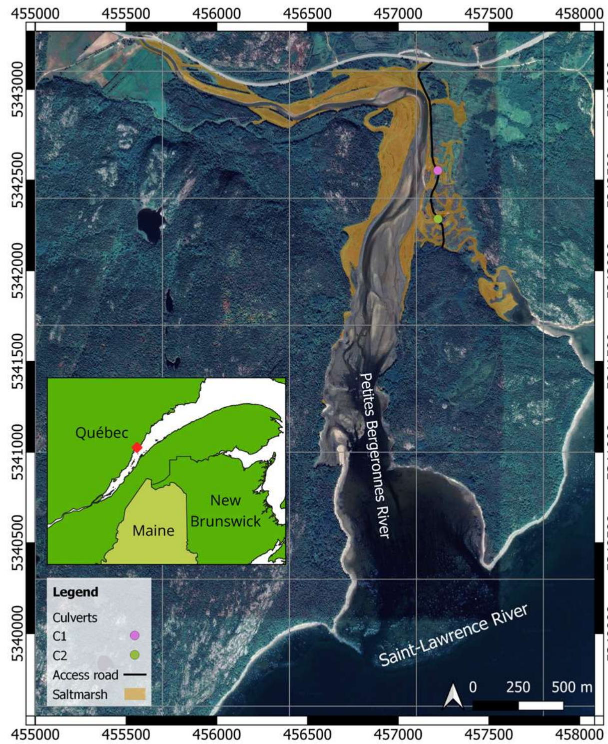

Figure 1 - Study area; saltmarshes located along the Petites-Bergeronnes River, Québec, Canada.

A detailed eco-geomorphic characterization of the marsh system was performed, considering hydrodynamics, morphodynamics, and vegetation characteristics. A summary of the data collected is provided in Table 1. Hydrodynamic data collection spanned the entire ice-free season of one year (2023).

Morpho-dynamic	• Short-term: sediment transport transects (deposition tiles, siphon samplers) • Medium-term: RTK survey of marsh edge (seasonal) • Long-term: Remote sensing and classification of saltmarsh zonation and extent (desktop)
Hydro-dynamic	• Water levels: RBR pressure sensors • Inundation dynamics: "Mini buoy" accelerometers (Balke et al., 2021) • Tidal currents: Nortek ECO ADCP
Vegetation	• Species zonation (quadrat surveys) • Seasonal bio-physical properties (stem diameter, length, biomechanics).

Table 1 - Data collection for eco-geomorphic

characterization of the Petites-Bergeronnes marshes.

RESULTS AND DISCUSSION

Results from the long-term morphological study (desktop; remote sensing) were unable to capture the marsh geomorphic conditions observed in the field. The desktop study was limited by critical data availability (high resolution aerial imagery, high temporal resolution elevation models, validation data). Drone surveys and RTK data of plant speciation and zonation have since been collected to address these knowledge gaps.

Results from the short-term morphological study (sediment transport transects) demonstrate that some regions of the marsh have potential for progradation, while others are sediment-starved due to the presence of a marsh cliff edge. Inundation dynamics informed by pressure sensors deployed throughout the site, coupled with “mini buoys” (Balke et al., 2021) deployed on the marsh surface, further support these findings (Figure 2). Inundation dynamics observed for the marshes connected via C1 (MB2) and C2 (MB6) indicate poor restoration success, with infrequent tidal flooding (IF < 0.001). Saltmarsh expansion under the observed conditions, and existing restoration interventions, is expected to be limited.

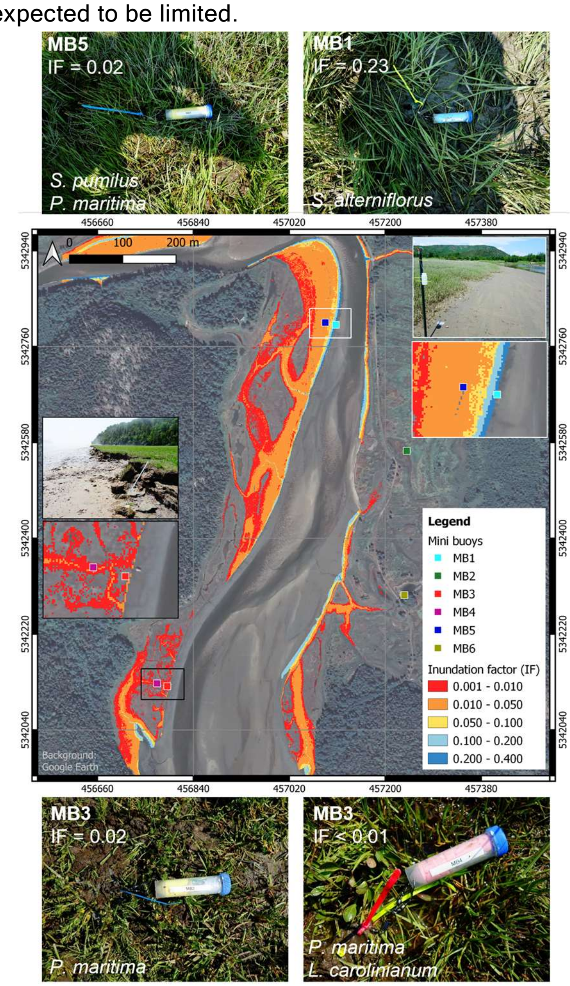

Figure 2 – Inundation dynamics from field data of water surface elevation and mini buoy deployment. IF = average inundation period/tidal period, calculated from four months of measured data (July-October 2023).

Vegetation data demonstrated seasonal variation in both species’ abundance and biophysical properties. Several interacting saltmarsh species were observed throughout the marsh, including species not yet considered in numerical models of marsh eco-geomorphic evolution (e.g., *Limonium carolinianum*). Consideration of such marsh vegetation variability has been identified as a critical gap in existing numerical models of saltmarsh evolution (Fagherazzi et al., 2020). The data collected herein will aid in addressing such knowledge gaps.

FUTURE WORK

This study has demonstrated that desktop methods may be unable to capture critical signals of marsh eco-geomorphic evolution, particularly where data resolution (spatial and temporal) is limited, as is the case for many Canadian saltmarshes. Numerical tools for modeling saltmarsh eco-geomorphic evolution, such as the one being developed from the data presented herein, are critical for assessment of marsh survival and restoration success. Preliminary inundation dynamics in the Petites-Bergeronnes (Quebec, Canada) marshes demonstrate poor restoration success within the target area, directly justifying the creation of such models. A more detailed numerical eco-geomorphic model (next steps) will aid in evaluation of marsh establishment considering the current restoration measures, as well as alternative interventions for optimization of saltmarsh expansion.

REFERENCES

Balke, Vovides, Schwarz, Chmura, Ladd, & Basyuni (2021): Monitoring tidal hydrology in coastal wetlands with the “Mini Buoy”: applications for mangrove restoration, Hydrology and Earth Systems Science, Copernicus, vol. 25, pp. 1229-1244.

Brand, Buffington, Rogers, Thorne, Stein, & Sanders (2022): Multi-Decadal Simulation of Marsh Topography Under Sea Level Rise and Episodic Sediment Loads, Journal of Geophysical Research: Earth Surface, AGU, vol. 127, pp. 1-20.

Desrochers, Maltais, Saint-Marc, & Morisette (2022): Rapport de caractérisation: Les marais de Les Bergeronnes. Comité ZIP de la Rive Nord de l’Estuaire. Baie-Comeau, Quebec.

Fagherazzi, Mariotti, Leonardi, Canestrelli, Nardin, & Kearney (2020): Salt Marsh Dynamics in a Period of Accelerated Sea Level Rise, Journal of Geophysical Research: Earth Surface, AGU, vol. 125, pp. 1-31.

Gourgue, van Belzen, Schwarz, Vandenbruwaene, Vanlede, Belliard, Fagherazzi, Bouma, van de Koppel, & Temmerman (2022): Biogeomorphic modeling to assess the resilience of tidal-marsh restoration to sea level rise and sediment supply, Earth Surface Dynamics, Copernicus, vol. 10, pp. 531-553.

Kumbier, Rogers, Hughes, Lal, Mogensen, & Woodroffe (2022): An Eco-Morphodynamic Modelling Approach to Estuarine Hydrodynamics & Wetlands in Response to Sea-Level Rise, Frontiers in Marine Science, vol. 9.