Understanding parameters for site characterization and their influence on restoration trajectory in tidal marshes in Nova Scotia, Canada

by

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A Thesis Submitted to
Saint Mary's University, Halifax, Nova Scotia
in Partial Fulfillment of the Requirements for the
Degree of Master of Science in Applied Science.

September, 2023, Halifax, Nova Scotia

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Abstract

This study investigated the characterization and trajectory of ten restoration and six natural tidal marshes by assessing site similarities and differences. Using previously collected data, a PCA identified three groupings along with environmental variables and some ungrouped sites and variables; one grouping—BEL, SCP, and SCW—shared similarities both pre- and post-restoration. Clusters identified during subsequent analyses were by sediment type (organogenic or minerogenic) and incorporated present-day data. Pre-conditions may influence the restoration trajectory of certain sites, particularly former agricultural lands and impoundments. Cumulative accretion estimates compared to IPCC sea-level rise projections several sites are threatened and identified one site of particular concern. However, vegetation data at the plot level shows increases in vegetated area and halophytic cover, and high marsh at sites into Year 10+ post-restoration. This study is one of the first to explore characterization and trajectory of both restoration and natural tidal marshes in mainland Nova Scotia.

September 1st, 2023

Acknowledgements

Completing this thesis has been one of the most challenging milestones within my life and without the foundation of support I've received from those mentioned below, this would not have been achievable. Firstly, I'd like to thank my supervisor Dr. Danika van Proosdij—you didn't know me through my undergraduate degree and took a chance on me by bringing me into your lab. Thank you for your endless wisdom and insight, and for cultivating a further love for Nova Scotia's coastlines by showing me these ecosystems through your eyes. To my committee members, Dr. Jeremy Lundholm and Tony Bowron—thank you for pushing me and steadfastly supporting me throughout this entire process. Jeremy, thank you for helping me run the statistics marathon to pull my results together and for your confidence in me through not only this thesis but my honours. Tony, your lighthearted nature was a warm welcome throughout this research—thank you for the jokes, laughs, and assorted field work to help keep me sane while writing. To Dr. Ellie Goud, thank you for being my external reviewer with such short notice—I appreciate your perspective and feedback. To Emily Hodgson, my field partner in all things muddy and pollen covered, thank you for taking the plunge to not only move to the Maritimes but hop into my crazy summer of field work without a second thought. I am so thankful I found a friend to help me tackle the workload and camp out with me in the middle of nowhere—thank you.

I would like to thank Mitacs Accelerate for helping to fund my research and for providing me the opportunity to work with CB Wetlands & Environmental Specialists (CBWES) throughout my research. The experience and skills I gained by working alongside the team at CBWES is immeasurable and was a vital component in the completion of the field work associated with my project—to CBWES, thank you. Within CBWES, I'd especially like to thank Jennie Graham for helping me with site selection, all things data management and for answering any questions or concerns at all hours of the day (or night), and to Sam Lewis for regularly checking in on me and always being willing to help—I cannot wait to continue working with you both.

Thank you to Saint Mary's University, the Intertidal Coastal Sediment Transport lab (In_CoaST), and TransCoastal Adaptations (TCA), all of which were crucial to the completion of this research project. To the Maritime Provinces Spatial Analysis Research Centre (Mp_SpARC) and the brains of the operation, Greg Baker, thank you for providing me a workspace, aerial imagery of my sites, and for your guidance and knowledge. I would not have made it to the finish line without my peers and others students. To Emily Baker, our multi-hour phone calls kept me grounded and assured me I wasn't alone through this process. To Kailey Nichols, thank you for the laughs, long nights in the lab, and for your positivity. Thank you both for your friendship, support and encouragement—I hope I can do the same for you both as you continue your education. And to Kendra Sampson and Maka Ngulube—your kindness and support from nearby and afar has been appreciated and I cannot thank you enough.

Personally, I'd like to thank my parents (Tammy and David), grandma (Doreen), grandpa (Charles), and brother (Matthew)—I love you all so much and I'm thankful to have had your support. To my fiancé (Kevin), thank you for being my sounding board, my anchor to reality, and for looking out for me—I'm so grateful to have you and our furry companions (Diesel and Bella). To my friends Catlin, Misty, Jiorgia, and Hallie, thank you for being there for me when I've needed it.

Thank you all who helped make this research possible.

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List of Abbreviations

OM	Organic matter
LOI	Loss on ignition
RSET	Rod Surface Elevation Table
MH	Marker Horizon
ABR	Abrams River Restoration
ABR-R	Abrams River Reference
BEL	Belcher St. Restoration
CON	Converse Restoration
BAS	Bass Creek (Reference)
CHV	Cheverie Creek Restoration
COG	Cogmagun Restoration
COR	Cogmagun Reference
LTR	Lawrencetown Reference
TFH	Three Fathom Harbour Restoration
MAV	Mavillette Restoration
MAV-R	Mavillette Reference
SCP	St. Croix South-East Restoration
SCW	St. Croix West Restoration
WS	Walton River Restoration
WRS	Walton River Reference

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Chapter 1 – Introduction & Literature Review

1.1 Tidal Marshes

Marshes—tidal, salt, or brackish—can be found along sheltered coastal areas in the upper intertidal zone and act as a transitional ecosystem between land and sea (Broome et al., 2019). Tidal marshes are characterized by low plant diversity and zonation of vegetation into communities based on elevation, inundation, salinity, and nutrient availability, in addition to competition and facilitation between wetland species (Morris et al., 2002; Barbier et al., 2011; Burden et al., 2013; Porter et al., 2015). While being highly variable environments, tidal marshes tend to exhibit similar landforms which include a marsh platform, banks, channels, and sometimes tidal flats (Figure 1.1). Many ecosystem services provided by tidal marshes are valuable to humans, such as pollution and erosion control, flood and storm mitigation, food and raw materials, water purification, tourism, carbon sequestration, and continued education (Barbier et al., 2011; Burden et al., 2013; Wollenberg et al., 2018). Tidal marshes are formed through eco-geomorphic interactions between plants, sediment, ice, changes in sea level, and human activity (Forbes et al., 1995; Chmura et al., 2001a; Slaymaker and Catto, 2020).

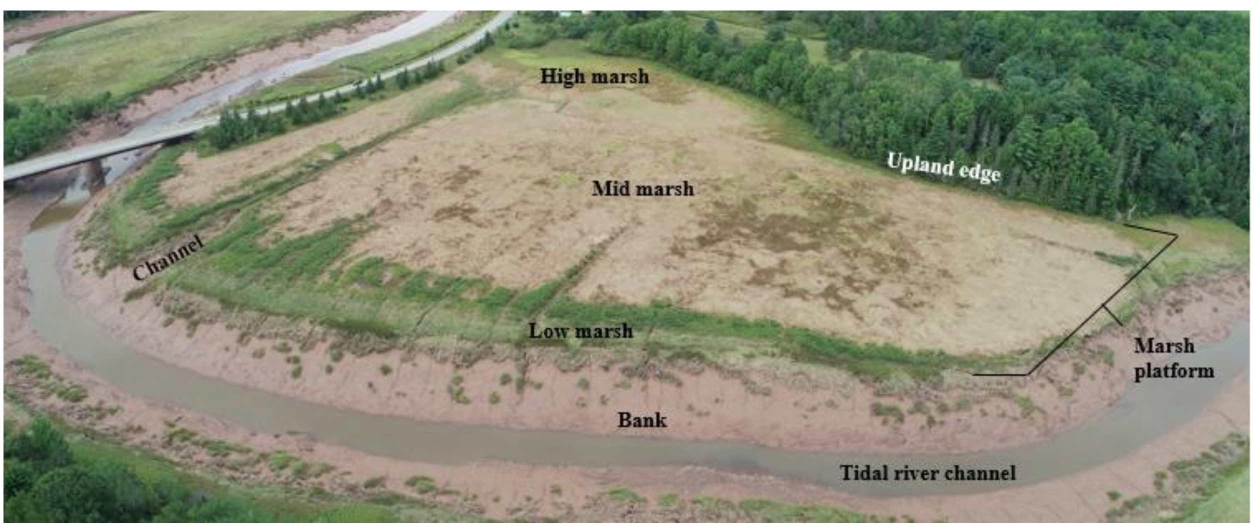


Figure 1.1. *A diagram highlighting the components of the tidal marsh landscape and its possible zonations. Imagery taken at the Cogmagun Reference site on September 5, 2022.*

Tidal marshes experience continual changes in biophysical processes due to seasonal variation (Townend et al., 2011). These variations can include winter and ice conditions (Bowron et al., 2012), tidal range variations from spring-neap cycles (Townend et al., 2011), and lunar nodal tidal cycles (French 2006, Townend et al., 2011). During the winter months, the frozen surface and presence of snow can impact the vegetation—the grasses die back, and aboveground biomass may be carried off the site or buried within the snow (van Proosdij, 2006a; Townsend et al., 2011). Ice densities can vary due to salt and sediment concentrations and have the potential to create ice jams in narrow channels (Sanderson and Redden, 2015; Slaymaker and Catto, 2020). Seasonal variation also impacts the concentration of suspended sediment in the water column (Poirier et al., 2017) and sediment deposition (Ollerhead et al., 1999; van Proosdij, 2006a).

Climate change and changing water levels have led to the ongoing changes and adaptations within many coastal ecosystems across the world (Romans et al., 2017; Tan et al., 2017). Where global or absolute sea-level rise is determined based on its relationship to the center of the Earth, relative sea-level rise is the change of the water height at a particular location considering land subsidence, currents, and other factors (NOAA, 2023). While much of Canada is rising, the Maritimes are sinking (James et al., 2021). Over the past two centuries, independent of climate change, changes in relative sea-levels and mean tidal ranges have risen due to the vertical lowering of landforms following the melting of ice post-glaciation (Greenberg et al., 2012; Slaymaker and Catto, 2020). Low-lying coastal ecosystems, such as tidal wetlands, are the most vulnerable to degradation or loss due to the ecological changes brought about by sea level rise and climate change (Borchert et al., 2018). Accelerated changes in vegetation distribution and pattern, vertical accretion, and erosion along the marsh edge have called into question the sustainability of these ecosystems into the future (Morris et al., 2002; Romans et al., 2017).

1.2 Implications for Restoration

1.2.1 History and Local Use

Areas along tide-dominated coastlines have been subject to human occupation since the last deglaciation, playing a role in the development of salt marsh communities (Slaymaker and Catto 2020). Many tidal marshes and other coastal ecosystems have been impacted through the implementation of tidal barriers as early as the 17th century (Byers & Chmura, 2007), and the growth and expansion of human settlements along the coastline (van Proosdij and Townsend, 2005; Brisson et al., 2014; Weston, 2014; Wollenberg et al., 2018). The early 1600s saw the arrival of Acadian settlers from Europe and their communities were established around Grand-Pré and Port-Royal within Nova Scotia (Slaymaker and Catto, 2020). It is estimated that 50% of the coastal wetlands in Nova Scotia were converted into agricultural dykelands using farming techniques brought to the region by these settlers (Sherren et al., 2015; Slaymaker and Catto, 2020). Typically, a dyke[1] with an aboiteau[2] was constructed; this allows freshwater to drain but would prevent inundation of the land behind the dyke on a rising tide (Slaymaker and Catto, 2020; Figure 1.2). By 1850, nearly all tidal marsh area that was suitable for agriculture had been drained around the Bay of Fundy (Slaymaker and Catto, 2020).

[1] A high berm which would act as a tidal barrier
[2] A sliding gate built into the dyke to allow freshwater to drain but prevent salt water intrusion

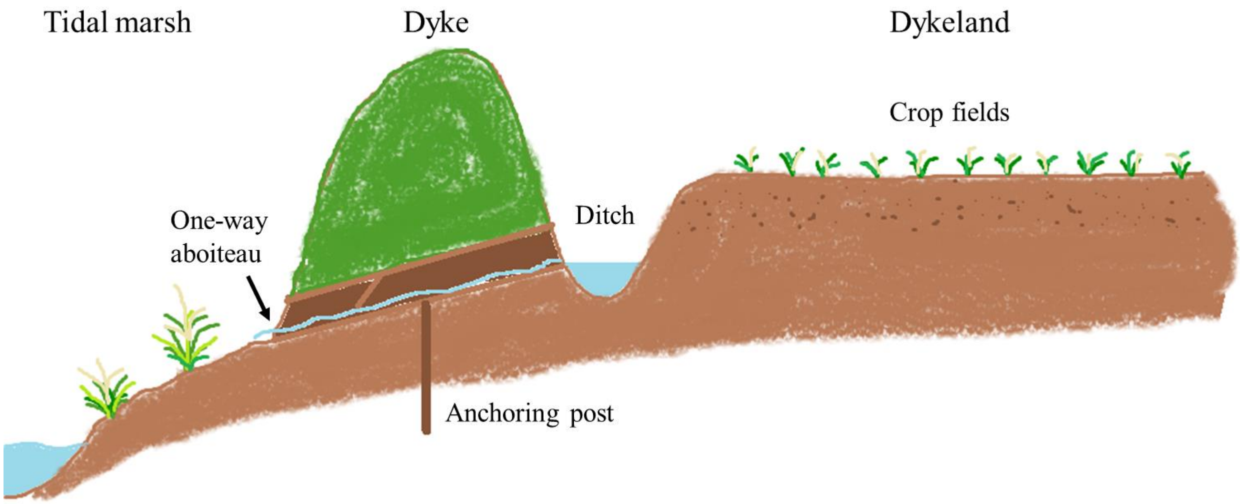


Figure 1.2. *A diagram showing the structure of the dykes built by the Acadians. The aboiteau would have allowed freshwater to drain but prevented tidal water from flowing into the ditch. The dyke would have been tall enough to prevent overtopping at high tide and during storm events. (Modified from a Grand-Pré illustration).*

Since 1981, the number of farmers and agricultural producers within Atlantic Canada has been on a steady decline; this has been attributed to aging individuals in the industry and fewer young farmers taking their place (Slaymaker and Catto, 2020). While the dykes have been part of coastal infrastructure in the region for centuries, their maintenance was conducted by the Acadians who built them, followed by the agricultural producers who farmed the land behind the dyke (Slaymaker and Catto, 2020). By 1950[3], many of the dykes were deteriorating and salt water was intruding into the dykelands; since then, the Nova Scotia Department of Agriculture (NSDA) has maintained the dykes which protects 16,139 ha of agricultural marshland[4] (van Proosdij et al., 2018). Options to address the status of historic dykes include topping them in order to raise the elevation to continue protecting agricultural land, intentional decommissioning, or the construction of new dykes inland of the former dykes, also called managed realignment, allowing for tidal flow and the re-establishment of tidal marsh (Slaymaker and Catto, 2020).

[3] https://novascotia.ca/natr/wildlife/habitats/dykelands/
[4] Reclaimed land for agricultural use that was once tidal marsh

Restoration of historic and damaged tidal wetlands began as the feasibility of maintaining existing tidal barriers was called into question and deemed unsustainable in the long term (van Proosdij and Dobek, 2005; Wollenberg et al., 2018; Sherren et al., 2021).

1.2.2 Restoration Practices

Tidal marsh restoration in Nova Scotia tends to fall within two categories: projects within infrastructure development and decommissioning projects (Bowron et al., 2012). The Nova Scotia Wetland Conservation Policy[5] outlines a framework for the conservation and management of wetlands to prevent loss for projects through government and non-government groups. There are no provincial or federal programs to guide tidal marsh restoration initiatives within Nova Scotia therefore, companies such as CB Wetlands and Environmental Specialists (CBWES Inc.) who specialize in restoration design and post-restoration monitoring, are important for the success of these projects. The first intentional tidal marsh restoration within Nova Scotia began in 2002 with the implementation of the Cheverie Creek Tidal River and Salt Marsh Restoration project (Bowron et al., 2012). Since that time, over 400 ha[6] of tidal wetland habitat have been restored throughout the province (Graham et al., 2022).

Restoration can occur at varying levels of intervention by humans. Passively, tidal marshes may be restored if a dyke is breached during a storm or weather event with no human involvement or to allow a dyke to degrade overtime by halting maintenance and upkeep to allow it to naturally breach on its own (Bowron et al., 2012). Active restoration results from planned removal of a dyke, sections of a dyke, or changes to a tidal barrier to restore or improve tidal flow (van Proosdij et al., 2010; Bowron et al., 2012). The primary goal of any human

[5] https://novascotia.ca/nse/wetland/docs/Nova.Scotia.Wetland.Conservation.Policy.pdf
[6] https://www.cbwes.com/restoration-and-compensation

manipulation within tidal wetland restoration in Nova Scotia is to restore tidal flow and allow for natural processes to rehabilitate the plants and wildlife (Bowron et al., 2012; Figure 1.3).

Figure 1.3. *A) Pre-restoration (August 9, 2015) and B) post-restoration (August 15, 2019) aerial image of the primary tidal crossing on John Doucette Road at the Mavillette Tidal Wetland Restoration site. Photos by CBWES Inc.*

For certain marshes, such as the Cogmagun Restoration project in Central Burlington, Nova Scotia, the construction of a tidal channel was needed to improve the success of the restoration (Bowron et al., 2015; Figure 1.4).

Figure 1.4. *An image showing the channel construction at the Cogmagun River Restoration site following the completion of the construction work. Photograph by J. Graham, 23 September 2009.*

Often, restored marshes are compared to the remaining natural, reference marshes to determine how quickly they are recovering and what ecosystem services they may provide. Within the literature, this monitoring design is often called Before-After Control Impact (BACI) monitoring and involves the collection of baseline data ("before") to compare pre- and post-restoration ("after") (Green, 1979; Stewart-Oaten et al., 1986; Smokorowski and Randell, 2017; Seger et al., 2021). The reference site would be the Control and the restoration site would be Impact within the comparison (Smokorowski and Randell, 2017). BACI monitoring designs, when the impacts are known at the restoration site and baseline data has been collected, can be suitable when isolating intervention effects from natural variability (Smokorowski et al., 2015; Smokorowski and Randell, 2017).

This paired technique associated with BACI within monitoring and research has been used widely to assess environmental impacts (Stewart-Oaten et al. 1986, Underwood, 1991, 1994, Smokorowski and Randall 2017). Following the construction of the Windsor causeway in 1970, sediment properties of other tidal mudflats in the Minas Basin of Nova Scotia were compared to those of the newly forming Windsor mudflats to understand their similarities and differences (Amos, 1977; Turk et al., 1980; van Proosdij and Townsend, 2005). Research into the effects of tidal barriers on soil chemistry around the Eastern shore of Cape Cod Bay used a 'natural' salt marsh as a control when examining the data from the tidally restricted marshes (Portnoy and Giblin, 1997). Following the BP-*Deepwater Horizon* oil spill in 2010, reference sites were used within research to examine the impact the spill had on 75 km of Louisiana salt marshes that experienced oiling (Silliman et al., 2012).

1.3 Environmental Drivers of Tidal Marshes

Environmental drivers, such as sediment characteristics, elevation, hydrology, and vegetation, are vital to the health of tidal marshes and it is important to understand how these processes impact both restoring and natural tidal marshes (Figure 1.5). Factors such as organic matter content, bulk density, mean inundation time, salinity, and halophytic cover, to name a few, can be measured and used to inform the status of selected environmental drivers. The formation and continued existence of a tidal marsh can greatly depend on how a tidal marsh may respond to these environmental drivers, and responses may vary depending on the morphology and geographical location of the site.

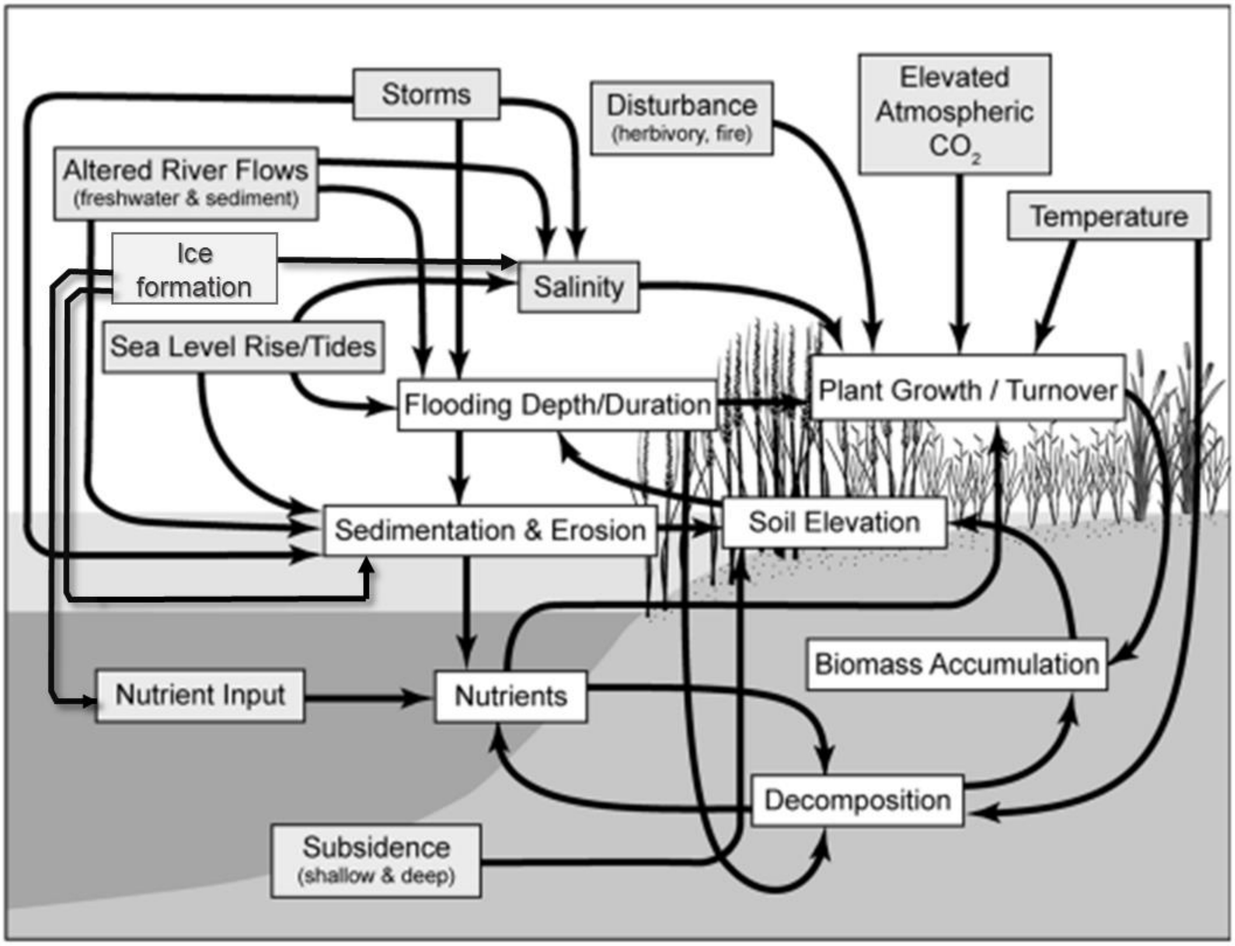


Figure 1.5. *A diagram showing environmental drivers and accretion processes that influence vertical development within tidal marshes (modified from Cahoon et al. 2009).*

1.3.1 Sediment Characteristics

Soil quality describes the ability of the soil to sustain productivity and the quality of the environment within an ecosystem and further the health of plants and animal (Doran and Parkin, 1994; Stanturf and Callaham Jr, 2021). From this, the soil health is the capacity for the soil to function, and continue functioning, as a sustaining ecosystem for plants, animals and human life (Allen et al. 2011; Stanturf and Callaham Jr, 2021). Sedimentation rates in tidal marshes are driven by numerous factors such as interactions between the wind and waves, water depth, inundation time, vegetation, biological processes, flocculation, distance between the marsh and the sediment source, and the geography of the site (van Proosdij et al., 2006; Weston, 2014;

French, 2019). The location of the tidal marsh along the coastline, tidal range, suspended sediment concentration (SSC), and developing channel networks can be important factors that influence the sediment characteristics of a site. There is uncertainty as to whether the tidal range of a marsh influences the transport of suspended sediment, with the assumption that macrotidal systems are more energetic and thus, may have higher sedimentation rates (French, 2019).

Research conducted between 1963 and 1973 on five marshes in Connecticut found that accretion rates were higher at the marshes with the greatest tidal range (Harrison and Bloom, 1977). Between 1977-1984, a study carried out in the Rhode River estuary of the Chesapeake Bay concluded that potential material exchange may be enhanced by increased inundation times due to higher water levels (Jordan et al., 1986). A study using data from North American and European tidal marshes found that resilience to sea-level rise increased with tidal range and suspended sediment; however, it is noted that macrotidal systems use less sediment to keep pace with rising water levels whereas microtidal systems would need most available suspended sediment to maintain a sustainable elevation (French, 2006). These generalizations, however, may not be representative of the processes truly taking place. A study in the Blyth Estuary, Suffolk, England–with a tidal range of 1.2 m-2.0 m–found that marshes were outpacing post-1964 sea-level rise, marsh area had grown 14% since 1887, and appeared to have an ‘adequate’ sediment supply that could maintain existing marsh elevations (French and Burningham, 2003). Research in the Waccasassa Bay area of Florida–tidal range of 1.2 m–inferred that redistribution of sediment during non-storm events may aid in sediment deposition on site when there is limited sediment within the water column to be deposited (Wood and Hine, 2007).

Movement of the sediment across the site in the absence of waves is driven by flow patterns and the depth of the water (van Proosdij et al., 2006). Sediment accumulation can vary within tidal marshes; however, tidal marshes can continue to expand as long as sea-level rise rates are below or equal to the rate of sedimentation (Slaymaker and Catto, 2020). Sedimentation within a tidal marsh can include both autochthonous and allochthonous sediments; the former of the two referring to accretion from internally derived organic material and the latter describing externally derived inorganic material (French, 2019). A study by Saintilan et al. (2022) found that tidal marshes with higher bulk density and lower percentages of organic carbon had lower rates of subsidence and higher vertical accretion rates. Coupling of autochthonous and allochthonous sediments within tidal marshes can promote vertical accretion and may allow for marshes to maintain or exceed an accretion rate higher than that of sea-level rise (Weston, 2014).

1.3.2 Elevation and Hydrology

Tidal marshes are dynamic systems which allow for them to respond and adapt to environmental changes. Often, this is through sediment accretion rates, and therefore elevation changes, which are known to fluctuate depending on storm events, changes in land use, and inevitably, sea level rise (van Proosdij and Dobek, 2005; Roman, 2017). For a tidal marsh to keep pace with sea level rise, the platform elevation must increase at a rate equal to or higher than that of rising sea levels (D'Alpaos et al., 2019; Blum et al., 2021). If a marsh is unable to accrete enough sediment vertically each year, the marsh may subside and begin to drown, negatively impacting plant growth and nutrient concentrations, leading to fluxes in methane and nitrous oxide and sediment toxicity (Byers and Chmura, 2014; Thorne et al., 2014; Weston, 2014; Roman et al., 2017). As marshes begin to transgress, the processes that allow for the accretion of sediment shift from 'biogenic (high marsh)' to 'minerogenic (low marsh)' as a response to changing hydrologic drivers (Blum et al., 2021). However, when organic sediments become the dominant sediment input over fine mineral material, minerogenic tidal marshes will begin to transition into organogenic tidal marshes (Allen, 2000). Contrary to marsh transgression, if there is decreased flooding or shorter inundation times/frequency, the vegetation may begin to transition from tidal to terrestrial (Rabinowitz and Andrews, 2022). The hydrology of a marsh plays an important role in the continued accretion of sediment, and therefore the elevation of a tidal marsh (Byers and Chmura, 2014).

Tidal marsh hydrology is not limited to the diurnal or semidiurnal flooding of the marsh platform; it also includes the main channel, various creek networks which are dynamic and continually expanding, and pannes (Novakowski et al., 2004; Neumeier et al., 2013; D'Alpaos et al., 2019). The location of the marsh within the tidal regime can also impact the site hydrology–tidal marshes may be microtidal, mesotidal, or macrotidal (Davies, 1964). Tidal marshes which experience a mean tidal range of less than 2 m are considered microtidal, whereas those with a mean tidal range over 4 m are called macrotidal (French, 2019). Those which have a tidal range that falls in between 2 m and 4 m are called mesotidal systems (French, 2019). An additional tidal range was identified in the early 2000's which describes systems with extreme tides (>10 m) such as the Bay of Fundy, and this was called hypertidal or megatidal (Allen, 2000; Davidson-Arnott et al., 2002). There are three important components to tidal marsh hydrology: inundation frequency, hydroperiod, and tidal range (flood depth) (Rabinowitz and Andrews, 2022). Monitoring these variables may help indicate early signs of hydrological change on a tidal marsh. Hydrology and elevation are the main drivers of ecosystem responses, with sedimentation –surficial sediments, consolidation, and dewatering–driving the colonization of plant communities.

1.3.3 Vegetation

Tidal marshes can be harsh environments for plants to grow and survive due to abiotic factors such as wave action, wind, inundation, and salinity, and biotic factors such as competition, facilitation, and consumers within the food web (Liu et al., 2020). These ecosystems tend to be dominated by grasses (Poaceae), sedges (Cyperaceae) and rushes (Juncaceae) and exhibit zonation of plant communities depending on salinity, inundation, and elevation (Porter et al., 2015). Marshes found in a macrotidal system are thought to foster a larger coverage of low marsh area than their mesotidal and microtidal counterparts due to these zones being found at higher vertical ranges at increased tidal ranges (Byers and Chmura, 2007; Bowron et al., 2012). Tidal marsh plants must be able to tolerate varying levels of salinity and prolonged periods of flooding; they often possess morphological and physiological adaptations to cope with these conditions such as foliar salt glands (Cahoon et al., 2021). Competitive species tended to dominate in the areas with more favorable conditions, whereas the subordinate plant species could be found in the environments with increased levels of salinity and inundation, indicating that they are more stress-tolerant than their competitive counterparts (Porter et al., 2015; Figure 1.6).

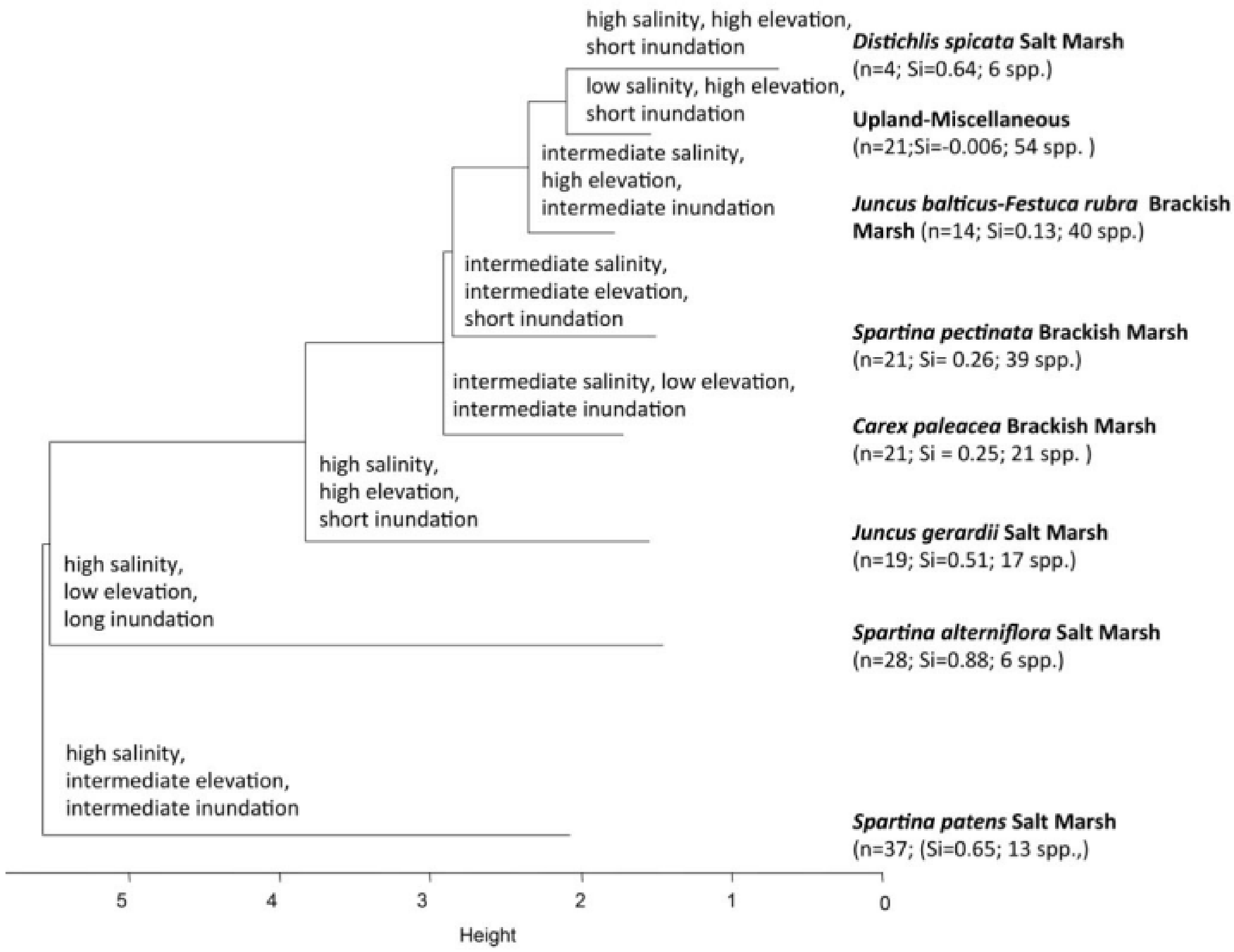


Figure 1.6. *Classification of dominant tidal marsh vegetation, bolded on the right, based on salinity, elevation, and inundation (Retrieved from Porter et al., 2015).*

Sedimentation and erosion were well documented in the literature however, further research indicates that vegetation may play a critical role in vertical accretion on the marsh platform (Cahoon et al., 2021). Plants can directly aid in vertical accretion through the accumulation of organic material within the biomass and soil, or indirectly through altering and slowing water flow and turbidity during inundation, allowing for capture of suspended sediment (Abbott et al., 2019; Cahoon et al., 2021; Figure 1.7). Vegetation present within a tidal marsh can impact wave action and tidal energy during storm surges, reducing wave heights by 70% and dissipating tidal energy by up to 90% (Slaymaker and Catto, 2020). Morphological elements of marsh plants such as vegetation height and biomechanical features such as stem flexibility have been found to contribute to wave dissipation (Rupprecht et al., 2017); wave dissipation is the result of plants and bottom friction together which creates drag and reduces wave energy (Schulze et al., 2019; Figure 1.8).

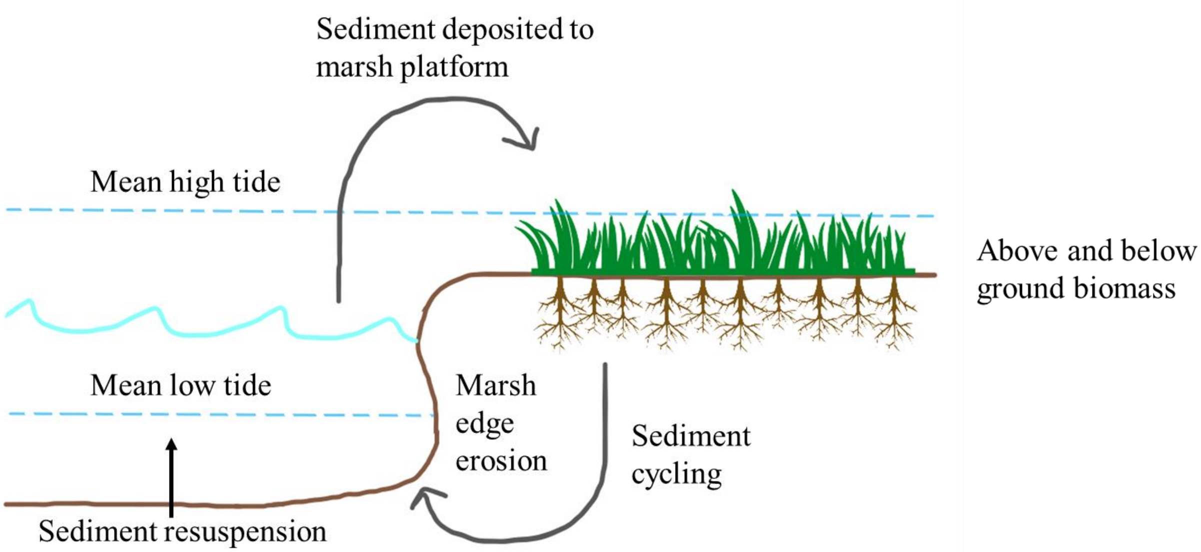


Figure 1.7. *The horizontal and vertical movements of sediment within a tidal marsh that influence their progression and accretion with the help of vegetation.*

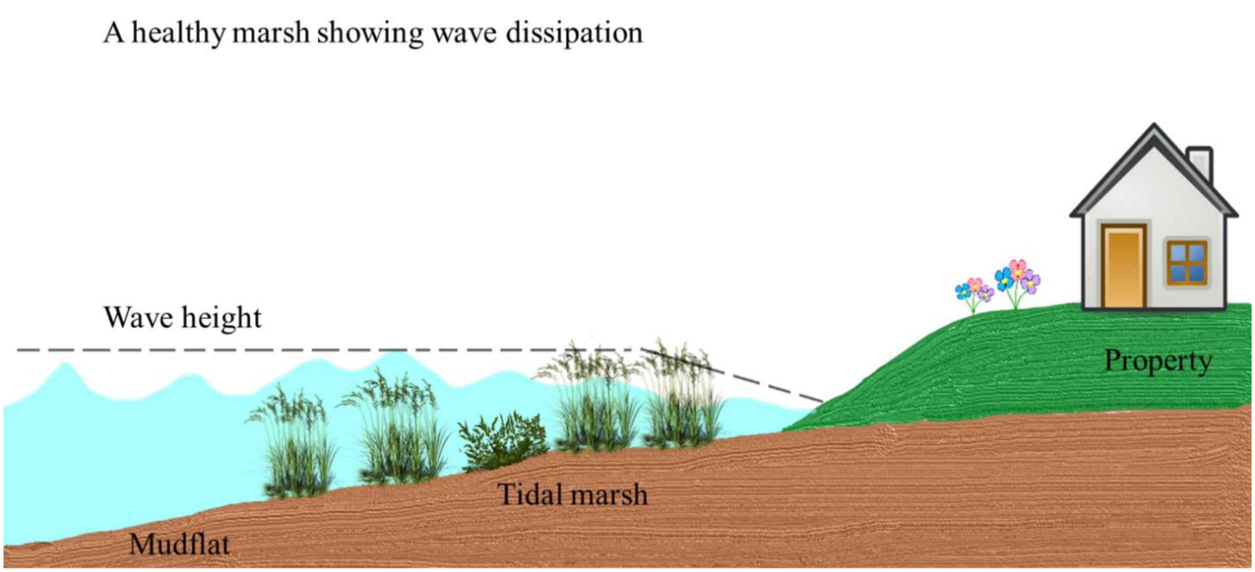


Figure 1.8. *A diagram showing the wave attenuating ability of healthy tidal marsh plants.*

Within the literature, there is evidence that plant communities within restored marshes do not exhibit the same vegetation as nearby natural marshes (Brooks et al., 2004). The differences in vegetation and success of plant communities may be impacted by differences in site topography, particularly that of creek networks, between restored tidal marshes and natural tidal marshes. Natural marshes exhibit heterogeneity within their surface topography, beginning as early as plant colonization on the mudflats which in turn leads to increased biodiversity among the plant communities on the marsh (Brooks et al., 2004). Restoring marshes tend to lack topographic heterogeneity, particularly landforms which were reclaimed for farming and were levelled and ditched, therefore, plant diversity is slow to develop (Brooks et al., 2004). Liu et al. (2020) found that biotic and abiotic stresses, which could impact the expansion of the plant communities and their health, were highly variable between sites. This emphasizes the importance of understanding the baseline characteristics of a site, such as the plant communities, as it may inform the long-term monitoring program and be indicative of changes occurring on a restoring marsh.

1.4 Knowledge Gaps and Local Research

Many created or restored tidal marshes are an 'imperfect substitute for natural marshes' (Mossman et al., 2012). Given the importance of these systems, there are questions regarding whether a tidal marsh can be characterized using pre-restoration environmental variables to better understand the outcome of restoration, and what environmental drivers should be used. In addition, there is little information on whether the pre-conditions of a restored tidal marsh will impact the future trajectory of the site. The concept of restoring a degraded tidal marsh to a natural tidal marsh has existed for decades, however, the trajectory of both restored and natural tidal marshes has not been widely explored. The inconsistencies and lack of research surrounding the characterization of tidal marshes, the future trajectory of restored and natural tidal marshes, and the potential impacts of pre-conditions are the foundation of this thesis and what this thesis intends to clarify.

An early study by Haven et al. (1995) compared habitat function between restoring and natural wetlands based on vegetation, sediment carbon, benthic infauna, zooplankton, fish abundance, crab abundance, and avian utilization. The authors concluded that while there are seasonal fluctuations between both the constructed and natural sites for animal use, there were many similarities between the sites given their parameters (Haven et al., 1995). That study, while ground-breaking at the time, focused on the impact of biotic stress on restored versus natural sites, and was very limited in terms of sites, only focusing on three sites–two constructed and one natural–within a small creek system located in Gloucester Point, Virginia.

Porter et al. (2015) explored the classification of tidal wetland vegetation within Nova Scotia using biotic and abiotic variables. Variables explored included the composition of the plant communities and environmental factors such as elevation, salinity, hydroperiod, inundation frequency, and sediment composition. They found that many sites across the region had the same plant community associations despite varying tidal ranges, inundation periods, and elevations (Porter et al., 2015). That study provides a baseline for a multi-site approach to characterization within a region, as well as indicates the conditions best suited for dominant tidal wetland plants. As it focused on classifying natural vegetation on tidal marshes, they only explored vegetation and excluded restoring marshes within Nova Scotia as they would not have been appropriate given the research objectives.

Tidal marsh restoration trajectory has become a popular avenue of research within the last decade as many restored marshes begin to age. A study by Wasson et al. (2019) concluded that the best metric for determining trajectory is to examine the distribution of vegetation across varying elevations, indicating that no single metric could be used to indicate trajectory, but a suite of metrics is needed. However, pre-conditions of the restored site and their effects on trajectory have not been as well explored. One recent study by Janousek et al. (2021), examining restoring tidal wetlands in the Pacific Northwest, found that pre-condition heterogeneity in elevation and land use may influence early post-restoration recovery. The parameters they examined included vegetation, elevation, soil salinity, and soil pH, and contained data from restoring and natural marshes (Janousek et al., 2021). They concluded that considering land cover and previous disturbance history of a site is beneficial in guiding the restoration design and monitoring process (Janousek et al., 2021). In addition, they suggested that exploring spatial heterogeneity on a new restoring marsh is needed to understand the rate of recovery and its magnitude (Janousek et al., 2021). This emphasizes the need to explore this question within restoring tidal marshes within Nova Scotia and determine if we see similar trends within our area.

The Geological Survey of Canada released a report exploring relative sea-level projections for Canada until 2100 under low, median, high, and enhanced emission scenarios (James et al., 2021). Projections—relative to average conditions between 1986 and 2005—show that sea levels within Nova Scotia could rise by 80 cm (low emission scenario, 95th percentile) or as high as 140 cm (high emission scenario, 95th percentile) by 2100 (James et al., 2021). Given these projections, it is important to understand the trajectory of both the restored and natural tidal marshes within this research and how rising water levels may impact them in the future.

1.5 Rationale for Research

Globally, tidal marshes are being lost or damaged; locally, approximately 80% of the salt marshes in the Bay of Fundy and 50% of the salt marshes in Nova Scotia have already been lost (Gallant et al., 2020). There are few remaining untouched, natural tidal marshes in Nova Scotia therefore, ecosystem restoration has been a popular avenue for rehabilitating damaged marshes (Burden et al., 2013). Tidal marsh restoration typically involves the re-introduction of tidal flow to areas which, in the past, have been ‘reclaimed’ for agriculture (Wollenberg et al., 2018). Contrary to this, a natural (reference) tidal marsh is an area that is untouched or that has not been recently altered by human activity.

Marsh restoration has been viewed as an ecosystem management method to counter the loss of the ecosystem services due to land reclamation (Wolters et al., 2005). As an intermediate system between land and ocean, tidal marshes can be vast areas or narrow fringes providing an array of ecosystem services to humans; however, this is not their sole value. The goal of restoration is to, “re-establish a self-organizing ecosystem on a trajectory to reach full recovery,” (SER, 2023), understanding that the initial trajectory may be fast and rapidly changing, long-term recovery may take decades or centuries (Burden et al., 2013). Restoration trajectory, often known as ecological trajectory, can be defined as, “the pathway of development taken by either an entire ecological community or individual ecosystem attribute during the process of restoration,” (Hobbs and Norton, 1996; Wallace et al., 2022).

The purpose of this thesis is to better understand and describe the restoration trajectory of a series of intentionally restored tidal wetlands and selected natural tidal wetlands in Nova Scotia. Further, it intends to determine if restoration trajectory can be indicated by the similarities and differences amongst sites, and to determine whether the site conditions pre-restoration impact this trajectory. This research is important as there have been no attempts to characterize tidal marshes or explore the trajectory of tidal wetlands within Nova Scotia. In addition, given the uptake of restoration projects within the province[7], understanding how previously restored sites have evolved is vital. Within many studies, reference marsh data is only compared to the data collected from the study site; rarely is it examined against the background of other sites within the area or province. To allow for restoration and reference sites to be examined outside of their original pairing, site trajectories will be explored for each site for comparison between groups of restoration and reference sites. This research will examine biotic and abiotic variables, taking into consideration the hydrology, soils and sediments, elevation, and plant communities of selected restoration and natural tidal marshes.

This thesis aims to explore and answer the following research questions:

1. Can potential restoration sites be classified based on their pre-restoration characteristics?
2. What is the restoration trajectory of the tidal marshes within this study?
3. What pre-conditions of potential restoration sites have an impact on their restoring trajectory?

[7] https://www.dfo-mpo.gc.ca/oceans/crf-frc/ns-ne-eng.html

Chapter 2 – Study Area

Tidal marshes are important ecosystems within the coastal zone with approximately 287 km^2 found in the Maritimes; over 50% of this area is found along the coast of Nova Scotia (Hanson and Calkins, 1996; Mendelsohn and McKee, 2000; Bowron et al. 2012). Based on the Köppen Climate Classification System, Nova Scotia is in the humid continental type and has been given the classification of Dfb (Köppen, 1900; Bowron et al. 2012; Porter et al. 2015). Areas that are classified within the humid continental type experience seasonal fluctuations in temperature and four seasons—these regions often have cold winters and hot summers (Köppen, 1900; Peel et al. 2017; Figure 2.1). Tidal marshes within Nova Scotia may be covered in snow and ice during the winter which can affect many variables such as sediment characteristics (grain size, suspended sediment concentration, organic matter, and bulk density) and vegetation growth (van Proosdij et al., 2006; Bowron et al. 2012; Porter et al. 2015; Poirier et al. 2017).

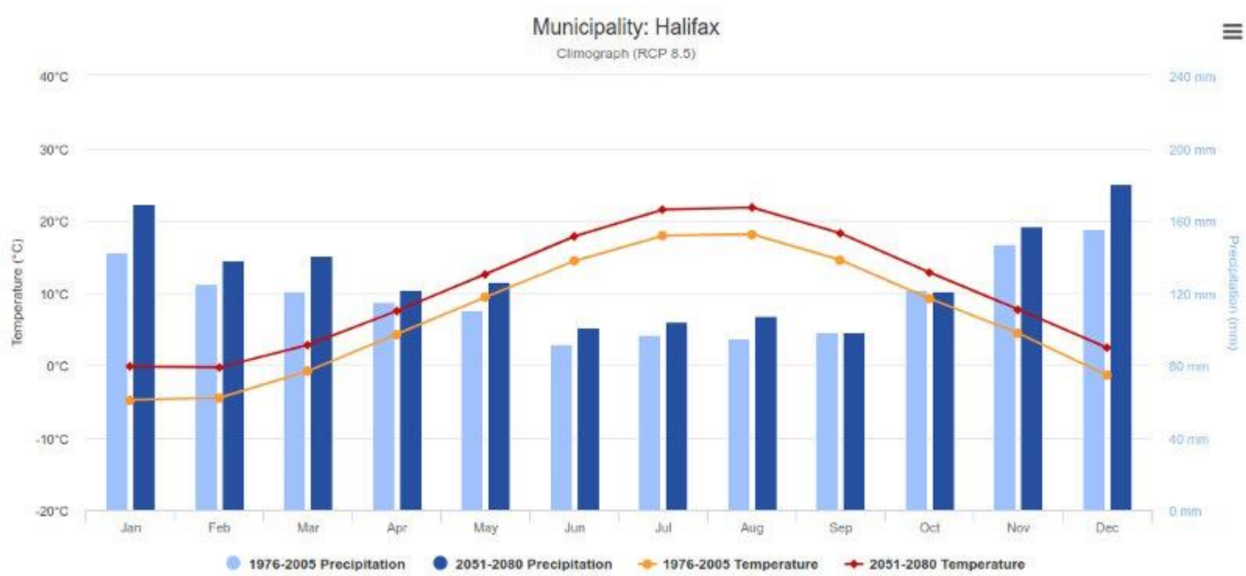


Figure 2.1. *Monthly mean temperature and total precipitation projections for 1976-2005 and 2051-2080 time periods for the city of Halifax. Vertical Bars represent precipitation and lines represent temperature—projections are under the high carbon scenario (RCP8.5). Retrieved from the Climate Atlas of Canada, 2019.*

Tidal marshes in this region may exhibit a distinct zonation of low marsh and high marsh with each area dominated by different plant communities. While salt tolerant or 'halophytic' species may be more common in the low marsh with *Sporobolus alterniflorus* (formerly *Spartina alterniflora*), other grass species such as *Distichlis spicata* or *Juncus gerardii* can be found at higher elevations within the marsh (Ganong, 1903; Hanson and Calkins, 1996; Bowron et al., 2012; Porter et al., 2015). There are three distinct coastlines within mainland Nova Scotia (Bowron et al. 2012; Porter et al. 2015) however, my study will be focusing on the Bay of Fundy and the Atlantic Coast (Figure 2.2).

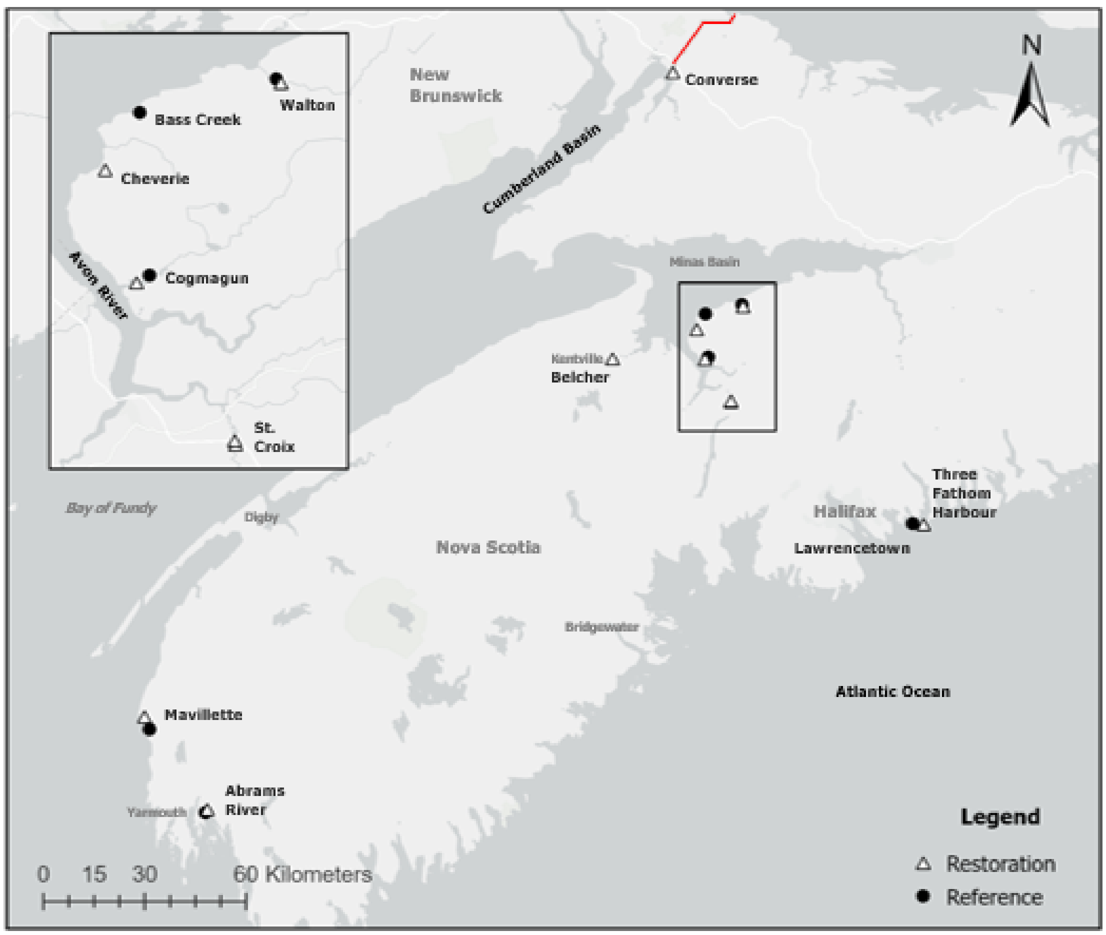


Figure 2.2. *A map of my study sites showing their location in Nova Scotia. The group along the Minas Basin in the Annapolis Valley are blown up to show their names and better show their location.*

2.1 The Bay of Fundy and the Minas Basin

The majority of sites within this study are located along the coast of the Bay of Fundy in the Minas Basin; these sites are Belcher St. (BEL), Bass Creek (BAS), Cheverie Creek (CHV), Cogmagun River restoration (COG) and reference (COR), Converse (CON), St. Croix South-East (SCP), St. Croix West (SCW), and the Walton River restoration (WS) and reference site (WRS). The Minas Basin is where most of the tidal marshes–including restored tidal marshes–within Nova Scotia can be found (Bowron et al. 2011; Porter et al., 2015). There are also two sites in the lower Bay of Fundy outside of the Minas Basin—the Mavillette restoration (MAV) and reference site (MAV-R). Tidal ranges are influenced largely by nearshore and offshore bathymetry, in addition to the configuration of the coastline (Slaymaker and Catto, 2020). The Bay of Fundy is a hypertidal system with tides ranging between 6 m at the mouth of the Bay (Yarmouth, NS) and can exceed 16 m in some areas (Burntcoat Head, Minas Basin, NS (Chmura et al., 2001; Desplanque and Mossman, 2004; Bowron et al., 2011; Tiner, 2013; Slaymaker and Catto, 2020). The widest section of the Bay can be found between Saint John, New Brunswick, and Digby, Nova Scotia, spanning 80 km and a depth of 150 m (Slaymaker and Catto, 2020).

Suspended sediment concentrations (SSC) within the Bay of Fundy can vary greatly depending on the location within the Bay; sediment inputs within the Minas Basin are high due to coastal/cliff erosion however, this basin acts as a sediment trap as the accumulation rates of sediment are comparable to the sediment inputs (Wilson et al., 2017). Within the Minas Basin, SSC can range from 150 $mg \cdot L^{-1}$on the marsh surface (van Proosdij et al., 2006a) to approximately 4000 $mg \cdot L^{-1}$ within the Basin (Amos & Tee, 1989) with peak highs during the winter and lows at the end of the summer (Poirier et al. 2017). Average SSC on the surface of a marsh within the Bay of Fundy is between 50 to 300 $mg \cdot L^{-1}$ (Gordon and Cranford, 1994;

Bowron et al. 2011). Within tidal rivers and upper reaches, fluid mud may be present which is described as SSC exceeding 10 $g \cdot L^{-1}$ (10 000 $mg \cdot L^{-1}$) or greater in concentration (Purcell, 2020). This has been observed at head of tide sites along the St. Croix River (Lemieux, 2012) and the Salmon River in Truro (18.7 $g \cdot L^{-1}$) (Purcell, 2020), both situated in the Minas Basin, where the highest tides in the world have been recorded (Wilson et al., 2017). Within the Upper Bay of Fundy, sediment composition was 95% coarse silt, 2.5% clay, and 1.5% sand with a median grain size of 36 μm (van Proosdij et al., 2006a; French, 2019).

2.2 The Atlantic Coast

Four sites within this study are located on the Atlantic Coast of the province: Abrams River restoration (ABR), Abrams River reference (ABR-R), Three Fathom Harbour (TFH), Lawrencetown Reference site (LTR) (Figure 2.2). Restoration projects along this coast often involved improving culverts through replacement and/or altering the size of the installed culvert (Bowron et al. 2012). The Atlantic Coast of North America is cooler through the summer months compared to the Bay of Fundy due to frequent high winds (Porter et al. 2015). Climatically, the Atlantic Coast experiences a milder winter than other areas of Nova Scotia and a cooler growing season through the spring and summer (Porter et al. 2015). The tides on this coast are semidiurnal like the Bay of Fundy, however, this is a microtidal region with tidal ranges between 0.2 m - 2.1 m (Porter et al. 2015). The Atlantic Coast of North America is a region that has been described as a 'hotspot' for accelerated sea-level rise (Boon, 2012; Sallenger et al., 2012; Kenigson & Han, 2014), however, another (Gehrels et al. 2020) has argued that the multi decadal cycle of higher and lower sea-levels may play a role in the tidal signal. Due to this uncertainty and its implication for tidal marsh restoration sites on the Atlantic Coast, it is important to include ABR, ABR-R, TFH, and LTR within this study.

2.3 Selected Sites

Sixteen tidal marshes from across Nova Scotia were chosen for this research—ten restoration sites and six reference sites (Figure 2.2; Table 2.1). Within the project description, it is mentioned whether there was work done on the site or whether it was used as a reference marsh during the restoration of another site.

Table 2.1. Site names, their short names, their coordinates, when the first post-restoration monitoring occurred, whether they are a restored or reference marsh, and a brief description of the work done at the site. Information provided by CBWES Inc from monitoring reports.

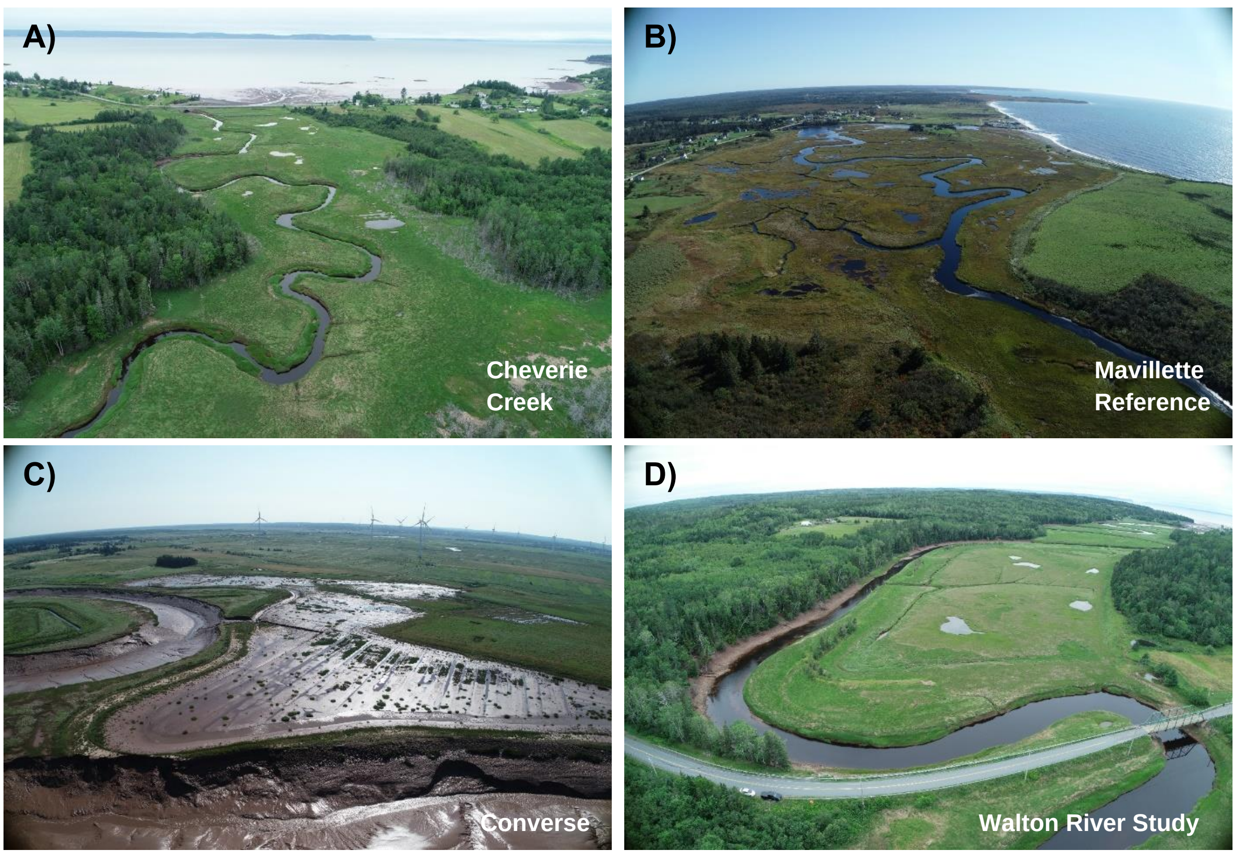
Site Name	Code	Coordinates	Year 1	Restoration or Reference	Project Description
Bass Creek	BAS	45°11'54.8"N -64°07'57.4"W	2006	Reference	Reference marsh to CHV
Cheverie Creek	CHV	45°09'38.5"N -64°10'03.9"W	2006	Restoration	Undersized culvert replacement followed by restoration
Walton River Restoration	WS	45.2209729°N -63.989720°W	2006	Restoration	Impoundment; dyke breach (5 locations; 1 channel created-erosion)
Walton River Reference	WRS	45.2224923°N -63.995075°W	2006	Reference	Reference marsh for WS
Lawrencetown Reference	LTR	44.644381°N -63.348067°W	2008	Reference	Reference marsh for TFH
Cogmagun Restoration	COG	45.0793130°N -64.130936°W	2010	Restoration	Impoundment; dyke breach in 1 location with 1 channel created
Cogmagun Reference	COR	45.0840560°N -64.116958°W	2010	Reference	Reference marsh for COG
St. Croix West	SCW	44.9692598°N -64.031025°W	2010	Restoration	Cattle pasture → tidal marsh; dyke breach (6 locations; 4 channels created)
St. Croix South-East	SCP	44.9663904°N -64.030879°W	2010	Restoration	Field/cattail wetland → tidal marsh; dyke breach (2 locations; 1 channel created)
Three Fathom Harbour	TFH	44.6439639°N -63.305864°W	2015	Restoration	Undersized culvert replacement followed by restoration

Belcher St	BEL	45.0739250°N -64.469817°W	2018	Restoration	Realignment of an agricultural dyke on the Cornwallis River
Abrams River Study	ABR	43.8480693°N - 65.936142°W	2019	Restoration	Undersized crossing restoration
Abrams River Reference	ABR-R	43.8440190°N - 65.950437°W	2019	Reference	Reference marsh to ABR
Converse	CON	45.8441977°N - 64.267855°W	2019	Restoration	Realignment of agricultural dyke on the Missaguash River
Mavillette Restoration	MAV	44.1060197°N - 66.184475°W	2019	Restoration	Upgraded crossing for a back barrier sandy system with dunes
Mavillette Reference	MAV-R	44.0684290°N - 66.163077°W	2019	Reference	Reference marsh for MAV

This collection of sites represents a variety of different conditions: they vary based on size, tidal range, elevation, plant communities, sediment characteristics, and the restoring marshes exist at varying years post-restoration (Figure 2.3; Table 2.2). CON and BEL are two restoring tidal marshes within the Bay of Fundy however, both demonstrated very different rates of re-vegetation post-restoration. MAV and ABR are sandy systems unlike the others and both sites have a lot of pannes present on the marsh platform. SCP and SCW are tidal fresh unlike the others within this study. TFH and LTR are both small—2.26 ha and 0.8 ha respectfully—whereas ABR/ABR-R are larger sites, collectively covering 76.1 ha. CHV was a partially-restricted tidal marsh prior to restoration whereas SCW was fully restricted and had been used as a cattle pasture prior to restoration.

BEL and CON are the only sites included in this study that are Nova Scotia Department of Agriculture (NSDA) projects. All other sites were Nova Scotia Department of Public Works (NSDPW) led projects with CBWES Inc leading the design and long-term monitoring programs. All projects had a year of baseline, pre-restoration monitoring followed by five years of post-restoration monitoring carried out by CBWES Inc and Saint Mary’s University (SMU) via the

Intertidal Coastal Sediment Transport Research Unit (In_CoaST). CHV and WS had additional monitoring (Year 7) and all sites have been used routinely as research sites by SMU. Monitoring is ongoing for ABR, ABR-R, MAV, MAV-R, CON, and BEL, and quarterly site visits continue to be conducted at TFH. The remaining sites are much older and have not been formerly monitored recently, ranging from LTR which was in Year 13 since initial monitoring began during the 2021-2022 field season, to SCP/SCW and COG/COR in Year 15, and BAS/CHV and WS/WRS in Year 17.




E)
Three Fathom
Harbour Restoration
F)
Belcher St.
Restoration
G)
Mavillette
Restoration
H)
Abrams River
Restoration
I)
Abrams River
Reference
J)
Bass Creek
Reference
K)
Cogmagun
Restoration
L)
Lawrencetown
Reference

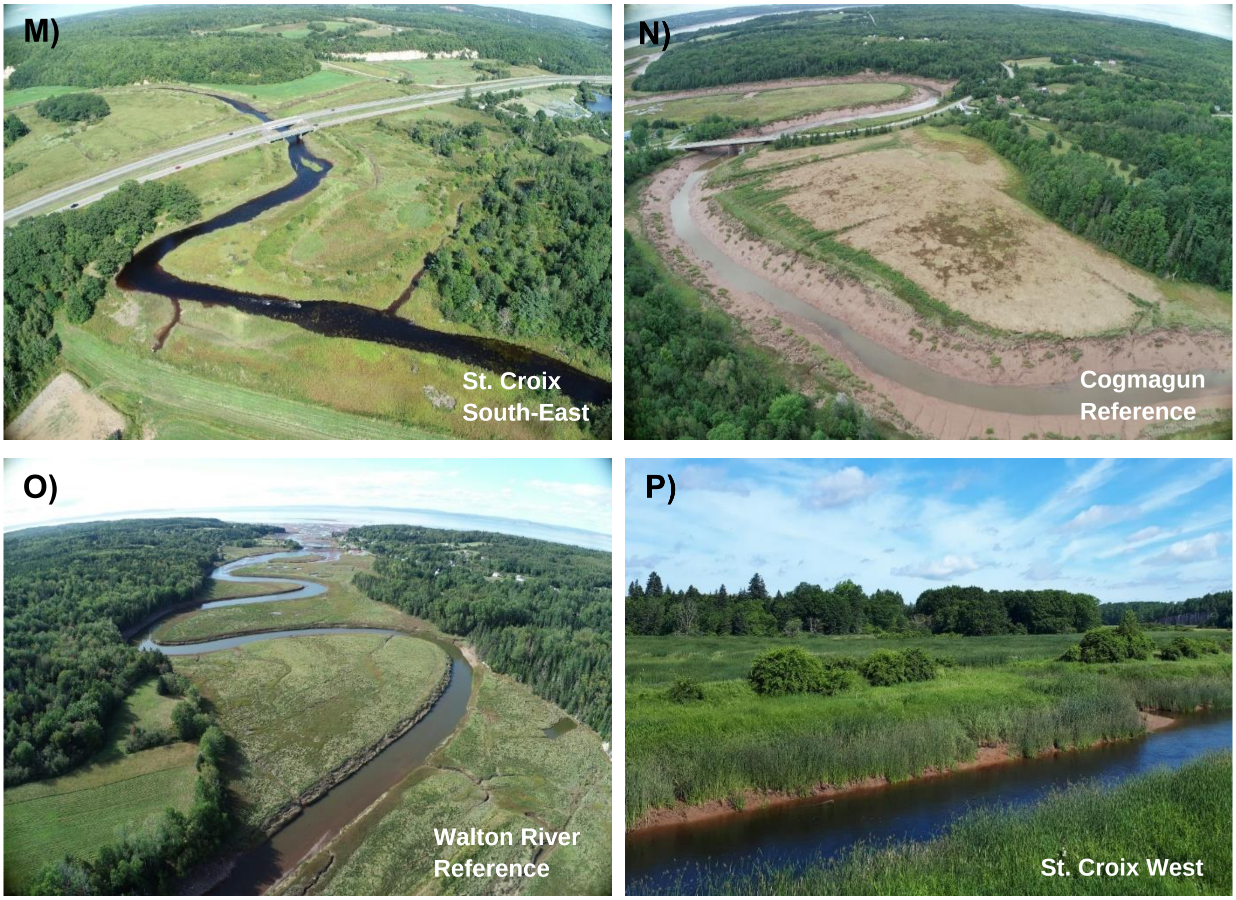


Figure 2.3. *Aerial or ground imagery of each site within this research showing the physical features of each site: A) Cheverie Creek, 2020; B) Mavillette Reference, 2021; C) Converse, 2021; D) Walton River Study, 2020; E) Three Fathom Harbour, 2020; F) Belcher St, 2021; G) Mavillette Restoration, 2021; H) Abrams River Restoration, 2021; I) Abrams River Reference, 2022; J) Bass Creek, 2022; K) Cogmagun Restoration, 2022; L) Lawrencetown Reference, 2022; M) St. Croix South-East, 2022; N) Cogmagun Reference, 2022; O) Walton River Reference, 2022; P) St. Croix West, 2020. Images A-I by S. Lewis, images J-O by G. Baker, and image P by K. Williams.*

Elevations reported in Table 2.2 for all sites except LTR and TFH are the average RSET elevations, in CGVD2013, derived from the most recent surveyed points from the RSETs on each site during the original monitoring program. At LTR and TFH, elevations were derived from a digital elevation model (DEM) of the marsh platform. The DEM at LTR was created using data from the Nova Scotia Topographic Database, survey data, and the “Topo to Raster” tool in ArcGIS (Bowron et al., 2013). At TFH, the DEM was created using provincial LIDAR and survey data (Kickbush et al., 2021).

Table 2.2. A table indicating the time of breach or construction, total marsh area, the position in the estuary and the reported elevation of each site. Elevations for each site are the latest reported values from the monitoring program prior to this research in CGVD2013. Mean water levels (MWL) and higher high water large tide (HHWLT) values are reported by the Canadian Hydrographic Service (CHS) stations closest to each site.

Site	Timing of breach/construction	Total Marsh Area (ha)	Estuary position	Latest Elevation (m)	MWL (m)	HHWLT (m)
ABR	Summer	76.1	Mesohaline	0.76	1.85	3.82
ABR-R	Reference condition		Mesohaline	1.40	1.85	3.82
BEL	Spring	9.7	Mesohaline	6.51	7.49	14.99
BAS	Reference condition	5.4	Polyhaline	5.49	7.53	15.48
CHV	Winter	43.04	Polyhaline	5.86	7.53	15.48
COG	Fall	9.49	Polyhaline	6.24	7.53	15.48
COR	Reference condition	6.1	Polyhaline	6.65	7.53	15.48
CON	Winter	15.4	Polyhaline	6.34	6.73	13.6
LTR	Reference condition	0.8	Mesohaline	0.67	1.11	2.11
MAV	Fall	90	Mesohaline	1.71	3.01	5.94
MAV-R	Reference condition	30	Mesohaline	1.79	3.01	5.94
SCP	Summer	5.89	Tidal Freshwater	6.62	7.49	14.99
SCW	Summer	10.03	Tidal Freshwater	6.47	7.49	14.99
TFH	Summer	2.26	Mesohaline	0.70	1.11	2.11
WS	Summer	12	Polyhaline	5.62	7.53	15.48
WRS	Reference condition	4.95	Polyhaline	5.98	7.53	15.48

Chapter 3 – Methods

3.1 Experimental Design

There are three components to this research—compilation of CBWES monitoring data, present day field data collection, and statistical analyses. The original post-restoration monitoring programs for all sites, excluding ABR, ABR-R, MAV, MAV-R, CON, and BEL, were completed prior to this research; most sites were associated with a habitat compensation project which required five years of post-restoration monitoring. Data collected during these monitoring programs included vegetation surveys, rod surface elevation tables (RSETs) and marker horizon (MH) data and indicated which plots sediment cores had previously been collected from. The vegetation data, which had been stored in a Microsoft Access database, was retrieved, and compiled into a Microsoft Excel sheet. The RSET/MH data and processed sediment core data was retrieved from the most recent post-monitoring report published for all sites.

All methods used are the procedures and protocols employed by CBWES and have been adopted and adapted from the literature (Neckles and Dionne, 2000; Konisky et al., 2002; Roman et al., 2002; USGS, 2005) and are used for the tidal wetland restoration projects that they work on. Sediment core collection follows a method outlined by the GPAC protocol (Neckles and Dionne, 2000); modifications from the original protocol include using 10 cm PVC rather than 20 cm PVC and the core is not sub sectioned during processing. Vegetation surveys follow a modified point intercept method (Roman et al., 2002) which explores abundance and composition of plant communities, core variables outlined by the GPAC protocol (Neckles and Dionne, 2000). Procedures for the use of RSETs and MHs follow those outlined by the United States Geological Survey (USGS, 2005) and are suggested for exploring sediment accretion and elevation within the GPAC protocol (Neckles and Dionne, 2000). Elevations, which were collected during the original monitoring programs under Canadian Geodetic Vertical Datum of

1928 (CGVD28), were converted to Canadian Geodetic Vertical Datum of 2013 (CGVD2013) to be comparable with the present-day data; conversions used for each site can be found in Table 3.1. These conversions were derived using GPS·H and the Easting/ Northing positions of the stations at each site provided in the past CBWES data. Vertical datums are height referencing systems with the Canadian Geodetic Vertical Datum being Canada's official system (GeoNOVA, 2016). CGVD28 was adopted in 1935 and was only replaced by CGVD2013 in 2013 therefore, those previously surveyed in CGVD28 elevations were converted (GeoNOVA, 2016).

Table 3.1 The conversion from CGVD28 to CGVD2013 for the sites which were originally reported in CGVD28 or had their baseline data collected in CGVD28. Conversions were determined using GPS·H[8] and site sampling station coordinates.

Site	CGVD28 to CGVD2013 conversion
BAS	-0.635
CHV	-0.634
COG / COR	-0.629
LTR	-0.606
MAV	-0.609
MAV-R	-0.614
SCP / SCW	-0.616
TFH	-0.601
WS / WRS	-0.638

Plot data was collected at the sampling stations laid out during the original monitoring program at each site to compare the present-day findings to the past data (Table 3.2). Sampling stations were laid out in an unbiased systematic sampling procedure first used during the Cheverie Creek Salt Marsh Restoration Project (Bowron and Chiasson, 2006). All sites included in this research follow this procedure except at MAV/MAV-R where targeted communities were selected to be sampled. Unbiased systematic sampling, as it pertains to the monitoring program, involves sampling along a transect laid out at each site at a predetermined interval and sampling

[8] https://webapp.csrs-scrs.nrcan-rncan.gc.ca/geod/tools-outils/gpsh.php

stations laid out along each transect. This method has been used within ecological research often due to its ease of application within the field, ability to sample evenly across a site, and its application within long-term monitoring (Bourdeau, 1953; Butler and McDonald, 1983; Krebs, 2014). Collection of the baseline data for my study began in 2021 and was completed during the summer of 2022; this baseline was collected with the intention to compare to the existing datasets provided by CBWES Inc. and SMU ranging from 2004-present. Site specific vegetation data may be found within Appendix B and Appendix C, and sediment data may be found in Appendix D and Appendix E.

Table 3.2 An overview of the sampling methods being employed within this study for the present-day baseline, when they were carried out, and why they are important considering the objectives of this study.

Category	Parameters	Sampling Method	Sampling Date in 2022	Why?
Soils and Sediment	Marsh Surface Elevation	Leica GNSS RTK surveying unit	April	To obtain an elevation at each plot where sediment cores and vegetation surveys are conducted
	Marsh Surface Elevation	Marker Horizons (MH)	April	To obtain an elevation at the marker horizons of the RSETs (not surveyed in this study) for use in determining cumulative accretion
	Sediment composition	Sediment cores (soil samples)	Sampled: April Processed: May	To better understand the belowground processes ongoing at sites of varying ages
Vegetation	Composition	Transect based, Point Intercept Method (1 m2 plots)	July / August	To determine the plant species and their communities present for later comparison between sites
	Abundance			

Table 3.3 An overview of each environmental driver and the attained variable collected during sampling. Highlighted in the fourth column is the analyses in which each variable was used.

Environmental Driver	Sampling Method	Attained Variable	Analyses (Q1, Q2, Q3, Map)
Geospatial	RPAS flight	NA	Map - see Appendix A
Elevation	RSET	Pre-Restoration Elevation	Q1[9]
	MH	SSC Proxy	Q1
		Surface Elevation	Q2[10]
	GNSS survey	Surface Elevation	Q1, Q2, Q3[11] & Map
		Cumulative Accretion	Q2 & Q3
	CBWES reports	Cumulative Accretion	Q2 & Q3
Sediment Characteristics	Sediment cores	Organic Matter Content	Q1, Q2 & Q3
		Bulk Density	Q1, Q2 & Q3
Hydrology	Water Level Loggers	Mean Inundation Time	Q1
	CBWES reports	Tidal Range	Q1
		Salinity	Q1
Vegetation	CBWES reports	Pre-Restoration Vegetation	Q1
	Vegetation survey	Mean Number of Species per plot	Q2
		Mean Number of Halophytic Species per plot	Q2
		Mean Number of Halophytic Cover per plot	Q2
		Vegetated Area	Q2
		Sporobolus sp. Abundance	Q2 & Q3

3.1.1 Sediment Core Collection

Sediment cores were taken at sampling stations at each site where cores had been collected during the original monitoring program. Each core measured approximately 10 cm long and was

[9] Can potential restoration sites be classified based on their pre-restoration characteristics?
[10] What is the restoration trajectory of the tidal marshes within this study?
[11] What pre-conditions of potential restoration sites have an impact on their restoring trajectory?

collected in a PVC tube. Each core was driven into the ground using a mallet and extracted with the help of a trowel and a knife. End caps were labelled either 'T' for top or 'B' for bottom to indicate the end closest to the surface and furthest from the surface respectively. Compaction does occur when using this method of sediment core collection and it is measured by the length of the resulting core (i.e 8 cm core in the 10 cm PVC tube indicates 2 cm of compaction). Cores were then transported to Saint Mary's University and stored in a freezer at -18 ^{o}C.

Following core collection, a bulk density sample was collected using a syringe. The syringe–once separated from the plunger–was pushed into the ground with the goal of collecting approximately 2 inches of material; however, more or less was acceptable as there only needed to be a known volume for later calculations. Once extracted from the ground, the plunger was returned to the top of the syringe carefully as to not extrude any material from the end. The bulk density sample was sealed in a bag and taped at the joint were the syringe and plunger met for stabilization during transport and storage. The sample was transported to Saint Mary's University and stored in a freezer at -18 ^{o}C.

3.1.2 Vegetation Surveys

A modified point intercept method was used to survey the vegetation plots at all sites at permanent 1 m^2 plots positioned at determined intervals (Roman et al., 2002; Bowron et al., 2020; Kickbush, 2021). Vegetation data from older datasets was collected in this manner and was continued into the 2021-2022 field season. The quadrat is divided into a grid of 25 squares (20 cm x 20 cm) and the intercept points pulled from those 25 squares are used as sampling points (Bowron et al., 2020; Figure 3.1). Any plant species found within the quadrat was recorded; a wooden dowel (3 mm in diameter) was held vertically to the first sampling point and lowered through the vegetation to the ground below (Bowron et al., 2020). Any species that touch the rod (a "hit") were recorded, and this is repeated for all twenty-five intercept points (Bowron et al., 2020; Kickbush, 2021). Species not hit were represented in the data as present and converted to a numerical value (0.25) so that they could be included in the analyses—percent cover estimates were derived by multiplying hits by four to get a value out of 100. Other categories, such as water, bare ground, rock or debris, were also recorded if hit by the dowel (Bowron et al., 2020; Kickbush, 2021). Landscape photographs were taken periodically throughout the site, as well as close-up photographs of each plot prior to the survey.

Figure 3.1. *A field photo showing a quadrat during a vegetation survey, July 26th, 2022.*

3.1.3 Surface Elevation and Cumulative Accretion

Marsh surface elevation can be best measured long-term through RSETs in conjunction with feldspar clay MHs to understand sediment accretion. They are installed and subsequently sampled to better understand the surface and subsurface processes influencing elevation changes within each site (Cahoon et al., 2020; Figure 3.2). RSETs are best for understanding the changes occurring to the internally derived below ground biomass whereas to understand the changes occurring to the externally derived sediments, marker horizons can provide the most information (Cahoon et al., 2020).

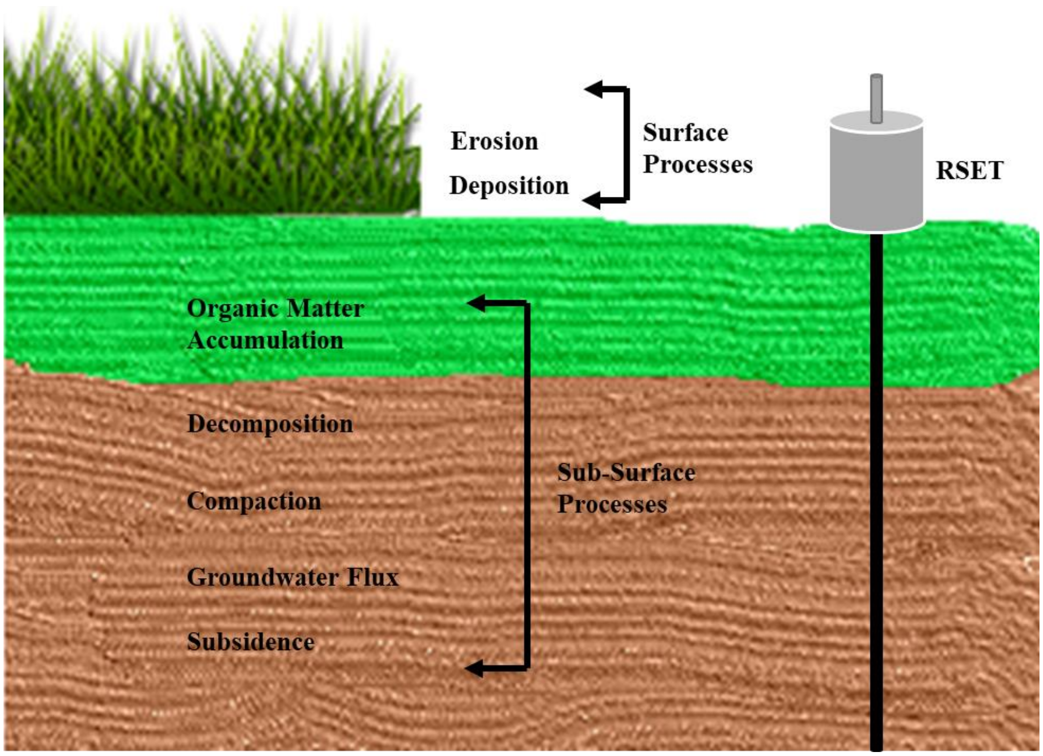


Figure 3.2. *Surface and sub-surface processes measured by the RSET – Marker Horizon method that determine elevation change in a wetland (modified from Lynch et al. 2015).*

RSETs consist of two parts: the SET arm for taking measurements and the rod SET which is permanently installed on the site and can be resampled at any point to compare to previously recorded data to infer changes regarding elevation overtime (Lynch et al., 2015; Figure 3.3). Three feldspar MHs are deployed with each RSET; the MHs are established according to the methods developed by Cahoon and Lynch (USGS, 2005). Vertical accretion at each marker is measured using a Cryogenic Corer (Lynch et al., 2015). Differences calculated from the surface accretion (MH) and the surface elevation (SET) measurements provide an estimation of the marsh surface elevation change by considering below ground and above ground processes (Cahoon et al., 2020).

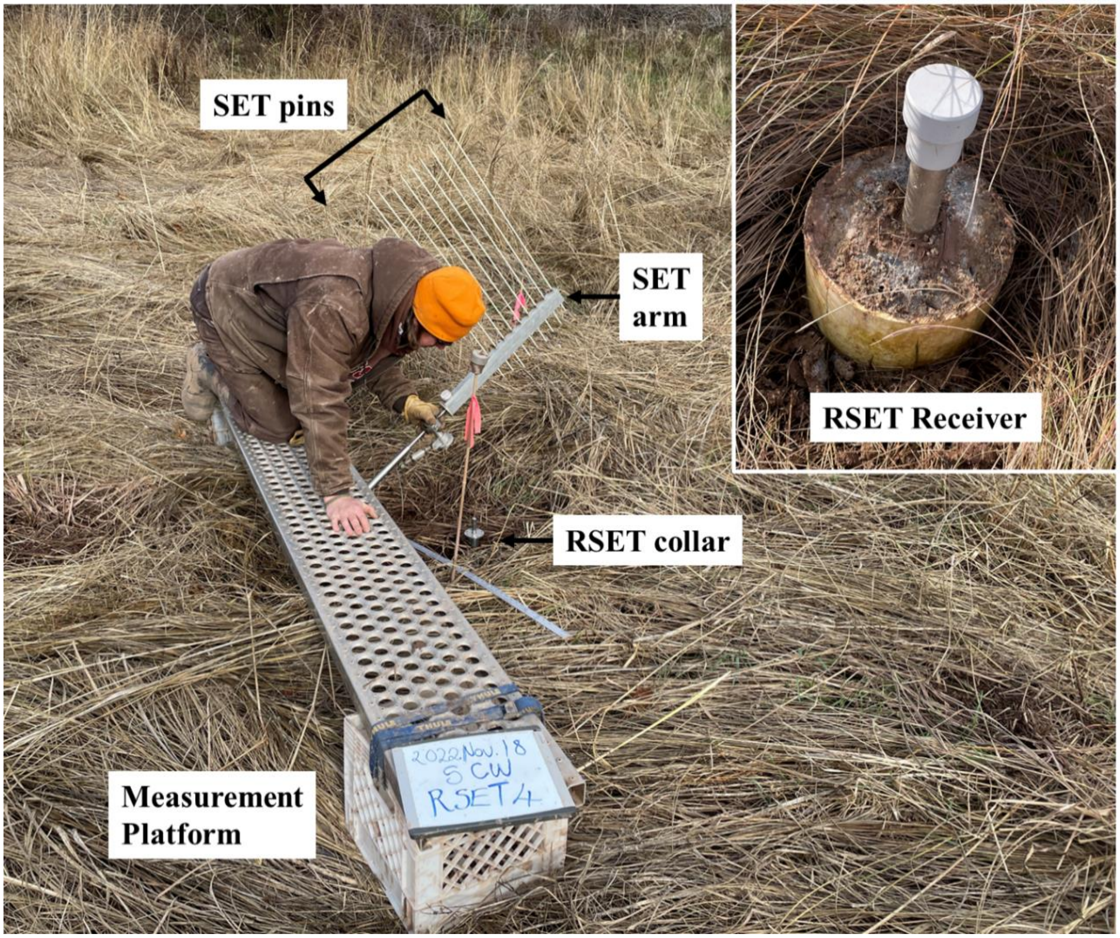


Figure 3.3. *An RSET set-up to be sampled in the field.*

All the sites outlined above had RSETs installed within their design phase or within Year 1 post-restoration except for LTR and TFH which only have a series of individual MHs. During the plot layout, the Leica GNSS RTK surveying unit was used to take coordinates (2 cm accuracy) and measure the elevation at the marker horizon locations and the location of the RSETs at each site. Re-surveying the RSETs in 2022 was not possible; however, the present-day elevations of the MHs could be compared with elevations taken during past surveys to explore changes in surface elevation. To explore the cumulative accretion at each site overtime, the reported net accretion values of the MHs associated with the low marsh RSETs were pulled from the CBWES reports (Bowron et al., 2013; Bowron et al., 2013a; Bowron et al., 2015; Bowron et al., 2015a; Bowron et al., 2022; Bowron et al., 2022a; Graham et al., 2022a; Graham et al., 2022b; Kickbush et al., 2021; Neatt et al., 2013). Pre-restoration accretion equalled zero and subsequent net accretion values were added each year to obtain cumulative accretion during the original monitoring program. Using the average of the 2022 elevations at the MHs, the Year 1 elevation was subtracted followed by the net accretion between pre-restoration and Year 1; elevations were not taken at the MHs pre-restoration and therefore, the pre-restoration elevation had to be determined in this manner.

3.1.4 Geospatial Data Collection

Georeferenced low-altitude aerial imagery for BAS, COG, COR, LTR, SCP, SCW, WS, and WRS was collected in July and early September; priority of flights was determined based on the date of the last obtained imagery for each site and whether the post-restoration monitoring program had concluded or was ongoing (Table 3.4). All sites were flown using a DJI Phantom 4 RTK[12] Remotely Piloted Aircraft System (RPAS) with an RGB camera, provided by the Maritime Provinces Spatial Analysis Research Centre (MP_SpARC; Greg Baker). Equipped with a GNSS antenna (Real-Time Kinematic and Post-Processing Kinematic), the flight data from the Phantom 4 can be collected with survey-grade positioning. Flights were conducted at an altitude of 120 m above ground level. For the Walton sites, the home point was much higher than the other sites (took off from a hill) therefore the above home point high was 100 m which translated to 120 m above ground level. Ground control points (GCPs) were laid out and surveyed with a Leica GNSS RTK surveying unit to ensure optimal georeferencing during post-

[12] https://www.dji.com/ca/phantom-4-rtk?site=brandsite&from=nav

flight processing (Bowron et al., 2020). Following the planned flight, the aircraft was flown to obtain oblique images of the sites for supplementary analysis. Imagery was collected with a front overlap of 80% and a side overlap of 70% at all sites flown in 2022. The imagery collected from the flights was used to create updated site maps for the older sites which were no longer being monitoring (see Appendix A).

Table 3.4. Aerial imagery information by site indicating year previously flown, the 2022 flight date, the flight altitude, and the average ground sampling distance.

Site	Previously Flown	2022 Flight Date	Flight Altitude (m)	Avg Ground Sampling Distance (GSD) (cm/in)
LTR	2012	12-Jul-22	120	3.55 / 1.40
BAS	N/A	06-Sep-22	120	3.74 / 1.47
COG	2015	05-Sep-22	120	3.61 / 1.42
COR	2015	05-Sep-22	120	3.64 / 1.43
SCW	2015	07-Sep-22	120	3.51 / 1.38
SCP	2015	07-Sep-22	120	3.59 / 1.41
WS/WRS	2012	06-Sep-22	120	3.65 / 1.44

3.1.5 Hydrological Variables

Hydrological variables—mean inundation time, tidal range and salinity—were only used within the exploration of the effect of pre-restoration conditions and site similarities/differences (Q1) and therefore, were taken from data previously collected by CBWES Inc. Using Year 1 hydrological data, mean inundation time was calculated collected using tide level recorders (Figure 3.4) and also through calculating the hydroperiod and inundation frequency for each site (Graham and Kickbush, 2021). Mean inundation time is the average time in which a station is flooded (Graham and Kickbush, 2021).

Mean inundation time was calculated by:

$$\textit{Mean Inundation Time (min)} = \textit{Hydroperiod min/ inundation frequency}$$

To calculate the mean inundation time, the two components within the equation also had to be calculated. Hydroperiod is the period of time in which a location is flooded during the recording time and the inundation frequency is the number of high tides that flood a location—regardless of duration (Graham and Kickbush, 2021).

Hydroperiod was calculated by:

*Hydroperiod (min) = countif(Tide Elevation > StationElevation)*TimeInterval*

Inundation frequency was calculated by:

Inundation Frequency (%) = countif(High Tide> Elevation)/ Total High Tides

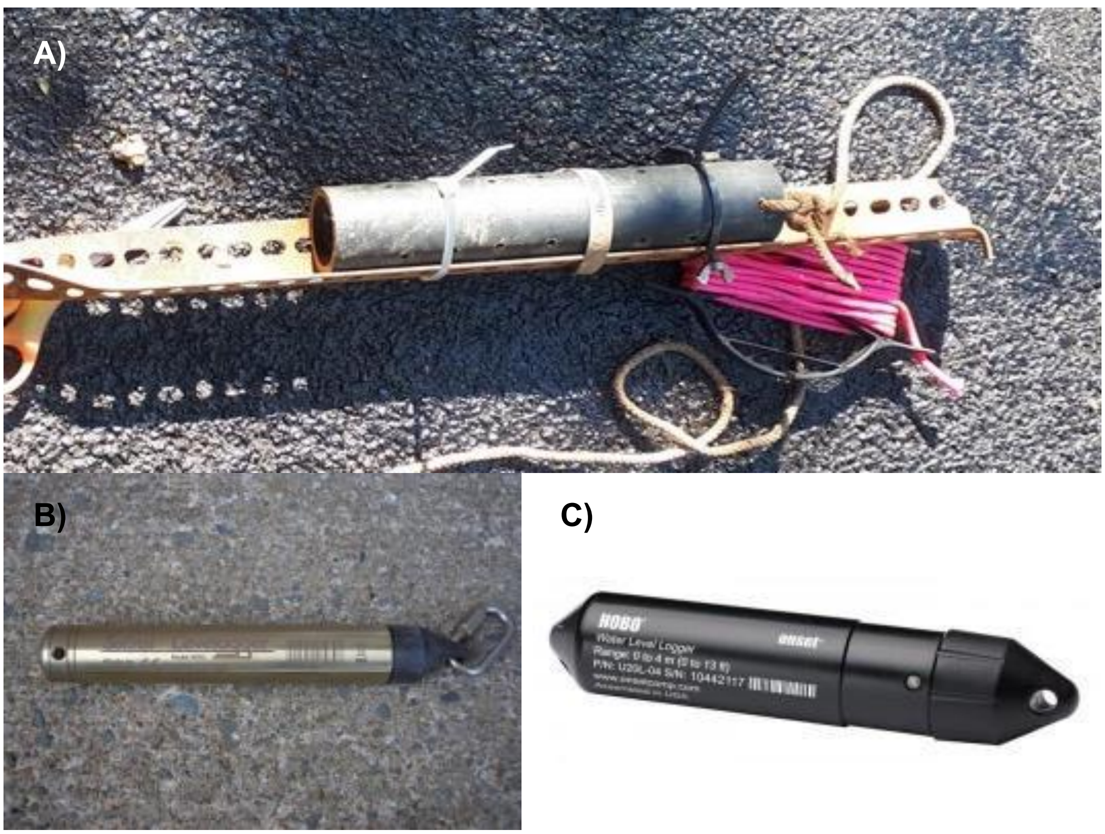


Figure 3.4. *A) a stillwell; B) a Solinst Model 3001 water level logger used at the older sites during post-restoration hydrological monitoring, and c) a HOBO water level logger which is the logger currently being used to collect post-restoration hydrological data at the newer sites. Photo B taken by N. Neatt, January 2008. Photo A & C taken by CBWES Inc., 2022.*

If already calculated during the original monitoring program, the mean inundation time was taken from the Year 1 report or from the datasheets if available. If the mean inundation time was not already calculated, the data from the level loggers installed in Year 1 provided by CBWES was used. The duration of the level logger deployment varied between the older and newer sites—only one logger was deployed during the older monitoring programs and was deployed on average for a month. During newer and ongoing monitoring programs, multiple level loggers are deployed across a site and may be recording for 75 days at a time. For all sites, the upstream logger was used to calculate mean inundation time to best capture the inundation of the full site.

Tidal range is, “the difference between high and low tide in a particular location,” (Dipper, 2022) and can vary depending on geographical location. Tidal range can govern the extent of the intertidal zone; it influences the vertical distance of the waves and currents which impact coastlines (Summerfield, 1991). For this study, the tidal range—microtidal, mesotidal, macrotidal, or megatidal—was determined through exploring past CBWES reports and exploring tides reported by the nearest Canadian Hydrographic Service (CHS) stations to each site. Salinity was rarely reported for each site and often was a range as salinity fluctuated at each site. Using the data available and the location of each site in relation to the mean high water line, sites were classified as tidal freshwater, oligohaline, mesohaline or polyhaline depending on the average salinity of each site. These salinity zones are based off the Venice System for the classification of marine waters (Table 3.5; Anonymous, 1958).

Table 3.5. The zone and respective salinity used to classify the sites using the Venice System (Anonymous, 1958).

Zone	Salinity (ppt)
Tidal Freshwater	<0.5
Oligohaline	0.5-5.0
Mesohaline	5.0-18.0
Polyhaline	18.0-30.0

3.2 Field Sampling

3.2.1 Plot Layout

Plot layout for the sites sampled in 2022 was carried out over two weeks in April of that year. Known coordinates collected previously by CBWES Inc. were used to relocate the sediment and vegetation sampling stations using a Leica GNSS RTK surveying unit (Lecia Geosystems; GS14) (Figure 3.5); sampling stations once located were re-measured to obtain a present-day marsh surface elevation value. RTK connections from the Leica SmartNet Network Correction Service are sent to the GNSS unit while it is being used to provide better positioning for coordinates (cm precision) (Bowron et al., 2020). In addition, sediment cores, a bulk density sample, and a soil salinity sample were collected at the same stations used by CBWES at each site during their monitoring program. Sampling stations were flagged with bamboo stakes.

Figure 3.5. *A Leica GNSS RTK surveying unit: A) in the case and B) in use (Lecia Geosystems; GS14).*

3.3 Lab Analyses

3.3.1 Core Processing - water and organic matter content

A drying oven, muffle furnace, and desiccator were used to process the cores. The cores had to be processed in batches due to the limited space in certain equipment; each batch took three days to process. The limiting factor was the muffle furnace as it can only hold 15 crucibles therefore, by running three samples per core, 5 cores could be processed at a time. Batches were run simultaneously to allow for faster analyses (i.e., one batch in oven, one in the furnace, etc). Cores were stored in the freezer before processing and had to be moved to the fridge 24 hours before processing could begin. Water and organic matter content were determined by loss on ignition, which involves heating a sample to a high temperature to burn off any volatile substances (Wollenberg et al., 2018). The amount 'lost' from the pre-ignition weight to the post-ignition weight is what the researcher is trying to determine [Pre-Post] (Wollenberg et al., 2018). All crucibles were weighed using a Denver Instrument SI-234 weigh scale and all values were recorded to the fourth decimal place in grams.

On day one, samples were sectioned using a standard ruler and a serrated knife: at the desired measurement needed (1 cm), the core was cut. Each sample measured 1 cm with the first sample being 0-1 cm, the second being 1-2 cm, and the last being 2-3 cm down from the top; this was consistent across all cores. Samples were identified as "A" (0-1 cm), "B" (1-2 cm), or "C" (2-3 cm) then were each placed in individual pre-weighed crucibles. The drying oven (Fisher Scientific 3511FS Gravity Convection oven) was preheated to 105 ^{o}C and the sample was placed in the drying oven for 24 hours. On day two, the samples were removed from the drying oven and placed in the desiccator (Fisher Scientific) for an hour to cool. After one hour, the samples were weighed then ground into a fine powder with a mortar and pestle and returned to their crucible. Following this, the sample was moved into the muffle furnace (Fisher Scientific Isotemp Muffle Furnace 550 Series). Samples were heated to 550 ^oC for four hours then allowed to cool in the furnace overnight. On day three, the samples were removed from the muffle furnace, placed in the desiccator for one hour then their final weight was recorded.

Water content was calculated by:

Water content (%) = ((Wet Weight - 105 ^oC Weight) / Wet Weight) 100*

To calculate organic matter content (OM) from loss on ignition fraction, the following calculation was used:

Organic Matter content (%) = ((105 ^oC Weight - 550 ^oC Weight) / 105 ^oC Weight) 100*

3.3.2 Core Processing - bulk density

During the procedure for the water and organic matter content samples on day one, a sample was also taken to allow for the calculation of bulk density. The volume (mL) of the sample was noted and once the pre-ignition weight was recorded, the bulk density samples were placed in the drying oven at 105 ^oC for 24 hours, alongside the samples for water and organic matter content. The following day, the samples were allowed to cool in the desiccator for one hour then their weight was recorded. This was the final step for the bulk density samples; they did not go into the muffle furnace. Bulk density (g/mL) is calculated by:

Bulk density (g/mL) = ((Dry Weight - Tin Weight) / Volume)

3.4 Geospatial Processing

3.4.1 Procedure

Flight data was used to generate a georeferenced orthomosaic of each site in Pix4D Mapper; this software was accessed at Saint Mary's University in MP_SpARC. Pix4D Mapper is a photogrammetry software used to process RPAS data and produce georeferenced outputs using imagery obtained during the flight[13]. GCPs were marked in the RayCloud Editor after the initial processing and all processing was completed using the settings for the highest accuracy. If the GCP was too blurry for the center to be determined in a photo, the photo was not marked and was skipped. The generated orthomosaic was then used in ArcGIS Pro as the base map for updated site maps (See Appendix A).

3.5 Statistical Analyses

3.5.1 Principal Component Analysis

A principal component analysis (Pearson, 1901) was used to classify sites based on pre-restoration characteristics and included only restoring tidal marshes. Environmental characteristics used in this analysis included elevation, salinity, inundation time, tidal range, organic matter content, bulk density, and pre-restoration plant communities. Data collected from MHs was also used and this served as a proxy variable for suspended sediment concentration as SSC has not been measured across the selected tidal marshes used in this research.

Salinity and tidal range were analyzed ordinally within a scale as measured values across all sites typically fell within a range which cannot be used in a PCA. The scale for salinity was divided into four values which corresponded to their relationship to the mean high water line: 1 – tidal freshwater, 2 – oligohaline, 3 – mesohaline, and 4 – polyhaline. Similarly, the scale for tidal range was divided into four values which indicated the difference between sequential high and low tide levels: 1 – microtidal, 2 – mesotidal, 3 – macrotidal, and 4 – megatidal (sometimes referred to as hypertidal). Pre-restoration plant communities were divided into three exclusive options—pasture, brackish, and salt marsh—that were binary in nature (zeros being no and ones

[13] https://www.pix4d.com/product/pix4dmapper-photogrammetry-software/

being yes). TFH and WS were freshwater sites pre-restoration and therefore, had zeros for all plant communities to indicate their difference from the other sites. Analyses were carried out in RStudio[14].

Once the dataset was imported into RStudio, the environmental variables were plotted to check for normality using histograms. Transformations were conducted on environmental variables if necessary then eigenvalues were identified to determine the axes that explained the most variation within the dataset (Cangelosi & Goriely, 2007). Values from the targeted principal component axes were converted into a dataframe which showed the component, the score associated with each environmental variable, and the site; these results were plotted in ggplot2 to show the findings. Analyses used the open-source software R 4.3.1 (Beagle Scout) (R core team, 2022); packages used included “vegan” for the PCA and “ggplot2” and “colorspace” for graphing the outputs.

3.5.2 Repeated Measures ANOVA

A repeated measures ANOVA (Vogt, 1993) is used when variables are measured two or more times to better understand how each variable shifts and changes overtime (Bergh, 1995). Elevation at the lowest 20th percentile plots, organic matter content, bulk density, and *Sporobolus* species abundances for organogenic and minerogenic tidal marshes—both restoration and reference tidal marshes—were plotted to better explore the trends in restoration trajectory; the division of sites into these categories is outlined in Table 3.6. These variables were tracked during pre-restoration monitoring at each site and in Years 1, 3, 5, and 10+ post-restoration. Averages were taken for each monitoring year for the plot data at the restoration and reference sites based on the division of sites into organogenic and minerogenic outlined in Table 3.6;

[14] https://posit.co/downloads/

sediment type for each site was determined by the OM content and bulk density data. These averages were plotted as scatterplots to observe the trend changes overtime—standard error was calculated for each average and added to the plots. A repeated measures mixed model ANOVA was used with fixed effects with year (pre- and post-restoration), sediment type, and site as random effects.

Table 3.6. A table indicating the condition and sediment type of each site within this project. Condition refers to whether the site has been restored or is in reference condition. Sediment type refers to the main method in which the site elevation increases—through mineral sediment deposition or through local decomposition of organic material.

Site	Condition (Restoration or Reference)	Sediment Type (Organogenic or Minerogenic)
ABR	Restoration	Organogenic
BEL	Restoration	Minerogenic
CHV	Restoration	Minerogenic
COG	Restoration	Minerogenic
CON	Restoration	Minerogenic
MAV	Restoration	Organogenic
SCP	Restoration	Minerogenic
SCW	Restoration	Minerogenic
TFH	Restoration	Organogenic
WS	Restoration	Minerogenic
ABR-R	Reference	Organogenic
BAS	Reference	Minerogenic
COR	Reference	Minerogenic
LTR	Reference	Organogenic
MAV-R	Reference	Organogenic
WRS	Reference	Minerogenic

Analyses used the open source software R 4.3.1 (Beagle Scout) (R core team, 2023); packages used included “lme4” for estimating random effects, “nlme” for fitting and comparing linear and non-linear mixed effects models, “multcomp” for multiple comparison testing of groups, and “emmeans” for conducting post-hoc comparison tests. Detailed random effects, ANOVA, and post-hoc test outputs can be found in Appendix F.

3.6 Exploring Restoration Trajectory

To explore the restoration trajectory of the sites, environmental variables from the previous analysis were used to identify patterns in responses within sites from pre-restoration to ten years plus post-restoration. These patterns and trends were explored through graphing each variable independently; sites were divided into two figures per response variable by whether they were a restored or natural site. Response variables included elevation, organic matter content, bulk density, and vegetation were plotted in a scatterplot to explore trends pre-restoration and in years one, three, five, and for applicate sites, a year 10+ post-restoration. Changes in elevation were explored through both RSETs and MHs data as well as elevation data collected through GNSS surveys of low marsh vegetation plots. Rather than averaging the elevations recorded at all the RSETs installed per site for each post-monitoring year, the RSET located in the low marsh of each site was selected and the elevations were plotted. Given that three MHs are associated with each RSET, an average of these MH elevations at the lowest RSET were used in addition to an average of the MHs installed without an RSET at LTR and TFH so they could be included within this exploration. Lastly, the 20^{th} percentile of the plots at each site were selected to target the lowest plots on each site and their elevations were recorded pre-restoration and during the post-restoration monitoring. An average of the lowest plots per site was used to plot the elevation changes per site using the GNSS survey data.

Further, plant species richness, halophytic species (Table 3.7) cover and abundance, vegetated area, and key plant species can be analyzed from the plots (Bowron et al., 2020). The number of “hits” within a plot is assessed as the plant species abundance while the halophytic species abundance is estimated as the total number of “hits” by halophytic species per plot to a maximum of 25 per species (as there are 25 squares within the quadrat) (Bowron et al., 2020).

Prior to analysis, values are multiplied by 4 to correspond with a cover percentage; values can be >100%. Key plant species used within this analysis included three *Sporobolus* species (formerly *Spartina sp*.) as they are the dominate grass species found within Nova Scotia's tidal marshes—their abundances were plotted to observe the change in dominant species overtime.

Table 3.7. The scientific name, common name, and synonym (if any) for the plant species considered halophytic within analysis.

Scientific Name	Common Name	Synonym
Atriplex glabriuscula	Glabrous orache	
Atriplex prostrata	Hastate orache	
Atriplex littoralis	Linear-leaved orache	
Atriplex patula	Spreading orache	
Atriplex sp.	Orache sp.	
Bolboschoenus maritimus	Saltmarsh Bulrush	*Scirpus maritimus*
Calystegia sepium	Hedge Bindweed	
Carex paleacea	Saltmarsh Sedge	
Distichlis spicata	Salt Spike Grass	
Juncus gerardii	Black Grass	
Lathyrus japonicus	Beach Pea	*Lathyrus maritima*
Limonium carolinianum	Sea Lavender	
Lysimachia maritima	Sea Milkwort	*Glaux maritima*
Plantago maritima	Seaside Plantain	
Potentilla anserina	Silverweed	*Argentina egedii*
Ranunculus cymbalaria	Alkali buttercup	
Ruppia maritima	Widgeon grass	
Salicornia depressa	Virginia glasswort	
Salicornia maritima	Glasswort	*Salicornia europaea*
Solidago sempervirens	Seaside Goldenrod	
Sonchus arvensis	Field Sow Thistle	
Spergularia canadensis	Canada sand spurrey	
Spergularia salina	Salt sand spurrey	
Sporobolus alterniflorus	Smooth cordgrass	*Spartina alterniflora*
Sporobolus pumilus	Salt meadow hay	*Spartina patens*
Sporobolus michauxianus	Broad leaf cordgrass	*Spartina pectinata*
Suaeda maritima spp maritima	Sea Blight	
Triglochin maritima	Sea Arrowgrass	
Zostera marina	Common eelgrass	

In addition, cumulative accretion was used as a proxy for net accretion. Elevations are not taken at the MHs when they are installed pre-restoration therefore, the first elevations and measurements are taken in Year 1. Without present-day RSET/MH measurements to explore net accretion, cumulative accretion was instead suggested to explore accretion; however, this was not simple given there were no pre-restoration elevations. Cumulative accretion was calculated by subtracting the net accretion from Year 1 from the Year 1 elevation at the MH to determine the elevation of the MHs. With the calculated pre-restoration elevation, it could be subtracted from the present-day elevation to determine cumulative accretion.

Chapter 4 – Results

4.1 Pre-Restoration Classification

From the initial histograms plotted to determine skew, four variables were identified as being non-normal. Transformations were conducted on the salinity, inundation time, tidal range, and organic matter variables for each site using log10; these transformed values were used in the PCA. Eigenvectors representing the correlation of the new principal components to the original values for the environmental variables were calculated for the targeted principal component axes (Table 4.1). From these scores, the first principal component has large positive associations with bulk density, elevation, SSC, tidal range, and pasture plant species. The second principal component appears to have a large positive association with inundation time, tidal range, salinity, and salt marsh plant species. There is a large positive association with salinity, pasture plant species, and organic matter content, and negative association with brackish vegetation within the third principal component. Lastly, the fourth component has large positive associations with inundation time, pasture and brackish plant species, and a large negative association with salt marsh vegetation. TFH and WS were freshwater sites pre-restoration and were not grouped within the three selected vegetation communities.

Table 4.1. Scaled eigenvectors for the environmental variables used within the PCA and the corresponding axes targeted to explain the variation within the dataset.

Sampling Method	Attained Variable	Code	PC1	PC2	PC3	PC4
RSETs	Pre-restoration Elevation	elv	1.38	0.45	0.31	-0.01
CBWES reports	Salinity	sal	-0.81	0.92	1.46	0.17
CBWES reports	Inundation time	it	0.27	1.61	-0.18	1.46
CBWES reports	Tidal range	tr	1.02	1.42	0.27	0.62
Marker horizon	Pre-restoration Elevation	mh	1.06	-1.15	0.19	0.72
Sediment cores	Organic matter	om	-1.11	-0.35	1.14	1.08
Sediment cores	Bulk density	bd	1.48	0.05	-0.43	-0.63
Vegetation Survey	Pre-restoration Vegetation	past	0.95	-0.82	1.17	1.28
Vegetation Survey	Pre-restoration Vegetation	brack	-0.57	0.56	-1.85	1.07
Vegetation Survey	Pre-restoration Vegetation	salt	0.07	1.17	0.92	-1.44

From the eigenvalues, components one through four were determined to explain 88% of the variation within the dataset. The first principal component was found to explain 38% variance whereas the second, third and fourth component explained 23%, 16%, and 11% respectfully. Each were graphed using ggplot2 in RStudio to better show the results of the analysis. The first and second principal component show clustering between BEL, SCP, and SCW and SSC (mh) and pasture plant species (past) in the bottom right quadrant (Figure 4.1). CHV and TFH can be found on opposite quadrants of the plot indicating their lack of similarity.

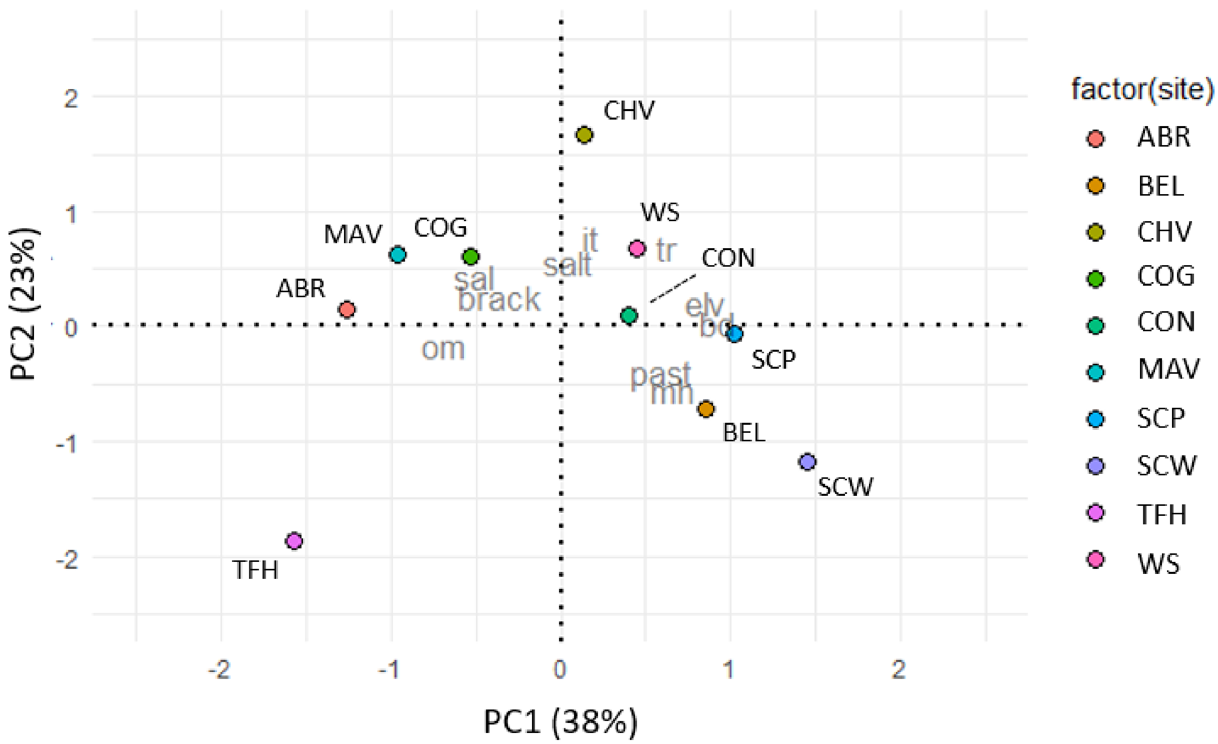


Figure 4.1. *Principal component scores for each environmental variable plotted with the restoring tidal marshes along the first and second principal component axes. Environmental variables are indicated by their abbreviation (From the* initial histograms plotted to determine skew, four variables were identified as being non-normal. Transformations were conducted on the salinity, inundation time, tidal range, and organic matter variables for each site using log10; these transformed values were used in the PCA. Eigenvectors representing the correlation of the new principal components to the original values for the environmental variables were calculated for the targeted principal component axes (Table 4.1). From these scores, the first principal component has large positive associations with bulk density, elevation, SSC, tidal range, and pasture plant species. The second principal component appears to have a large positive

association with inundation time, tidal range, salinity, and salt marsh plant species. There is a large positive association with salinity, pasture plant species, and organic matter content, and negative association with brackish vegetation within the third principal component. Lastly, the fourth component has large positive associations with inundation time, pasture and brackish plant species, and a large negative association with salt marsh vegetation. TFH and WS were freshwater sites pre-restoration and were not grouped within the three selected vegetation communities.

) and restoring sites are indicated by coloured circles.

Exploring the first and third component, CHV, CON, and BEL are clustered in the upper right quadrant (Figure 4.2). TFH remains alone while SCP has moved away from all other sites and environmental variables.

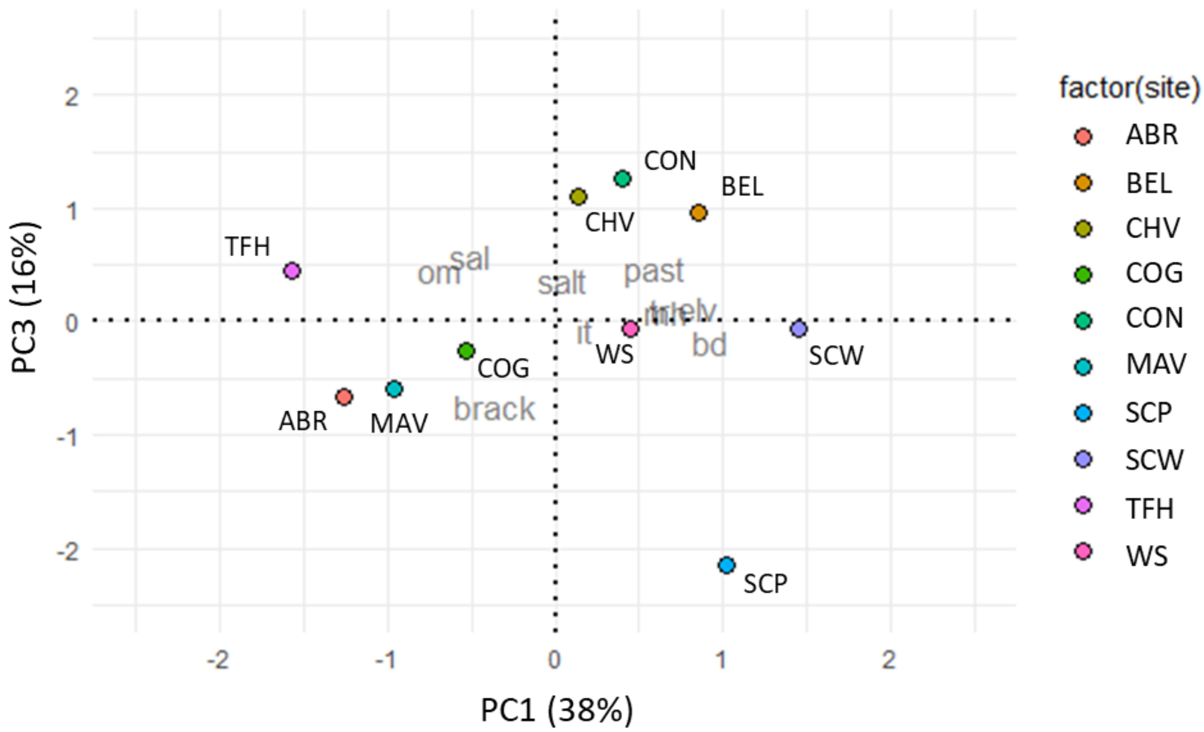


Figure 4.2. *Principal component scores for each environmental variable plotted with the restoring tidal marshes along the first and third principal component axes. Environmental variables are indicated by their abbreviation (From the* initial histograms plotted to determine skew, four variables were identified as being non-normal. Transformations were conducted on the salinity, inundation time, tidal range, and organic matter variables for each site using log10; these transformed values were used in the PCA. Eigenvectors representing the correlation of the new principal components to the original values for the environmental variables were calculated for the targeted principal component axes (Table 4.1). From these scores, the first principal component has large positive associations with bulk density, elevation, SSC, tidal range, and

pasture plant species. The second principal component appears to have a large positive association with inundation time, tidal range, salinity, and salt marsh plant species. There is a large positive association with salinity, pasture plant species, and organic matter content, and negative association with brackish vegetation within the third principal component. Lastly, the fourth component has large positive associations with inundation time, pasture and brackish plant species, and a large negative association with salt marsh vegetation. TFH and WS were freshwater sites pre-restoration and were not grouped within the three selected vegetation communities.

) and restoring sites are indicated by coloured circles.

The first and fourth component showed TFH continuing to remain alone (Figure 4.3). There are no distinct clusters observed within these axes.

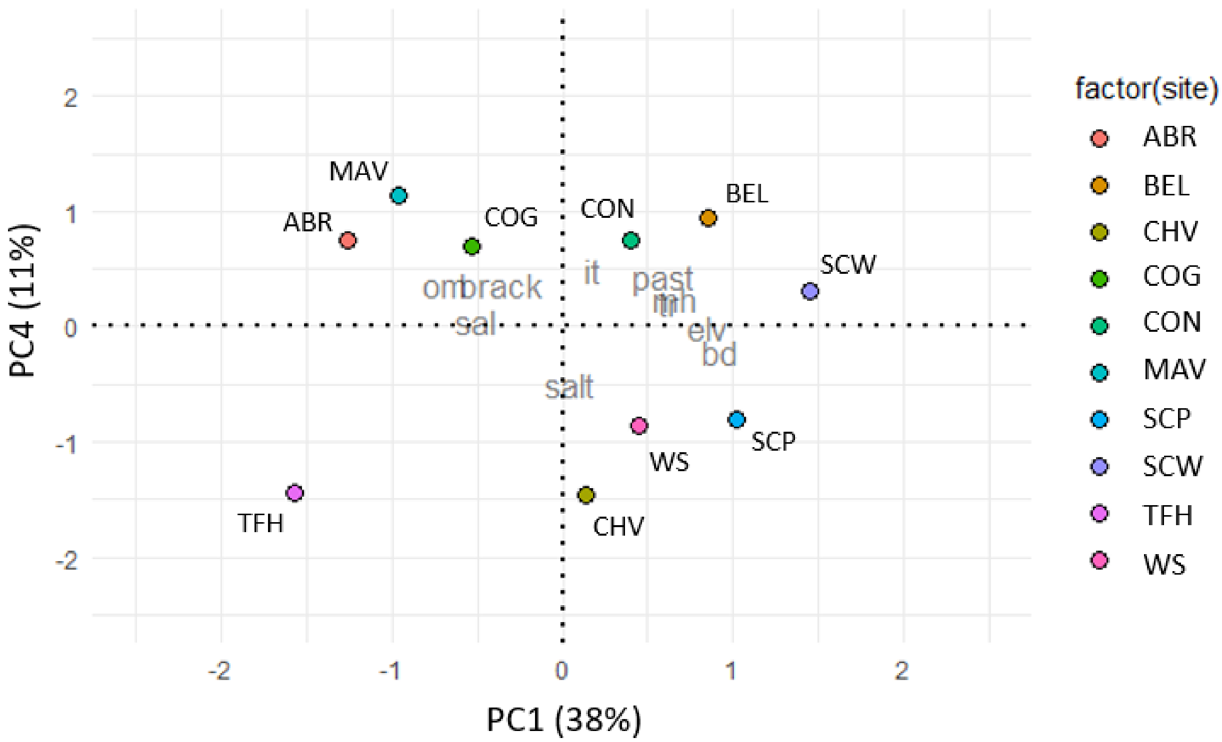


Figure 4.3. *Principal component scores for each environmental variable plotted with the restoring tidal marshes along the first and fourth principal component axes. Environmental variables are indicated by their abbreviation (Table 4.1) and restoring sites are indicated by coloured circles.*

Sediment type (sms) was added to the list of environmental variables following the initial principal component analysis to better understand the impact of sediment type on pre-restoration classification. Eigenvectors representing the correlation of the new principal components to the original values for the environmental variables were calculated for the targeted principal component axes (Table 4.2). From the scores, the first component has large associations with sediment type (sms) and organic matter content. There are also large negative associations with elevation, bulk density, SSC, and pasture plant species. Inundation time, tidal range, salinity, and salt marsh vegetation were found to have large positive associations with the second component. Lastly, the third component showed large positive associations with organic matter, salinity, and pasture plant species. TFH and WS were freshwater sites pre-restoration and were not grouped within the three selected vegetation communities.

Table 4.2. Scaled eigenvectors for the environmental variables used within the PCA and the corresponding axes targeted to explain the variation within the dataset.

Sampling Method	Attained Variable	Code	PC1	PC2	PC3
NA	Sediment type	sms	1.34	-0.38	-0.35
RSETs	Pre-restoration Elevation	elv	-1.37	0.31	0.21
CBWES reports	Salinity	sal	0.61	1.11	1.51
CBWES reports	Inundation time	it	-0.30	1.54	-0.38
CBWES reports	Tidal range	tr	-1.04	1.30	0.08
Marker horizon	Pre-restoration Elevation	mh	-0.88	-1.31	0.15
Sediment cores	Organic matter	om	1.02	-0.16	1.25
Sediment cores	Bulk density	bd	-1.37	-0.16	-0.55
Vegetation Survey	Pre-restoration Vegetation	past	-0.84	-0.93	1.12
Vegetation Survey	Pre-restoration Vegetation	brack	0.54	0.56	-1.87
Vegetation Survey	Pre-restoration Vegetation	salt	-0.17	1.2	0.85

From the eigenvalues, components one through three were determined to explain 86% of the variation within the dataset. The first principal component was found to explain 46% variance whereas the second component and third component explained 23% and 17% respectfully. Each were graphed using ggplot2 in RStudio to better show the results of the analysis. The first and second principal component show clustering between BEL, SCP, and SCW and SSC (mh), pasture plant species (past), and bulk density (bd) in the bottom left quadrant (Figure 4.4). Within these axes, there was also clustering of COG, MAV, and ABR with salinity (sal) and brackish vegetation (brack). CHV and TFH can be found on opposite quadrants of the plot indicating their lack of similarity.

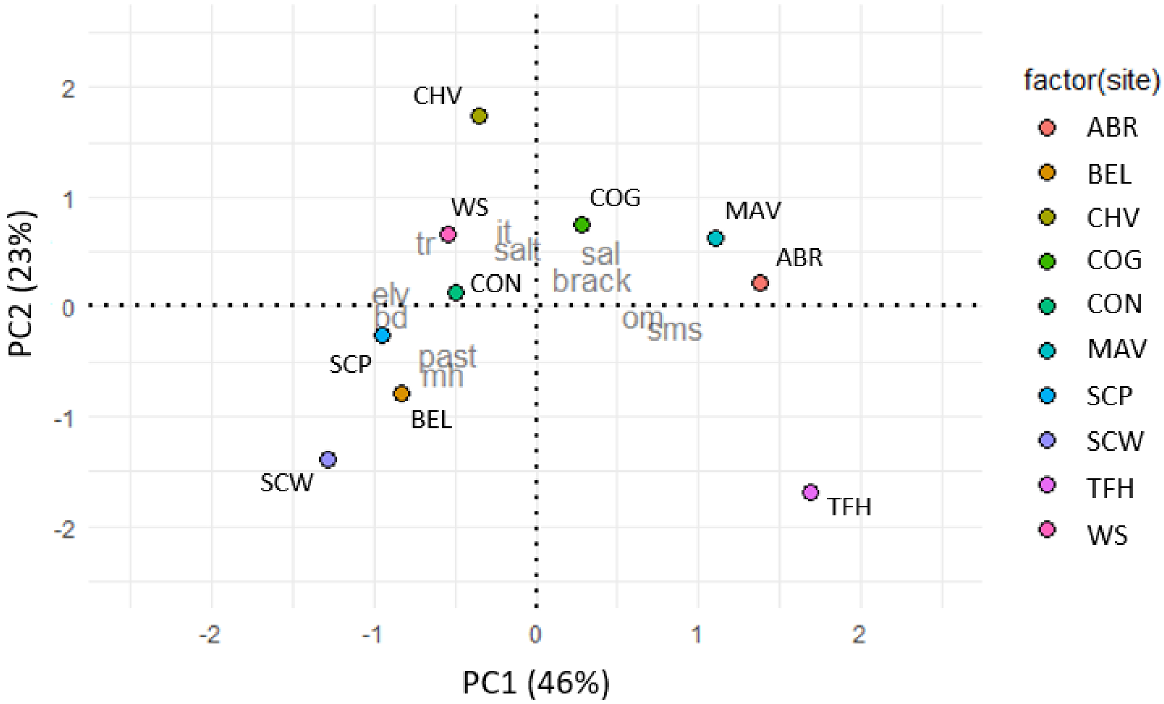


Figure 4.4. *Principal component scores for each environmental variable plotted with the restoring tidal marshes along the first and second principal component axes. Environmental variables are indicated by their abbreviation (Table 4.2) and restoring sites are indicated by coloured circles.*

Exploring the first and third component, TFH remains alone in the upper right quadrant and SCP has moved away from the other sites and environmental variables (Figure 4.5). There are no distinct clusters observed within these axes.

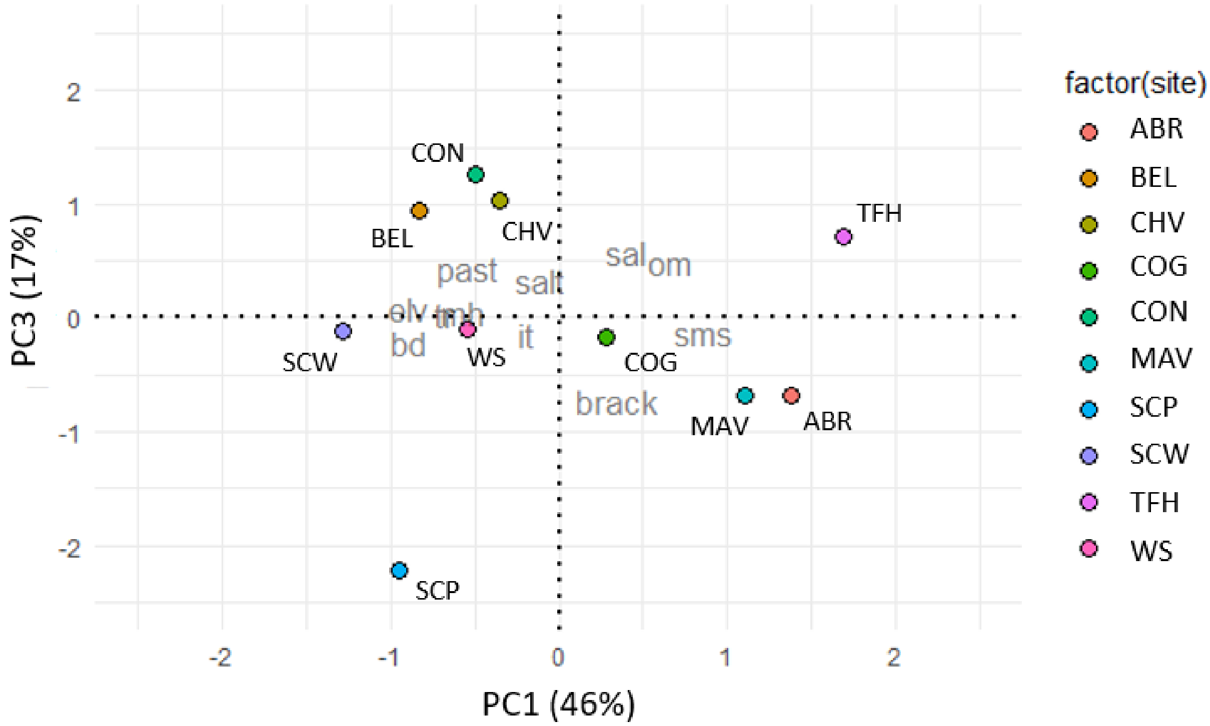


Figure 4.5. *Principal component scores for each environmental variable plotted with the restoring tidal marshes along the first and third principal component axes. Environmental variables are indicated by their abbreviation (Table 4.2) and restoring sites are indicated by coloured circles.*

4.2 Restoration Trajectory – Sites

Scatterplots highlighting the change in elevation, organic matter content, bulk density, and vegetation during pre- and post-restoration were created to better visualize the trajectory of each variable and how it influences restoration trajectory at each site. Vegetation data included the abundances of three *Sporobolus* species commonly found on tidal marshes. All elevations are in CGVD2013, error bars are in standard error, and a 'jitter'[15] was applied to avoid overlap of points within the figures.

[15] https://sociology.fas.harvard.edu/files/sociology/files/scatterplots.pdf

4.2.1 Elevation – Low Marsh GNSS Survey

Elevations collected at low marsh plots measured through GNSS surveys were plotted at the restoration (Figure 4.6-A) and reference (Figure 4.6-B) sites. From this exploration of plot data between pre-restoration and Year 1 post-restoration, elevations at ABR, CHV, and WS remained the same and decreased at COG (-0.11 m) and CON (-0.06 m) (Figure 4.6-A). During this time, there were increases in elevation at the other sites with the largest increase occurring at TFH (+0.19 m), followed by BEL and SCP (+0.07 m) (Figure 4.6-A). Rapid increases in elevation between Year 1 and Year 3 were recorded at BEL (+0.43 m) and TFH (+0.16 m) while this occurred later, in Year 5, at CHV (+0.68 m) (Figure 4.6-A). Between pre-restoration and Year 3, ABR elevations increased from 0.23 m to 0.30 m and MAV elevations saw an increase from 1.35 m to 1.41 m in Year 3 (Figure 4.6-A). During this time, elevations at CON continued to decrease from 6.10 m pre-restoration to 5.82 m in Year 3 (Figure 4.6-A). By Year 5 post-restoration, low marsh plot elevations at BEL, CHV, SCP, SCW, and TFH were higher than those recorded pre-restoration (Figure 4.6-A). The largest increase during this period was at CHV (+0.68 m), followed by BEL (+0.58 m) and TFH (+0.39); during this time, elevations decreased at WS (-0.18 m) (Figure 4.6-A). For restoring sites in Year 10+, elevations at COG and WS, which were below pre-restoration elevations in Year 5, had increased to exceeding pre-restoration values (Figure 4.6-A). By Year 10+ post-restoration, all sites increased in elevation except for CHV which had a Year 5 elevation of 4.72 m and had decreased to 4.58 m—CHV elevations were higher than pre-restoration despite the decrease in Year 10+ (Figure 4.6-A).

Elevations in the low marsh plots at the reference sites showed slight increases at ABR-R (0.06 m) and MAV-R (0.1 m) from pre-restoration to Year 3, similar to the trends observed at the corresponding restoring sites (Figure 4.6-B). Between pre-restoration and Year 5, elevations at

BAS plateaued and were steady but increased between Year 5 and Year 10+ (+0.53 m) (Figure 4.6-B). Elevations at WRS began increasing in Year 3 (+0.1 m) and continued into Year 5 and Year 10+; between pre-restoration and Year 10+, elevations increased from 4.42 m to 4.77 m at WRS (Figure 4.6-B). At COR, elevations fluctuated across all years; however, by Year 10+, elevations rose by 0.36 m from the recorded pre-restoration elevation (Figure 4.6-B). Lastly, elevations of low marsh plots at LTR remain below 0 m however, there was an increase in elevation between pre-restoration and Year 10+ (+0.09 m) (Figure 4.6-B). When comparing the low marsh plot elevations at the restoration and reference sites, ABR-R had higher elevations than ABR across all years while MAV-R had lower elevations than MAV (Figure 4.6). CHV had lower elevations than BAS (except in Year 5) while COG had higher elevations than the reference site (COR); WRS had higher elevations than WS across all years (Figure 4.6).

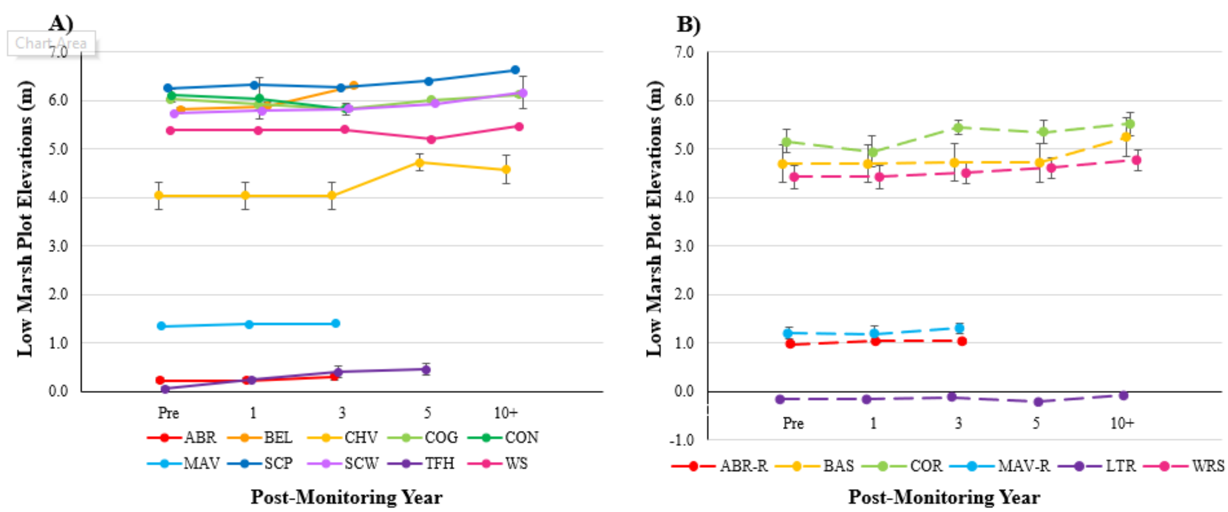


Figure 4.6. *Elevations of low marsh plots at A) restoration and B) reference sites surveyed during pre-restoration and years 1, 3, 5, and 10+ post-restoration. Error bars are in standard error and plots were jittered to avoid overlap of the data points.*

4.2.2 Elevation –Marker Horizons

Surface elevation at the MHs associated with the low marsh RSETs examined in Figure 4.7 were averaged and plotted over the indicated post-monitoring years; MHs not associated with an

RSET were installed at LTR and TFH and are included in these plots. Elevations at MHs increased slightly each year at ABR, BEL, MAV, SCP, SCW, and TFH whereas no change was recorded at CON (where Year 1 data was missing) during the same period of time (Figure 4.7-A). At CHV, MH elevations decreased between Year 3 and Year 5 from 5.56 m to 5.29 m however, elevations increased in Year 10+ (5.58 m) and are similar to those recorded in Year 1 (Figure 4.7-A). MH elevations at COG decreased in Year 3 (-0.22 m) but by Year 10+, had exceeded the Year 1 recorded elevation, increasing from 6.16 m to 6.21 m (Figure 4.7-A). Similar to COG, elevations at WS decreased in Year 5 (-0.08 m) but had increased and exceeded Year 1 values by Year 10+ (5.61 m to 5.64 m) (Figure 4.7-A).

Low marsh MH elevations at the reference sites showed similar trends to the restoring sites (Figure 4.7-B). ABR-R elevations increased slightly between Year 1 and Year 3 (+0.03 m) while elevations at MAV-R remained the same (1.36 m) (Figure 4.7-B). Between Year 3 and Year 5, elevations at BAS decreased from 5.11 m to 5.03 m and at WRS, elevations decreased 0.22 m (5.88 m to 5.66 m) (Figure 4.7-B). By Year 10+, elevations of the low marsh MHs increased and exceeded recorded values from Year 1 at BAS (5.74 m) and WRS (5.92 m) (Figure 4.7-B). Similar to COG, MH elevations at COR decreased between Year 1 and Year 3 (-0.11 m) however, by Year 10+, COR elevations increased from 6.58 m in Year 1 to 6.67 m (Figure 4.7-B). Lastly, elevations at LTR were higher by Year 10+ (0.04 m) than recorded elevations from Year 1 (-0.01 m) (Figure 4.7-B); elevations at this site increased between Year 5 and Year 10+ by 0.11 m.

When comparing the MH elevations of the restoration and reference sites, ABR-R had higher elevations across all years compared to ABR, whereas, the opposite was observed at MAV-R; MAV had higher elevations across all years (Figure 4.7). BAS had higher MH elevations in the low marsh than CHV in Year 10+; prior surveys found CHV MH elevations higher up until Year 5 post-restoration (Figure 4.7). Both COR and WRS had higher elevations than their corresponding restoration sites, COG and WS, across all years (Figure 4.7). Elevations at LTR were much lower (-0.67 m in Year 5) than TFH across all years (Figure 4.7).

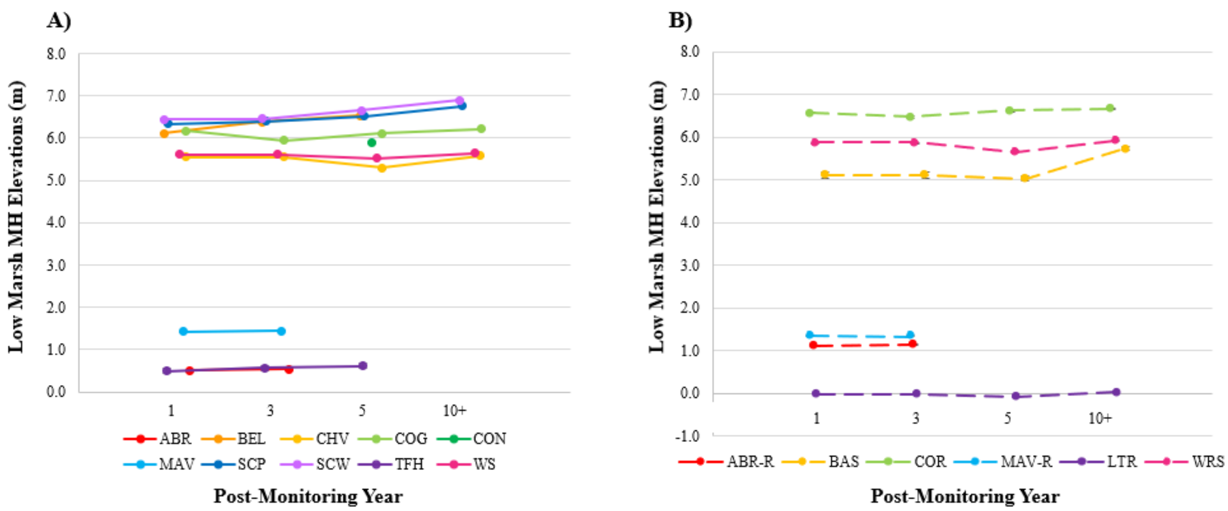


Figure 4.7. *Elevations of MHs associated with low marsh RSETs at A) restoration and B) reference sites surveyed during years 1, 3, 5, and 10+ post-restoration. Error bars are in standard error and plots jittered to avoid overlap.*

4.2.3 Cumulative Accretion - Marker Horizons

Total cumulative accretion was derived from the MH data and measured surface elevations for the restoring (Figure 4.8-A) and reference (Figure 4.8-B) sites. At the restoring sites between pre-restoration and Year 1, BEL had the highest net accretion at 27.0 cm, followed by SCW (18.3 cm) and SCP (9.3 cm) (Figure 4.8-A). By Year 2, BEL continued to have the highest cumulative accretion and also had the highest net accretion between Year 1 and Year 2 (+ 6.2 cm), followed by SCP (+4.5 cm) and SCW (+3.6 cm) (Figure 4.8-A). When exploring ABR, CON and MAV, CON had the highest cumulative accretion from pre-restoration to Year 3 (+7.7 cm), followed by ABR (+6.2 cm) and MAV (+1.7 cm) (Figure 4.8-A). SCW had the highest cumulative accretion from pre-restoration to Year 4 (+44.2 cm) and the highest net accretion between Year 3 and Year 4 (+11.2 cm), followed by SCP (+7.3 cm) (Figure 4.8-A). By Year 5, SCW continued to have the highest cumulative accretion (+46.0 cm) whereas WS had the lowest cumulative accretion at 4.0 cm between pre-restoration and Year 5 (Figure 4.8-A). In Year 6, CHV and WS both saw increases in their cumulative accretion which continued into Year 7; WS had the largest increase in accretion from 4.0 cm to 6.0cm during this period compared to CHV (4.8 cm to 5.3 cm) (Figure 4.8-A). Cumulative accretion at TFH in Year 7 was 6.6 cm; the largest increase in net accretion occurred between Year 1 and Year 3 (+2.8 cm) (Figure 4.8-A).

By Year 13, cumulative accretion since pre-restoration was highest at SCW at 63.4 cm, followed by SCP at 50.3 cm and COG at 4.8 cm; cumulative accretion at COG decreased from 5.3 cm in Year 5 to 4.8 cm in Year 13 (Figure 4.8-A). CHV and WS had a cumulative accretion from pre-restoration to Year 17 of 2.2 cm and 4.6 cm respectively; both experienced decreases in accretion between Year 5 and Year 17 (Figure 4.8-A). When exploring the sites with Year 10+ data, only SCP and SCW had a total cumulative accretion at the marker horizons that was higher than the reported Year 5 values (Figure 4.8-A). The largest decrease in cumulative accretion during this period occurred at CHV which decreased from 5.3 cm in Year 5 to 2.2 cm in Year 17 (Figure 4.8-A).

At the reference sites, the highest net accretion at the marker horizons between pre-restoration and Year 1 was recorded at WRS (+0.8 cm), followed by COR (+0.7 cm) and MAV-R (+0.4 cm); LTR saw the smallest increase during this period (+0.05 cm) (Figure 4.8-B). In Year 2, only BAS, COR, and LTR had reported data—cumulative accretion was highest at LTR (1.86 cm) (Figure 4.8-B). BAS saw a net accretion of 0 cm in Year 2 (Year 1 data was not available) (Figure 4.8-B). At WRS in Year 2, there was a net accretion of 17.9 cm however, this was likely due to a melted block of ice (as reported) and was determined to not be representative of the cumulative accretion—this value was excluded from the scatterplot. In Year 3, cumulative accretion was highest at LTR at 2.8 cm, followed by MAV-R (2.4 cm) and COR (2.2 cm); BAS had the lowest cumulative accretion during this period at 0.4 cm (Figure 4.8-B). Between pre-restoration and Year 3, cumulative accretion at ABR-R was 0.6 cm (Figure 4.8-B). All reference sites saw an increase in cumulative accretion in Year 4 with LTR continuing to have the highest cumulative accretion (Figure 4.8-B). By Year 5, COR had the highest cumulative accretion (4.0 cm), followed by LTR and WRS (2.1 cm) (Figure 4.8-B). From pre-restoration to Year 7, cumulative accretion at the marker horizons at BAS was 2.6 cm compared to WRS in which cumulative accretion was 4.7 cm (Figure 4.8-B).

BAS, COR, LTR, and WRS have data for Years 10+ and all reference sites showed an increase in their total cumulative accretion between Year 5 and Year 10+ (Figure 4.8-B). By Year 13 at COR, cumulative accretion increased from 4.0 cm in Year 5 to 9.7cm (Figure 4.8-B). LTR had an increase in cumulative accretion from 2.1 cm in Year 5 to 6.8 cm in Year 15 (Figure 4.8-B). In Year 17, cumulative accretion at WRS increased from 4.7 cm to 5.5 cm however, the largest increase during this period occurred at BAS which saw an increase in cumulative accretion from 2.6 cm to 63.0 cm (+60.4 cm) (Figure 4.8-B).

When comparing the restoring sites to the reference sites, cumulative accretion was generally higher at the restoring sites. Between pre-restoration and Year 1, the restoring sites all had larger increases in cumulative accretion than the reference sites (Figure 4.8). In Year 3, only one reference site had a higher cumulative accretion than its restoring site which was MAV-R (Figure 4.8). All of the restoring sites had higher cumulative accretion rates than their original paired reference site by Year 5—this does not include BEL, SCP and SCW which had the highest cumulative accretion of all restoring sites as their reference sites were not included in this study (Figure 4.8). This trend, however, does not continue in Years 10+ as all of the reference sites had higher cumulative accretion rates than their restoring sites—the largest difference is observed when comparing Year 17 at CHV (2.2 cm) and BAS (63.0 cm) (Figure 4.8).

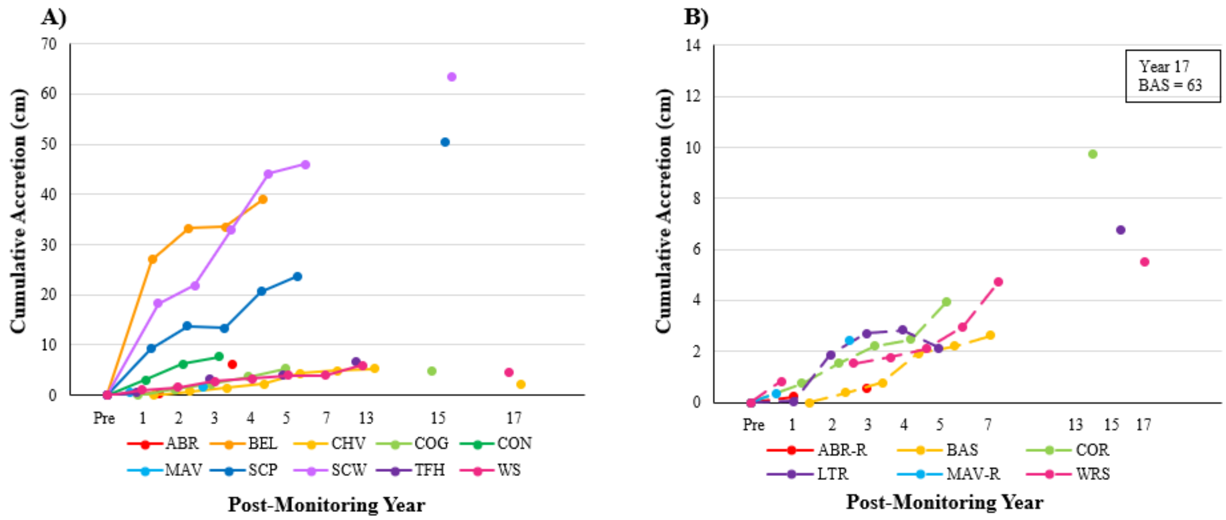


Figure 4.8. *The cumulative accretion measured at the marker horizons from Year 1 to the 2022 survey which spanned various post-monitoring years: A) at the restorations sites and B) at the reference sites. All accretion measurements are in centimeters and plots were jittered to better visualize the results.*

4.2.4 Soils and Sediments

A scatterplot of average organic matter by each site overtime showed a large decrease in organic matter content at all restoring sites between pre-restoration and Year 1 (Figure 4.9-A); The largest decrease in OM content during this period was at CON which dropped by 42.8%, followed by COG which experienced a decrease of 38.1%, and BEL which dropped by 24.6% (Figure 4.9-A). Decreases in OM content continued between Year 1 and Year 3 at all sites except SCW (+0.5%) and WS (+1.7%) (Figure 4.9-A). By Year 5, the site with the highest organic matter content was TFH at 51.5% while SCW had the lowest at 5.5% (Figure 4.9-A). Due to experimentation with new equipment, there are no pre-restoration and Year 1 post-restoration values for MAV and MAV-R, however, in Year 3, their average organic matter content was

2.1% and 1.9% respectively (Figure 4.9-A). Overall, MAV and MAV-R had the lowest average OM content across all sites. Alongside the restoring sites, reference sites were also plotted by average organic matter (Figure 4.5-B). Between pre-restoration and Year 1, the organic matter content increased at LTR by 23.4% (Figure 4.9-B). Increases were also observed at BAS and WRS while decreases occurred at ABR-R and COR (Figure 4.9-B).

There is a cluster of sites which contained less than 20% organic matter by Year 5 and these were all sites located around the Minas Basin, except for MAV and MAV-R but had low OM values (Figure 4.9). The sites with the highest Year 5 OM content are all located on the Atlantic coast of Nova Scotia—LTR, TFH, ABR, and ABR-R. For the sites which are 10+ years post-restoration, all sites exhibited a decrease in OM content between Year 5 and Year 10+ with LTR having the highest decline at 9.5% and SCW having the lowest decrease at 0.3% (Figure 4.9). The cluster of Minas Basin sites remain at the bottom of the graphic below 20.0% OM content whereas LTR remains high at 36.8% (Figure 4.9).

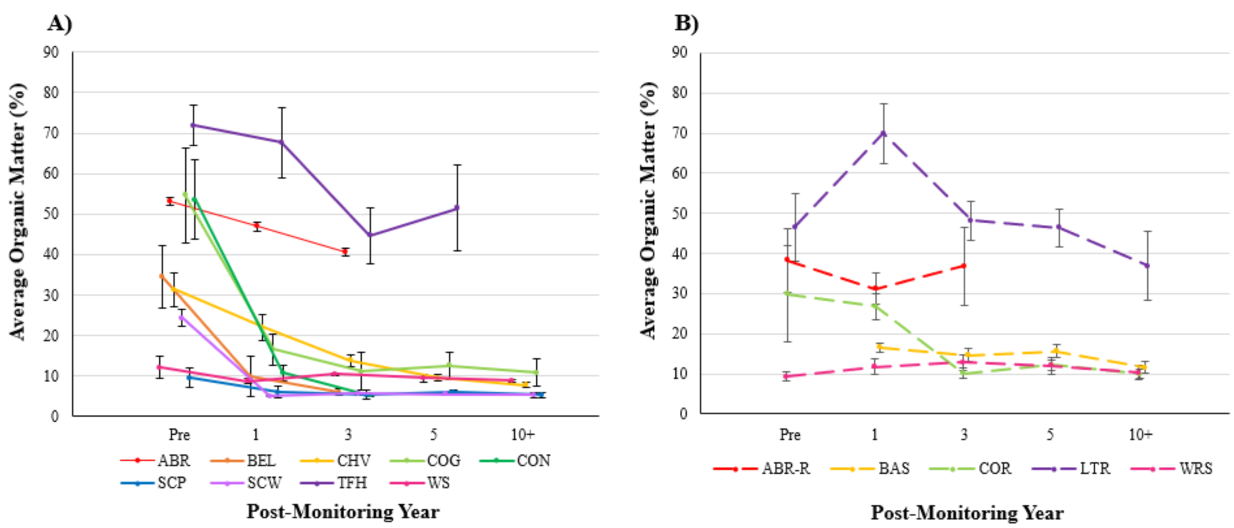


***Figure 4.9**. Scatterplots with lines and makers showing the average organic matter content of each site: A) Restoring sites prior to restoration—indicated by 'Pre'—and the monitoring year post-restoration—indicated by 1, 3, 5, or 10+, and B) Reference sites included in this study with their paired data from 'Pre' and the post-monitoring years 1, 3, 5, or 10+. OM contents are in percentages. Error bars are in standard error and plots jittered to avoid overlap.*

Scatterplots of average bulk densities for restoring sites (Figure 4.10-A) and reference sites (Figure 4.10-B) pre- and post-restoration showed a distinct cluster of sites at the bottom of the figure, a cluster of sites between 0.50 g·cm^{-3} and 0.60 g·cm^{-3}, and a cluster with bulk densities of above 0.70 g·cm^{-3}. The bottom cluster consists of ABR, ABR-R, LTR, and TFH with LTR having the lowest bulk density at 0.15 g·cm^{-3} (Figure 4.10). MAV and MAV-R, which are not in the figure due to lack of data, had Year 3 bulk densities of 0.15 g·cm^{-3} and 0.20 g·cm^{-3} respectively, putting them within this cluster as well. The middle cluster of sites were BAS, CHV, COG, COR, and WRS with the lowest of this cluster being COR at 0.51 g·cm^{-3} and CHV having the highest at 0.63 g·cm^{-3} (Figure 4.10). The upper most cluster consists of BEL, CON, SCP, SCW, and WS with the lowest bulk density being WS at 0.73 g·cm^{-3} and the highest being SCP at 0.82 g·cm^{-3} (Figure 4.10). At Year 10+, the bulk density of WS dropped from 0.73 g·cm^{-3} in Year 5 to 0.43 g·cm^{-3} and bulk density at SCW increased by 0.26 g·cm^{-3} (Figure 4.10). The bulk density of LTR increased between Year 5 and Year 10+ by 0.1 g·cm^{-3} (Figure 4.10).

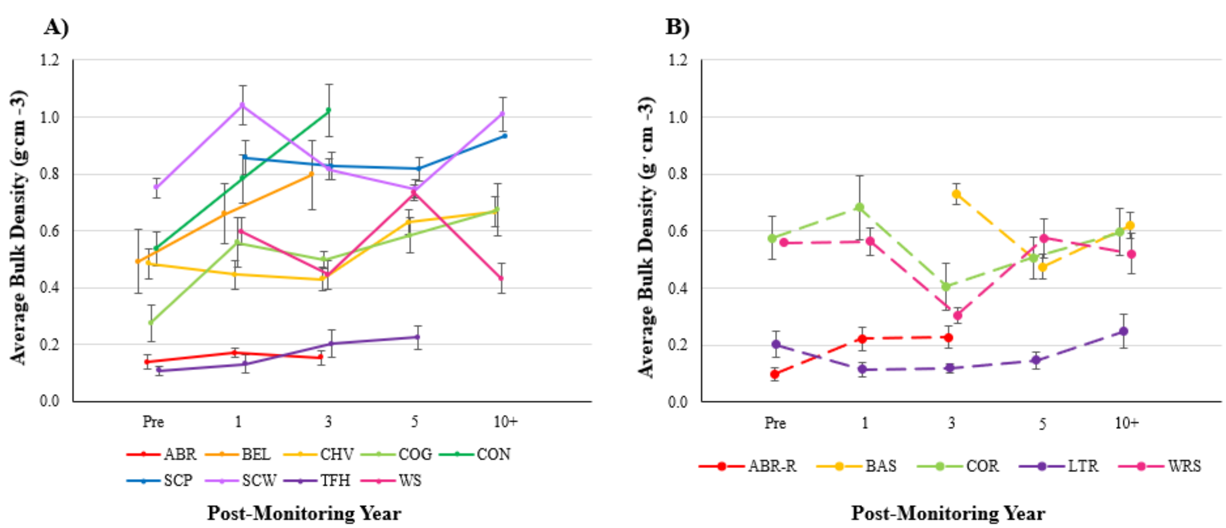


Figure 4.10. *Scatterplots with lines and makers showing the average bulk densities of each site: A) restoring sites prior to restoration—indicated by 'Pre'—and the monitoring year post-restoration—indicated by 1, 3, and 5, and B) Reference sites included in this study with their paired data from 'Pre' and the post-monitoring years 1, 3, 5, or 10+. Error bars are in standard error and plots jittered to avoid overlap.*

4.2.5 Vegetation – Plot Data and Cover

Following construction, the mean number of species per plot decreased at ABR, BEL, COG, CON, MAV, and TFH between pre-restoration and Year 1 post-restoration with the largest decrease occurring at MAV (-3.6 species), followed by BEL (-3.5 species) ((Figure 4.11-A). This value dipped slightly at CHV (-0.4 species) during this same period whereas increases were observed at SCP, SCW, and WS (Figure 4.11-A). Data for ABR, BEL, CON, and MAV currently do not extend past Year 3 however, all but ABR showed an increase in between Year 1 and Year 3; between pre-restoration and Year 3, mean species per plot at ABR decreased from 3.4 to 2.0 (Figure 4.11-A). By Year 5, the number of species at TFH continued to decrease slowly with pre-restoration having 7.6 species per plot and Year 5 having 4.8 species (Figure 4.11-A). Values remained higher than pre-restoration at all other sites except for SCP (-0.4 species) (Figure 4.11-A). At 10+ years post-restoration, the mean number of species per plot at CHV, COG, and SCP was lower than the pre-restoration values while values at SCW and WS were higher than their pre-restoration values (Figure 4.11-A). The largest decline occurred at CON which went from 4.0 species to 2.8 species per plot whereas SCW plot species increased from 2.9 to 3.4 species (Figure 4.11-A).

At the reference sites, all sites showed a decrease in the mean number of species per plot between pre-restoration at the restoring site and the final monitoring year recorded except for ABR-R; the mean number of species has continued to increase at ABR-R throughout post-monitoring (Figure 4.11-B). By Year 3, ABR-R continued to increase in mean species per plot with species increasing from 2.2 pre-restoration to 4.2; at MAV-R, the mean species per plot decreased from 5.7 pre-restoration to 5.5 by Year 3 (Figure 4.11-B). By Year 5, BAS, COR, and LTR showed an increase in the mean number of species per plot whereas WRS species were decreasing—mean species decreased from 2.8 to 2.3 per plot from pre-restoration to Year 5 (Figure 4.11-B). Mean species per plot decreased at BAS, COR, LTR, and WRS between Year 5 and Year 10+ and only BAS continued to contain more species per plot in Year 10+ than pre-restoration (from 2.78 to 2.84 species) (Figure 4.11-B). The largest decline in mean species per plot between pre-restoration and Year 10+ was WRS (-0.7 species) (Figure 4.11-B).

When examining restoring and reference sites that were paired during the original monitoring program, the mean number of species per plot were higher at ABR-R and MAV-R than their restoring sites, ABR and MAV (Figure 4.11). At 10+ years post-restoration, restoring sites CHV, COG, and WS had a higher mean number of species per plot than their reference sites, BAS, COR and WRS respectively (Figure 4.11). TFH, while not yet at 10 years post-restoration, also has higher values than its paired reference—LTR—which showed a decrease between Year 5 and Year 10+ (Figure 4.11).

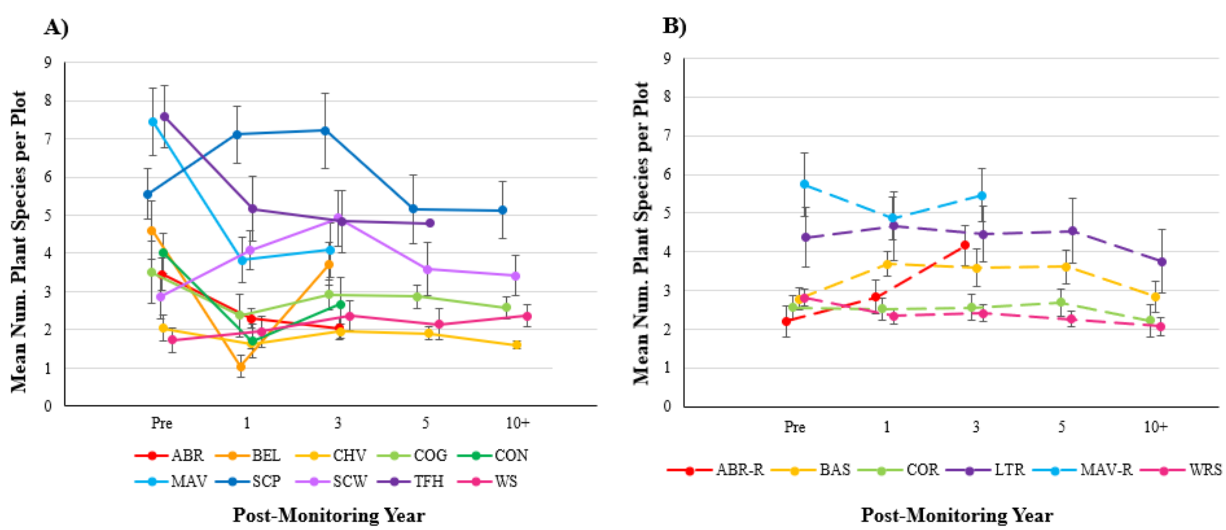


Figure 4.11. *Vegetation plot data summaries showing the mean number of plant species per plot from pre-restoration and years 1, 3, 5, and 10+ post-restoration at A) the restoring sites and, B) the references sites, within this research. Error bars are in standard error and plots jittered to avoid overlap.*

Halophytic species richness per plot increased at all restoring sites between pre-restoration and Year 1 except at BEL and TFH; the number of halophytic species at BEL decreased from 0.25 species to 0.05 whereas there was no change at TFH (Figure 4.12-A). By Year 3 at ABR and MAV, halophytic species richness per plot had decreased from Year 1 (-0.2 and -0.5 respectively) while during the same period, halophytic species increased at BEL and CON (+1.5 and +0.5 species respectively) (Figure 4.12-A). At TFH, by Year 5, halophytic species richness per plot continued to slowly increase since pre-restoration from 0.3 species to 0.6 species (Figure 4.12-A). When observing restoring sites at Year 10+, halophytic species richness per plot at SCP increased from 0.2 species pre-restoration to 0.63 species while SCW halophytic species increased from 0 to 1.4 species per plot during the same time (Figure 4.12-A). By Year 10+ post-restoration, WS halophytic species richness per plot increased from 0.74 pre-restoration to 2.3 species, CHV saw an increase from 1.4 to 1.5 species, and COG increased from 0.4 to 2.0 species (Figure 4.12-A).

Halophytic species richness within the plots at the reference sites between pre-restoration and Year 1 post-restoration increased at ABR-R and BAS, and decreased at LTR, MAV-R, and WRS; there was no change at COR (Figure 4.12-B). During this period, the largest increase in the number of halophytic species per plot occurred at ABR-R (+0.5 species) whereas WRS experienced the largest decrease (-0.3 species) (Figure 4.12-B). By Year 3, mean halophytic species richness per plot at ABR-R increased from 1.8 species pre-restoration to 3.4 species and MAV-R increased from 2.0 species pre-restoration to 2.5 species (Figure 4.12-B). By Year 5, halophytic species richness at BAS increased from 2.4 species pre-restoration to 2.9 species per plot; increases since pre-restoration also occurred at COR (+0.3 species), and LTR (+0.6 species) (Figure 4.12-B). Halophytic species richness decreased in both Year 3 and Year 5 at WRS—from pre-restoration to Year 5, halophytic species richness decreased from 2.6 species to 2.2 species (Figure 4.12-B). Between Year 5 and Year 10+, for the reference sites in which this data is available, all sites showed a decrease in halophytic species (BAS, COR, LTR, and WRS) (Figure 4.12-B). The largest decrease occurred during this time at BAS (2.9 to 2.2 species), followed by COR (2.7 to 2.1 species) and LTR (2.4 to 1.8 species) (Figure 4.12-B). By Year 10+, all sites—BAS, COR and WRS—had experienced a decreased in their halophytic species richness counts per plot from their pre-restoration except for LTR which saw no change (Figure 4.12-B). Upon comparing the paired restoring and reference sites, all reference sites had higher mean halophytic species richness per plot than their restoring sites except for WRS, which had been decreasing since the pre-restoration survey (Figure 4.12-B).

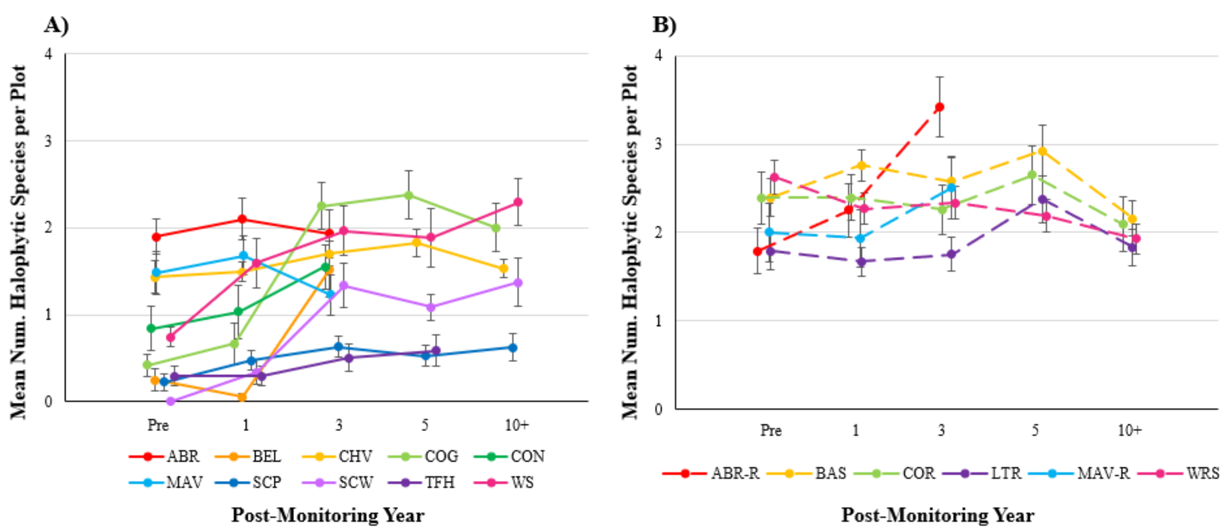


Figure 4.12. *Vegetation plot data summaries showing the mean number of halophytic plant species per plot from pre-restoration and years 1, 3, 5, and 10+ post-restoration at A) the restoring sites and, B) the references sites, within this research. Error bars are in standard error and plots jittered to avoid overlap.*

When exploring mean halophytic species cover per plot at the restoring sites, increases were observed at CHV, CON, MAV, SCP, SCW, and TFH between pre-restoration and Year 1 post-restoration (Figure 4.13-A). The largest increase in halophytic cover was at CHV (+36.5%), followed by SCP (+17.4%) and CON (+5.4) (Figure 4.13-A). During this period, halophytic species cover decreased at ABR, BEL, COG, and WS; ABR showed the largest decrease per plot (-15.3) (Figure 4.13-A). Halophytic cover increased rapidly at BEL (+58.7), COG (+65.4), SCW

(+67.4), and WS (+65.8) in Year 3 while cover decreased at MAV (-8.4) (Figure 4.13-A). There was an increase in Year 3 at ABR (+3.0 overall), BEL (+55.6 overall), and CON (+23.3 overall) whereas during this same period, MAV experienced a decline in halophytic cover (-7.1 overall) (Figure 4.13-A). By Year 5, all sites had halophytic species cover values higher than their pre-restoration values per plot with COG having the highest cover per plot (Figure 4.13-A). By Year 10+, halophytic species cover decreased at all sites except WS; however, Year 10+ values continue to be higher than recorded values during pre-restoration (Figure 4.13-A).

At the reference sites between pre-restoration and Year 1, mean halophytic species cover per plot decreased at LTR (-0.7) and MAV-R (-12.6) while all other sites saw an increase; BAS saw the largest increase from 62.4 to 116.2 (Figure 4.13-B). By Year 3, increases were observed at ABR-R and MAV-R; between pre-restoration and Year 1, ABR-R cover increased from 123.4 to 159.7 whereas MAV-R cover increased from 105.7 to 128.3 (Figure 4.13-B). By Year 5, halophytic species cover had increased at all sites—BAS, COR, LTR, and WRS—since pre-restoration; the largest increase in halophytic cover per plot from pre-restoration to Year 5 was at BAS (+78.9) (Figure 4.13-B). Halophytic species cover, by Year 10+, decreased at all sites except LTR which increased slightly (+4.3); values recorded at COR, LTR, and WRS in Year 10+ continued to be higher than the values initially recorded during the pre-restoration (Figure 4.13-B). When comparing the halophytic cover per plot between the restoration and reference sites, all of the reference sites had higher pre-restoration values than their corresponding restoring site (Figure 4.13). All reference sites had higher halophytic cover than their restoring sites across all years except WRS which had lower cover in Year 10+ than WS (Figure 4.13).

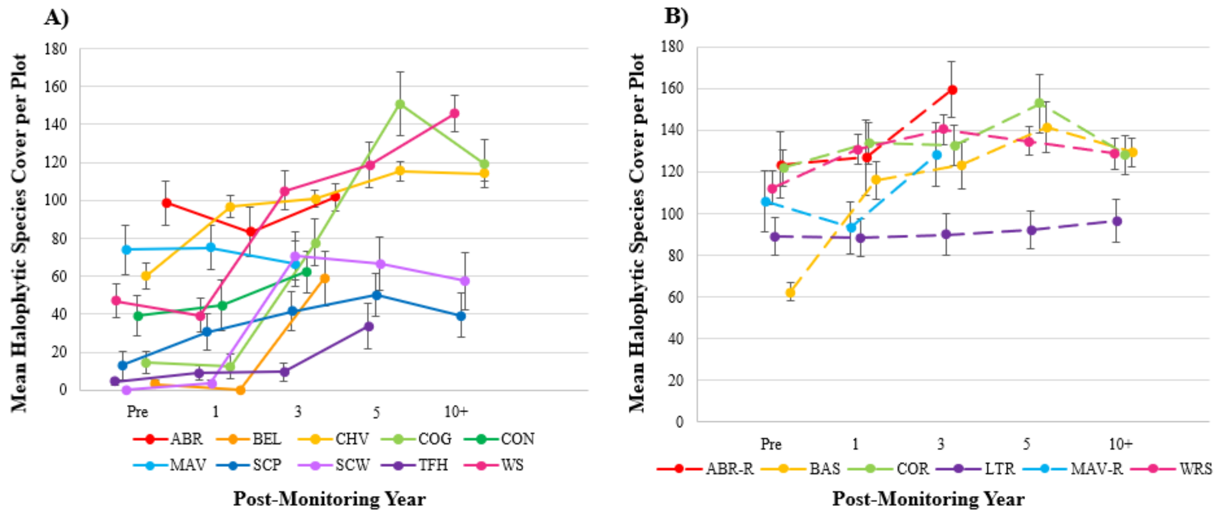


Figure 4.13. *Vegetation plot data summaries showing the mean halophytic species cover per plot from pre-restoration and years 1, 3, 5, and 10+ post-restoration at A) the restoring sites and, B) the references sites, within this research. Error bars are in standard error and plots jittered to avoid overlap.*

Vegetated area per plot following construction decreased at all restoring sites except for SCP—in which no change was recorded—and WS in which an increase from 66.5% to 100% cover occurred (Figure 4.14-A). The largest decrease during this time occurred at BEL which dropped from 94.8% to 32.8%, followed by CON which decreased 92.8% to 42.3% (Figure 4.14-A). Between Year 1 and Year 3, rapid increases in vegetated area occurred at BEL (+53.1) and COG (+55.3); by Year 3, all sites had vegetated area values above 75% except CON which had the lowest vegetated area at 56.6% (Figure 4.14-A). Vegetated area per plot by Year 5 was >90% at all restoring sites with Year 5 data except for TFH at 78.4% (Figure 4.14-A). At Year 10+, all five restoring sites—CHV, COG, SCP, SCW, and WS—had vegetated areas within the plots of 100% (Figure 4.14-A). All sites had higher vegetated area per plot in their most recent vegetation survey than pre-restoration except TFH which in Year 5 had a vegetated area of 78.2% (-5.8% since pre-restoration) (Figure 4.14-A).

At the reference sites, vegetated cover remained above 80% across all years and all sites (Figure 4.14-B). There was little change in ABR-R vegetated area until Year 3 when cover rose from 83.3% to 95.5% while MAV-R remained above 98% in all years plotted (Figure 4.14-B). By Year 5, LTR vegetated area within the plots began to decrease from 95.8% in Year 3 to 85.3% while all other reference sites were >99% (Figure 4.14-B). Vegetated area in Year 10+ within the plots was 100% at all reference sites except for LTR (90.7%) (Figure 4.14-B). When comparing vegetated area at the restoring sites and the reference sites, ABR-R had lower vegetated area than ABR pre-restoration however, by Year 3, vegetated area per plot at ABR-R was higher than ABR (95.5% and 84.8% respectively) (Figure 4.14). Similar to ABR-R, MAV-R had lower vegetated area within the plots pre-restoration than MAV but by Year 3, had reached 100% cover whereas MAV vegetated cover was 78.4% (Figure 4.14). BAS, COR, and WRS had higher pre-restoration vegetated areas than their restoring sites; by Year 10+, CHV, COG, and WS vegetated areas rose to match their reference sites (100% each) (Figure 4.14). Vegetated cover at LTR was lower than the other reference sites but continued to be higher than TFH across all years (Figure 4.14).

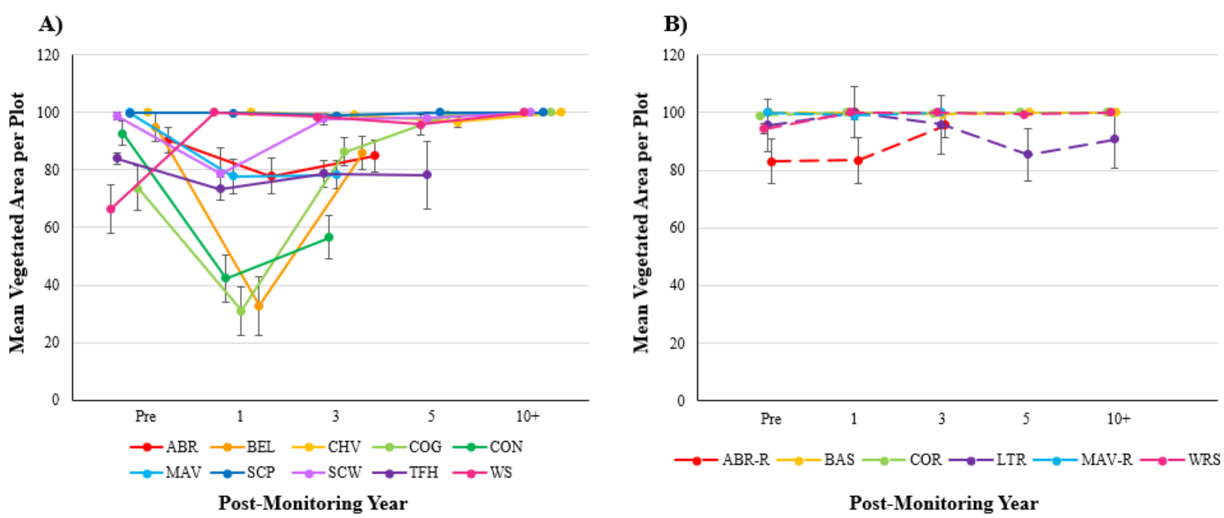


Figure 4.14. *Vegetation plot data summaries showing the mean vegetated area per plot from pre-restoration and years 1, 3, 5, and 10+ post-restoration at A) the restoring sites and, B) the references sites, within this research. Error bars are in standard error and plots jittered to avoid overlap.*

4.2.6 Vegetation – Sporobolus Abundances

Abundances of *S. alterniflorus* per plot at the restoring sites, most sites show an upward trend between pre-restoration and Year 1 post-restoration and another increase between Year 1 and Year 3 (Figure 4.15-A). Sites that did not follow this trend were BEL, which did not have *S. alterniflorus* on the site until Year 3, SCP which does not have *S. alterniflorus* within the sampling stations of the restoring site, and TFH which did not have *S. alterniflorus* within the sampling stations until Year 5 (Figure 4.15-A). By Year 5, all sites except for SCW had abundances of *S. alterniflorus* higher in Year 5 than in Year 3—there was a 2.7% decrease at SCW (Figure 4.15-A). The largest increase during this period was at COG with an increase from 34.6% to 72.5% (Figure 4.15-A). At the restoring sites with Year 10+ data, abundances of *S. alterniflorus* had decreased at all sites with the largest decrease occurring at COG (-53.7 % per plot), followed by SCW (-31.3% per plot), and WS (22.4 % per plot)—there was no *S. alterniflorus* in the sampling plots at SCP and SCW (Figure 4.15-A).

At the reference sites, increases in *S. alterniflorus* abundance per plot were observed during pre-restoration to Year 1 at all sites except for ABR-R and LTR which showed a decrease in *S. alterniflorus* (Figure 4.15-B). At Year 3, *S. alterniflorus* abundance increased per plot at ABR-R (+2.7%), LTR (+0.5%), and MAV-R (+2.3%) while BAS, COR, and WRS showed decreases in *S. alterniflorus* abundance (by -3.0%, -4.1%, and -10.2% respectively) (Figure 4.15-B). By Year 5, all sites continued to show decreases in *S. alterniflorus* abundance except for BAS (+4.5%) (Figure 4.15-B). At Year 10+ post-restoration, *S. alterniflorus* abundance per plot was lower than the pre-restoration abundance for all sites except for BAS (+11.6%) and LTR (+0.2%) (Figure 4.15-B).

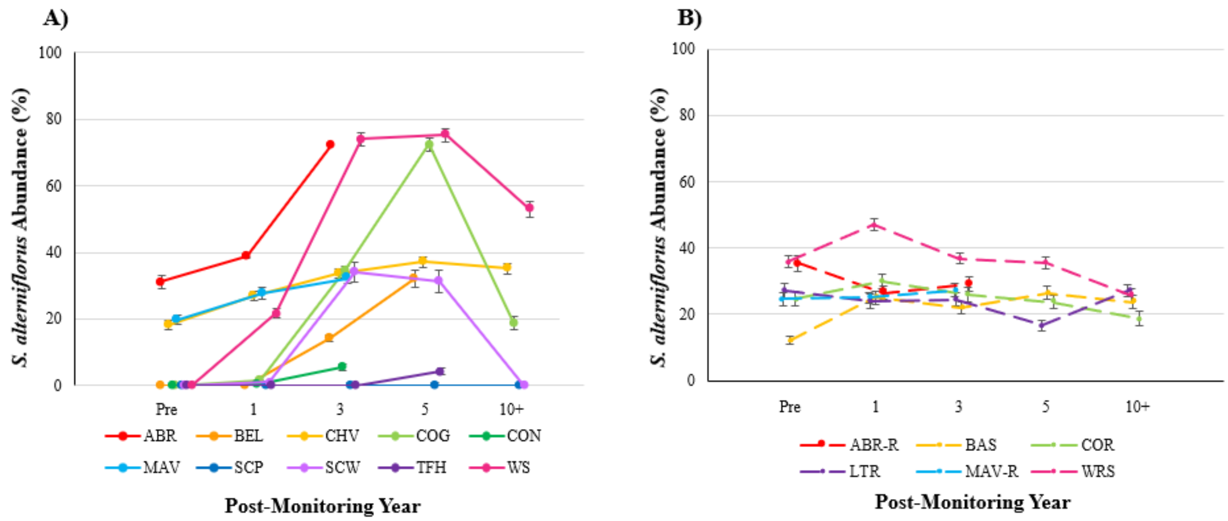


Figure 4.15. *Sporobolus alterniflorus abundances pre-restoration and Years 1, 3, 5, and 10+ post-restoration across all sites: A) restoration sites and B) reference sites. Error bars in standard error and plots.*

At the restoring sites between pre-restoration and Year 1, *S. pumilus* abundance per plot increased at CHV, CON, and WS while it decreased at ABR and MAV—*S. pumilus* was not found at BEL, SCP, and TFH across all years (Figure 4.16-A). *S. pumilus* abundances at ABR continued to decrease into Year 3, whereas, abundances increased at MAV between Year 1 and Year 3 (+6.3%) (Figure 4.16-A). By Year 5, abundances of *S. pumilus* had increased at all sites with the highest increase from pre-restoration occurring at CHV (+23.2%) (Figure 4.16-A). At Year 10+ post-restoration, CHV abundances had decreased slightly from Year 5 abundances (-1.5%) whereas increases were observed at COG (+43.2%) and WS (+48.7%) (Figure 4.16-A). At the reference sites, all sites showed an increase in abundances between pre-restoration and Year 3 with the highest increases occurring at BAS (+16.3%), WRS (+15.1%), and ABR-R (+15.1%) (Figure 4.16-B). By Year 5, increases in *S. pumilus* abundances continued at CON (+12%) and LTR (+8.2%) while decreases were recorded at BAS (-13.9%) and WRS (-7.9%) (Figure 4.16-B). *S. pumilus* abundances by Year 10+ post-restoration decreased at COR and WRS while BAS and LTR showed a slight increase (+1.1% and +0.8% respectively) (Figure 4.16-B).

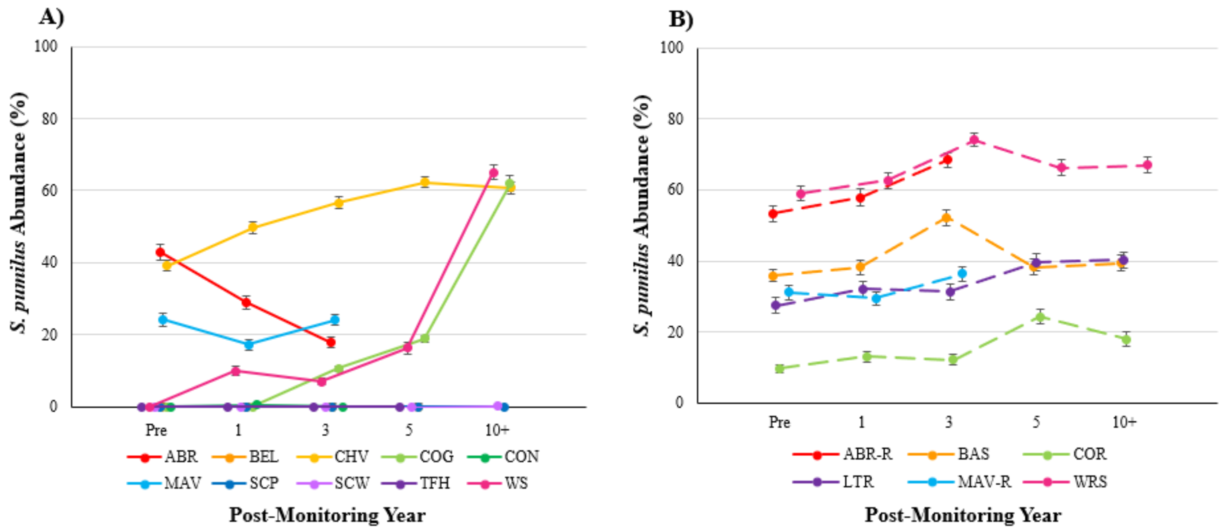


Figure 4.16*. Sporobolus pumilus abundances pre-restoration and Years 1, 3, 5, and 10+ post-restoration across all sites: A) restoration sites and B) reference sites. Error bars in standard error and plots.*

S. michauxianus was found pre-restoration at ABR, BEL, COG, CON, MAV, SCP, and TFH—by Year 1, *S. michauxianus* was also found at SCW; during this period, *S. michauxianus* abundances per plot increased by 17.4% at SCP (Figure 4.17-A). By Year 3, abundances of *S. michauxianus* at ABR were 0% per plot and there was a decrease in abundances at MAV and TFH between Year 1 and Year 3 (Figure 4.17-A). All other sites showed increases in *S. michauxianus* abundances in Year 3—BEL, SCP, SCW and WS also showed increases into Year 5 (Figure 4.17-A). Despite the decrease in Year 3, *S. michauxianus* abundances per plot increased 18.7% at TFH in Year 5 (Figure 4.17-A). At CHV, *S. michauxianus* abundances decreased steadily from Year 3 to Year 10+ (-0.8%) while COG saw a decrease between Year 3 and Year 5 (-6.5%) then a slight increase by Year 10+ (+2.1%) (Figure 4.17-A). By Year 10+, abundances of *S. michauxianus* decreased at SCP (-15.6%) and WS (-3.1%) while SCW saw a slight increase in abundance (+0.8%) (Figure 4.17-A).

At the reference sites, *S. michauxianus* abundances per plot decreased between pre-restoration and Year 1 at ABR, BAS and COR and increased at LTR, MAV-R, and WRS;

abundances were highest in Year 1 at MAV-R (16.6%) (Figure 4.17-B). Abundances of *S. michauxianus* increased in Year 3 at ABR-R and MAV-R (+3.1% and +4.1% respectively)—other sites saw increases (BAS and COR) and decreases (LTR and WRS) in *S. michauxianus* abundances (Figure 4.17-B). By Year 5, BAS, LTR and WRS showed increases in *S. michauxianus* abundances—COR decreased in Year 5 (-2.8%) despite having the highest abundance of *S. michauxianus* per plot during this period, and continued to decrease into Year 10+ post-restoration (-3.2%) (Figure 4.17-B). Post-restoration in Year 10+, BAS and LTR abundances of *S. michauxianus* decreased whereas WRS saw an increase in abundance (+7.0%) (Figure 4.17-B). When comparing pre-restoration abundances of *S. michauxianus* to Year 10+ (for the sites in which Year 10+ data is available), BAS and WRS saw increases in *S. michauxianus* (+3.5% and +11.3% respectively) while COR and LTR abundances decreased during this time (-4.1% and -1.9% respectively) (Figure 4.17-B). Both ABR-R and MAV-R showed increases in *S. michauxianus* abundances from pre-restoration to Year 3 (Figure 4.17-B).

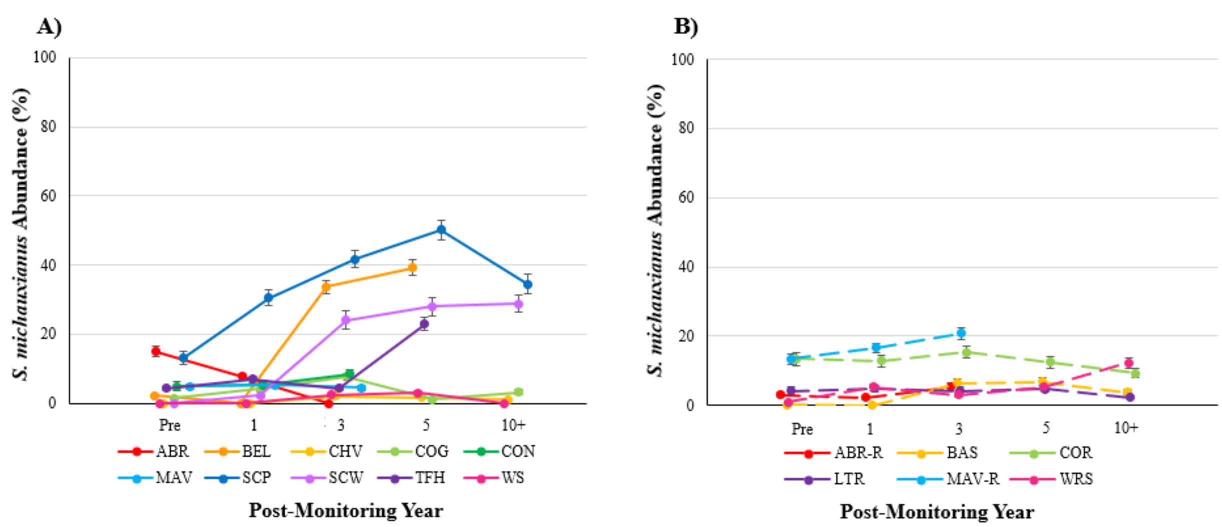


Figure 4.17. *Sporobolus michauxianus abundances pre-restoration and Years 1, 3, 5, and 10+ post-restoration across all sites: A) restoration sites and B) reference sites. Error bars in standard error and plots.*

4.3 Restoration Trajectory – Sediment Type

4.3.1 Surface Elevation

Elevations at the low marsh plots at the organogenic restoration sites increased between pre-restoration and Year 1 post-restoration (+0.12 m); by Year 5, elevations had increased at these sites from 0.82 m pre-restoration to 1.20 m (Figure 4.18-A). At the minerogenic restoration sites, elevations remained stable between 5.7 – 5.8 m from pre-restoration into Year 10+ post-restoration (Figure 4.18-A). At the organogenic reference sites, elevations at the low marsh plots increased between pre-restoration and Year 3 post-restoration (+0.09 m) (Figure 4.18-B). There was a decrease in Year 5 and Year 10+ post-restoration elevations at the organogenic reference sites however, there is only data available from these years for LTR and is not representative of the other sites (ABR-R and MAV-R) (Figure 4.18-B). LTR experienced a decline in elevation in Year 5; however, there was an increase by Year 10+ post-restoration (+0.17 m) (Figure 4.18-B). Exploring the same period at the minerogenic reference sites, there was little change between pre-restoration and Year 5 elevations; however, by Year 10+, elevations had increased from 5.58 m pre-restoration to 5.86 m (+0.28 m) (Figure 4.18-B).

A mixed linear model with random effects of site and plot nested within site was used to analyse the interactions between sediment type (sms) and year in case sms groups differ in one year but not in another (Table F-1; Table F-7). A post-hoc comparison test was conducted following the ANOVA to explore which group means differ from each other (Table F-1; Table F-7). The largest effect is the main effect of substrate type, with all minerogenic sites having higher marsh platform elevations than all the organogenic sites (Figure 4.18; Table F-1). This test showed a significant difference between the minerogenic restoration sites prior to Year 10+ and in Year 10+, indicating a group interaction between sediment type (sms) and year (Table

F-1). This comparison also showed a significant difference between the organogenic restoration sites prior to Year 5 and in Year 5, further indicating the sms:year interaction effect (Table F-1). In addition, this test showed a significant difference between the elevation at the minerogenic reference sites pre-restoration and in Years 1, 3 and 5 (group = b) and in Year 10+ (group = c), indicating a group interaction between sediment type (sms) and year (Table F-7).

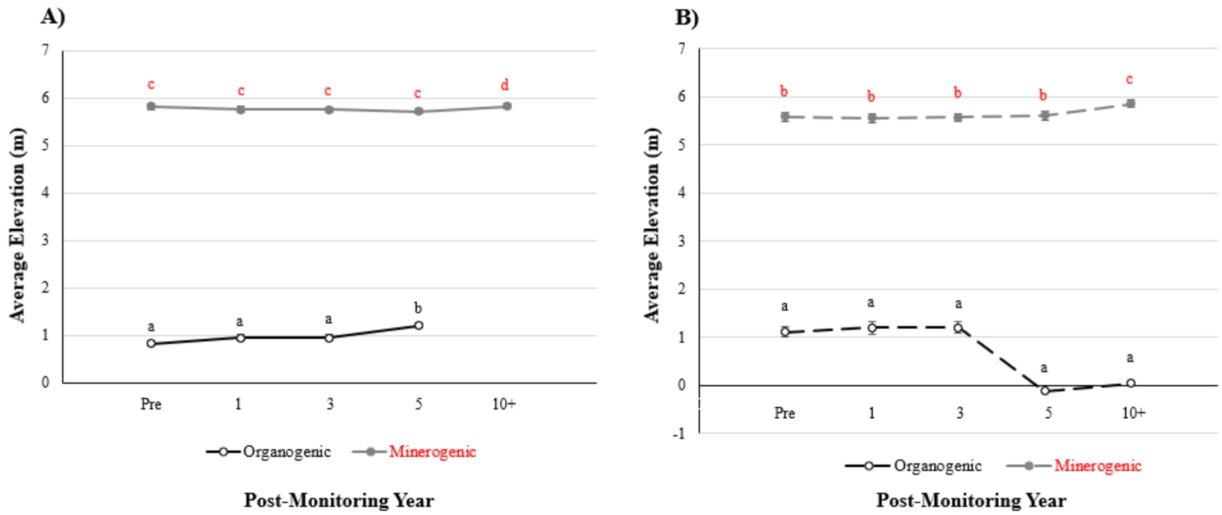


***Figure 4.18**. The average elevation pre-restoration and years 1, 3, 5, and 10+ post-restoration of the organogenic and minerogenic tidal marshes within this research, divided as A) restoration sites and B) reference sites. Error bars in standard error.*

4.3.2 Total Cumulative Accretion

Total cumulative accretion at the organogenic restoration sites between pre-restoration and Year 3—the years which include the most organogenic sites—increased from 0.5 cm in Year 1 to 3.7 cm in Year 3 (Figure 4.19-A). By Year 5, cumulative accretion reached 4.1 cm and in Year 7, rose to 6.6 cm (Figure 4.19-A)—note that Year 5 only included accretion data from TFH as ABR and MAV only had data up to Year 3 available. At the minerogenic restoration sites, cumulative accretion rose from 8.4 cm in Year 1 to 13.4 cm in Year 3—by Year 5, cumulative accretion reached 16.6 cm and included all minerogenic restoration sites except BEL and CON

(Figure 4.19-A). The average cumulative accretion in Year 10+ reached 25.1 cm, an increase of 8.5 cm since Year 5 (Figure 4.19-A).

At the organogenic reference sites, total cumulative accretion increased in Year 3 from 0.2 cm in Year 1 to 1.9 cm (Figure 4.19-B). By Year 5, cumulative accretion rose to 2.1 cm and in Year 10+, increased again from 2.1 cm to 6.8 cm—note that Year 5 and 10+ cumulative accretions only include LTR data (Figure 4.19-B). When exploring cumulative accretion at the minerogenic reference sites, there was an increase from 0.8 cm in Year 1 to 1.4 cm in Year 3 (Figure 4.19-B). Between Year 3 and Year 5, average cumulative accretion rose 1.2 cm to 2.6 cm however, it was Year 10+ which saw the largest increase in cumulative accretion with an average of 26.1 cm (Figure 4.19-B). Note that while COR and WRS showed large increases at this time, cumulative accretion at BAS rose from 1.9 cm to 63.0 between Year 5 and 10+ (Figure 4.8).

When comparing the restoration and reference sites, the restoring sites had higher cumulative accretion rates than the references sites between Year 1 and Year 5 at both the organogenic and the minerogenic marshes (Figure 4.19). By Year 10+ at the minerogenic sites, the reference site had a higher cumulative accretion rate than the restoration sites however, there was only a 1 cm difference between their cumulative accretion (26.1 cm and 25.1 cm respectively) (Figure 4.19). As for the organogenic marshes, there was no Year 10+ data available for the restoration sites to compare with the reference sites.

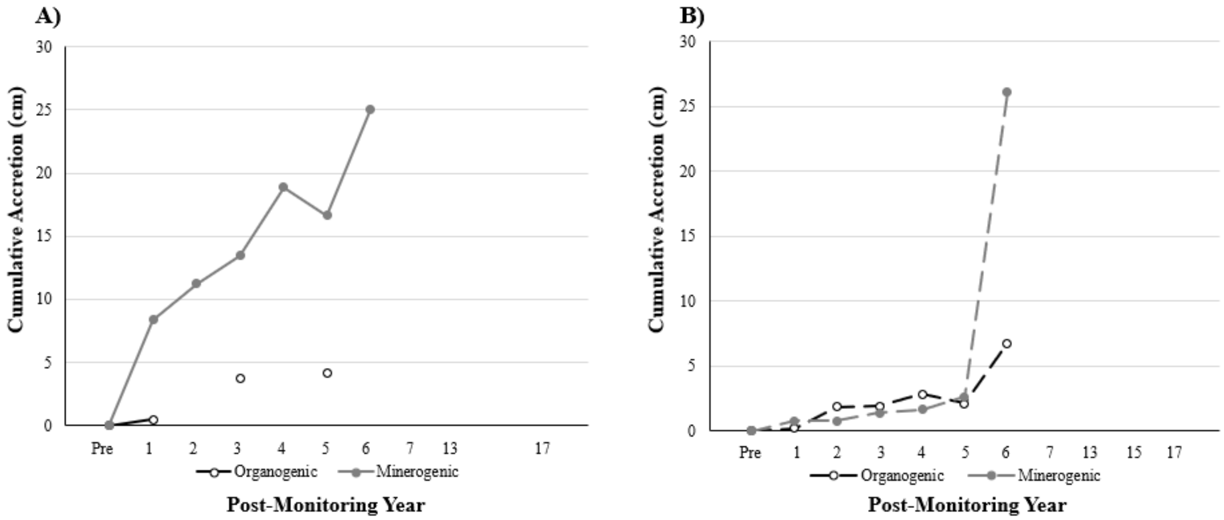


Figure 4.19. *The average cumulative accretion from pre-restoration (T = 0) and years 1 through 5 and 10+ post-restoration of the organogenic and minerogenic tidal marshes within this research, divided as A) restoration sites and B) reference sites.*

4.3.3 Organic Matter Content

When exploring organic matter content at the organogenic restoration sites, there was a decline in OM content between pre-restoration and Year 1 (-5.1 %) and a large decrease between Year 1 and Year 3 from 55.6% to 30.6% (Figure 4.20-A). By Year 5, OM content at the organogenic restoration sites increased from 30.6% in Year 3 to 75.1% (+44.5%); from pre-restoration to Year 5, there was an increase in OM content of 14.4% (Figure 4.20-A). At the minerogenic restoration sites—similar to the organogenic restorations sites—there was a decrease in OM content between pre-restoration and Year 1 (-19.4%) and another decrease from Year 1 to Year 3 (-4.0%) (Figure 4.20-A). OM content continued to decrease in Year 5 and Year 10+ post-restoration; from pre-restoration to Year 10+, OM content decreased from 32.5% to 7.5% (Figure 4.20-A). OM content is higher at the organogenic restoration sites than the minerogenic restoration sites across all years (Figure 4.20-A).

At the organogenic reference sites, there was an increase in OM content between pre-restoration and Year 1 (+8.1%) followed by a decline from 50.5% in Year 1 to 32.4% in Year 3

(Figure 4.20-B). Year 5 and Year 10+ OM content data is only available for LTR, however, there was an increase in Year 5 followed by a decrease in Year 10+ to 36.8% (Figure 4.20-B). At the minerogenic reference sites, there was a decrease in OM content from 22.5% during pre-restoration to 12.1% in Year 1 (Figure 4.20-B). There was a slight increase in OM content in Year 3 and 5 (+1.3% and +0.7% respectively) followed by a decline in Year 10+ post-restoration (-3.1%) (Figure 4.20-B). From pre-restoration to Year 10+, OM content at the minerogenic reference sites decreased 11.5%; OM content is higher at the organogenic reference sites than the minerogenic reference sites across all years (Figure 4.20-B). When comparing restoration to reference, the minerogenic reference sites have a higher average OM content than the minerogenic restoration sites in Year 5 and into Year 10+ post-restoration (Figure 4.20). At the organogenic sites, the opposite is true where OM content is higher at the restoration sites than the reference sites pre-restoration and into Year 5; the exception is in Year 3 where OM content was 1.8% higher at the reference sites than the restoration sites (Figure 4.20).

A mixed linear model with random effects of site and plot nested within site was used to analyse the interactions between sediment type (sms) and year in case sms groups differ in one year but not in another (Table F-2; Table F-8). A post-hoc comparison test was conducted following the ANOVA and showed a significant difference in organic matter content between the post-restoration years at the minerogenic restoration sites (group = a) and pre-restoration, Year 1, and Year 5 at the organogenic restoration sites (group = b, c & d) (Figure 4.20; Table F-2). These differences highlight how organic matter content may differ depending on sediment type. Additionally, there was a significant difference in the organic matter content pre-restoration (group = d) and in Year 3 (group = a, c) at the organogenic restoration sites, indicating a group interaction between sediment type (sms) and year (Figure 4.20; Table F-2). At the reference sites, there was a significant difference in organic matter content between pre-restoration at the minerogenic reference sites (group = b) and Years 1 and 10+ (group = a) (Figure 4.20; Table F-8). These differences indicate a group interaction between sediment type (sms) and year for organic matter content at the reference sites (Figure 4.20; Table F-8).

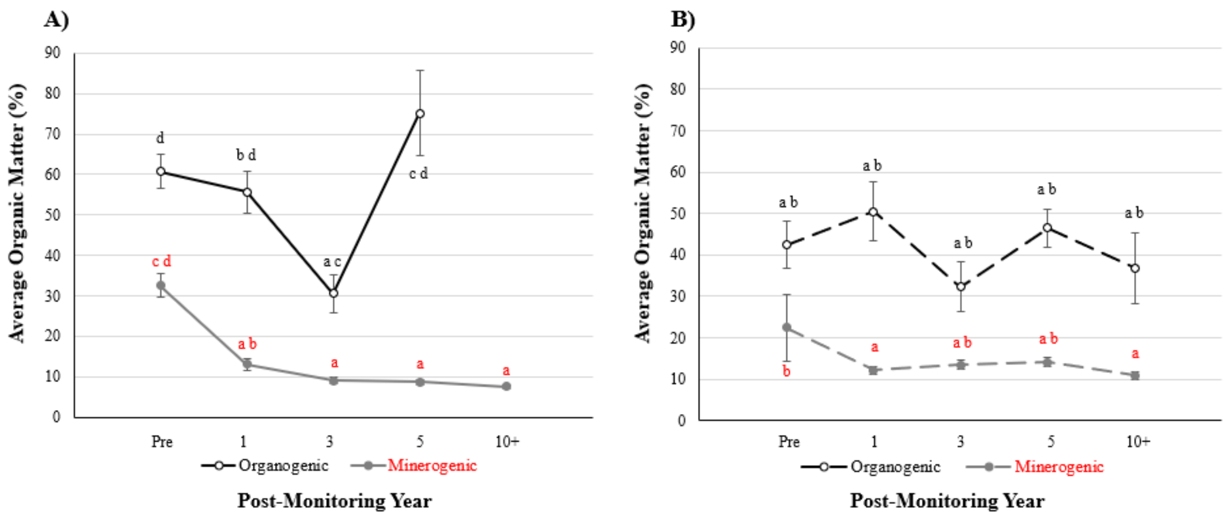


Figure 4.20. *The average organic matter pre-restoration and years 1, 3, 5, and 10+ post-restoration of the organogenic and minerogenic tidal marshes within this research, divided as A) restoration sites and B) reference sites. Error bars in standard error.*

4.3.4 Bulk Density

Bulk density at the organogenic restoration sites increased between pre-restoration and Year 1 from 0.13 g·cm^{-3} to 4.84 g·cm^{-3} (Figure 4.21-A). There was a decrease in bulk density in Year 3 and Year 5 post-restoration; by Year 5, bulk density was 0.12 g·cm^{-3} (Figure 4.21-A). At the minerogenic restoration sites, there was an increase in bulk density from 0.53 g·cm^{-3} to 0.68 g·cm^{-3} between pre-restoration and Year 1 post-restoration (Figure 4.21-A). Following a slight decrease in Year 3 (-0.02 g·cm^{-3}), bulk density at the minerogenic restoration sites continued to increase into Year 5 and Year 10+ to 0.69 g·cm^{-3} then 0.75 g·cm^{-3} respectively (Figure 4.21-A).

At the organogenic reference sites, bulk density increased between pre-restoration and Year 1 (+0.02 g·cm^{-3}) and between Year 1 and Year 3 (+0.01 g·cm^{-3}) (Figure 4.21-B). By Year 5, there was a decrease in bulk density from 0.18 g·cm^{-3} in Year 3 to 0.15 g·cm^{-3}—bulk density in

Year 10+, however, increased to 0.25 $g \cdot cm^{-3}$ (Figure 4.21-B). At the minerogenic reference sites, bulk density values increased and decreased overtime however, pre-restoration and Year 10+ post-restoration bulk density values were the same (0.57 $g \cdot cm^{-3}$) (Figure 4.21-B). Bulk density values at the organogenic reference sites were higher than those at the minerogenic reference sites across all years (Figure 4.21-B).

A mixed linear model with random effects of site and plot nested within site was used to analyse the interactions between sediment type (sms) and year in case sms groups differ in one year but not in another. A post-hoc comparison test was conducted following the ANOVA to explore which group means differ from each other (Table F-3; Table F-9). This test showed significant difference between the bulk density in Year 5 at the organogenic restoration sites (group = a) and Years 1 (group = c, d) and 3 (group = b) (Figure 4.21; Table F-3). There also appeared to be a significant difference between the bulk density pre-restoration at the minerogenic restoration sites (group = c) and in Years 5 and 10+ post-restoration (group = d), (Figure 4.21; Table F-3). At the reference sites, a post-hoc test showed a significant difference between the bulk density at the organogenic reference sites in Year 3 (group = a) and in Years 1 (group = b, c), 5 and 10+ (group = b) (Figure 4.21; Table F-9). Additionally, there was a significant difference at the minerogenic reference sites between Year 3 (group = c, d) and Years 1, 5, and 10+ (group = e) (Figure 4.21; Table F-9). These differences highlight how bulk density content may differ depending on the year and indicate a possible group interaction between sediment type (sms) and year at the reference sites (Figure 4.21; Table F-9).

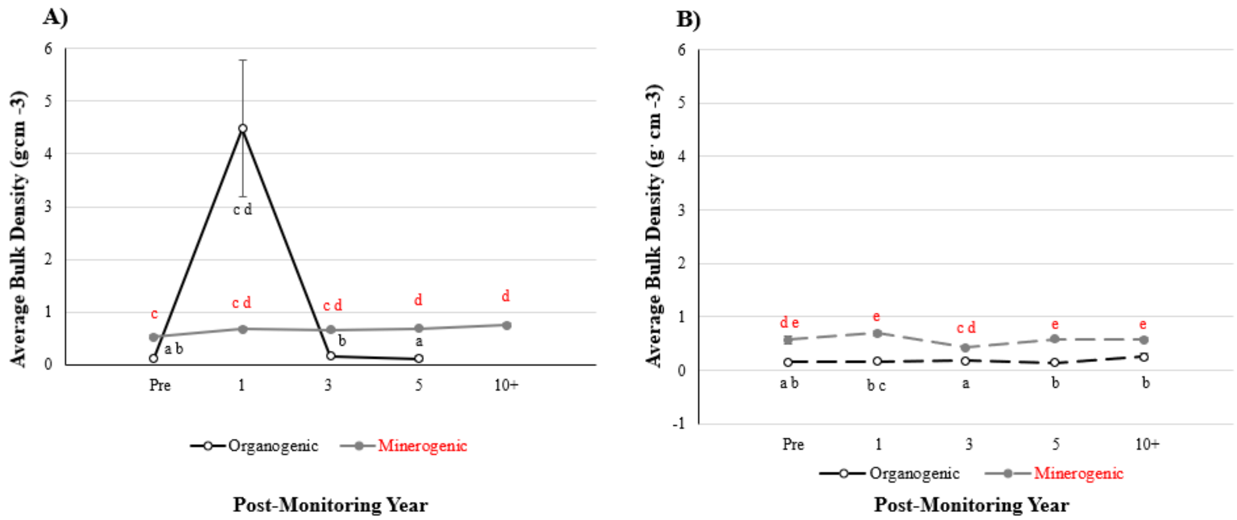


Figure 4.21. *The average bulk density pre-restoration and years 1, 3, 5, and 10+ post-restoration of the organogenic and minerogenic tidal marshes within this research, divided as A) restoration sites and B) reference sites. Error bars in standard error.*

4.3.5 Sporobolus Abundances

Vegetation data can be compared at organogenic and minerogenic sites overtime as well to explore the present and absence of species. *S. alterniflorus* abundance per plot at both the organogenic and minerogenic restoration sites increased from pre-restoration until Year 3 post-restoration (Figure 4.22-A). By Year 5, *S. alterniflorus* abundances decreased from 33.6% to 4.2% at organogenic restoration sites; however, it is important to note that only TFH data was available for Year 5 (Figure 4.22-A). When looking at *S. alterniflorus* abundance per plot at the minerogenic restoration sites, there is an increase from pre-restoration (6.2%) into Year 5 post-restoration (38.5%) (Figure 4.22-A). Like the organogenic restoration sites, the later years experienced a decrease with a decline between Year 5 and Year 10+; *S. alterniflorus* abundances per plot went from 38.5% in Year 5 to 28.7% in Year 10+ (Figure 4.22-A).

S. alterniflorus abundance per plot at the organogenic reference sites showed increases and decreases in abundance overtime however, between pre-restoration and Year 10+, there was little change in abundance (28.6% and 27.2% respectively) (Figure 4.22-B). This trend is similar at the minerogenic reference sites as pre-restoration abundances of *S. alterniflorus* (24.8%) and Year 10+ post-restoration abundances (23.0%) showed little change (Figure 4.22-B). When comparing the organogenic restoration and reference sites, the reference sites had higher abundances of *S. alterniflorus* pre-restoration and by Year 5 (Figure 4.22). At the minerogenic sites, the restoration sites had higher abundances of *S. alterniflorus* than the reference sites by Year 5—and into Year 10+ post-restoration—however, this was not the case pre-restoration (Figure 4.22).

A mixed linear model with random effects of site and plot nested within site was used to analyse the interactions between sediment type (sms) and year in case sms groups differ in one year but not in another. A post-hoc comparison test was conducted following the ANOVA to explore which group means differ from each other (Table F-4; Table F-10). This test showed a significant difference between *S. alterniflorus* abundance in Year 10+ post-restoration at the minerogenic restoration sites (group = c, e) and pre-restoration / Year 1 (group = a, b) and Year 5 (group = d, f) (Figure 4.22; Table F-4). There was also a significant difference between pre-restoration *S. alterniflorus* abundance at the organogenic restoration sites (group = a, c, d) and Year 3 post-restoration (group = b, e, f) (Figure 4.22; Table F-4). Both of these differences indicate the potential for sediment type and year interactions at the restoration sites (sms:year). Additionally, the post-hoc comparison test at the reference sites showed that the shared group numbers indicate there are no significant differences between sediment type (sms) and year with respect to the abundance of *S.alterniflorus* at the reference sites (Figure 4.22; Table F-10).

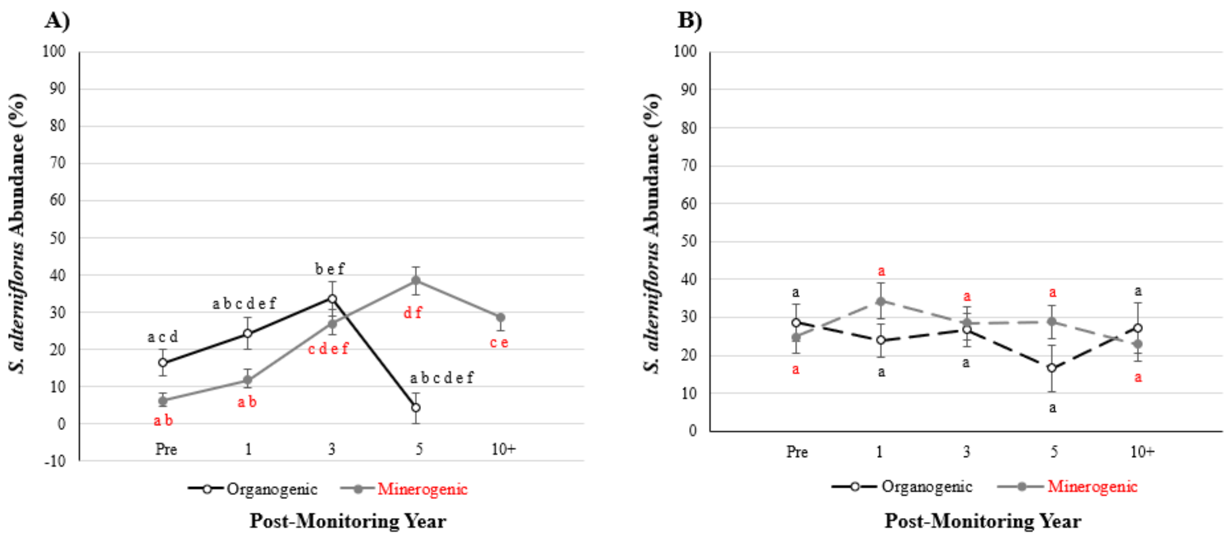


Figure 4.22. *The abundance of Sporobolus alterniflorus pre-restoration and years 1, 3, 5, and 10+ post-restoration of the organogenic and minerogenic tidal marshes within this research, divided as A) restoration sites and B) reference sites. Error bars in standard error and plots.*

S. pumilus abundances per plot at the organogenic restoration sites were the highest pre-restoration (23.7%) and continued to decrease overtime from 16.4% (Year 1), to 13.9% (Year 3), and finally, 0% in Year 5 (Figure 4.23-A). The opposite has occurred at the minerogenic restoration sites. Pre-restoration, *S. pumilus* abundances were 11.9% per plot and increased in Year 1 to 16.6% and then to 19.3% in Year 3 (Figure 4.23-A). By Year 5, there was a larger increase between Year 3 and Year 5 (+11.5%) and between Year 5 and Year 10+ (18.1%)— *S. pumilus* abundance per plot increased 36.8% between pre-restoration and Year 10+ post-restoration (Figure 4.23-A).

At the reference sites, there was a similar trend between organogenic and minerogenic. Abundances of *S. pumilus* pre-restoration at the organogenic reference sites were 36.9% per plot and peaked in Year 3 (44.1%) (Figure 4.23-B). In Year 5, *S. pumilus* abundances decreased to 39.6% per plot however, between Year 5 and Year 10+, there was a slight increase (+0.6%) in abundance per plot (Figure 4.23-B). Pre-restoration *S. pumilus* abundances at the minerogenic reference sites were 36.2% which increased to 47.8% by Year 3 (Figure 4.23-B). Following a decrease in Year 5 (-3.9%), *S. pumilus* abundances in Year 10+ post-restoration only slightly decreased (-0.8%) with abundances per plot being 43.1% (Figure 4.23-B).

When comparing the restoration and reference sites, the organogenic reference sites had higher abundances of *S. pumilus* across all years and increased overtime whereas the restoration site saw *S. pumilus* abundances per plot decline to 0% (Figure 4.23). There were increases at the minerogenic restoration and reference sites from pre-restoration into the post-monitoring years. Pre-restoration, the restoration sites had less *S. pumilus* per plot than the reference sites (-24.3%) however, by Year 10+, the restoration sites had surpassed the reference site plot abundances of *S. pumilus* by 5.6% (Figure 4.23). From pre-restoration to Year 10+, abundances of *S. pumilus* at the restoration sites increased from 11.9% to 48.7% whereas abundances at the reference sites increased from 36.2% to 43.1% (Figure 4.23).

A mixed linear model with random effects of site and plot nested within site was used to analyse the interactions between sediment type (sms) and year in case sms groups differ in one year but not in another. A post-hoc comparison test was conducted following the ANOVA to explore which group means differ from each other (Table F-5; Table F-11). At the restoration sites, there was a significant difference between the pre-restoration and Year 1 abundances of *S. pumilus* at the minerogenic restoration sites (group = a) and Year 5 (group = b) and 10+ (group = c) post-restoration (Figure 4.23; Table F-5). This indicates a possible group interaction between sediment type (sms) and year. At the reference sites, the shared group numbers indicate there are no significant differences between sediment type (sms) and year with respect to the abundance of *S.pumilus* at the reference sites (Figure 4.23; Table F-11).

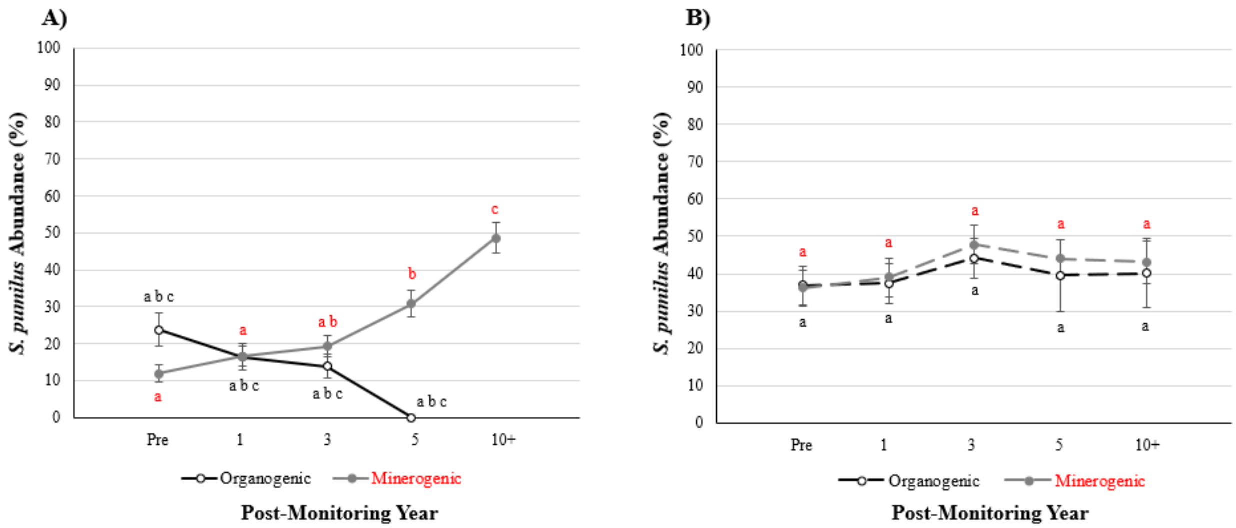


Figure 4.23. *The abundance of Sporobolus pumilus pre-restoration and years 1, 3, 5, and 10+ post-restoration of the organogenic and minerogenic tidal marshes within this research, divided as A) restoration sites and B) reference sites. Error bars in standard error and plots.*

When exploring *S. michauxianus* abundances at the organogenic restoration sites, there was a decrease between pre-restoration into Year 3 post-restoration; *S. michauxianus* abundance was 8.4% pre-restoration and 2.9% in Year 3 (Figure 4.24-A). By Year 5, *S. michauxianus* abundances per plot increase from 2.9% to 22.8% (Figure 4.24-A). At the minerogenic restoration sites, there was an increase in Year 1 (+2.0%) and between Year 1 and Year 3 (+7.4%) (Figure 4.24-A). By Year 5, there was a slight decrease in *S. michauxianus* abundances per plot (-0.1%) which continued into Year 10+ (-4.4%) (Figure 4.24-A).

S. michauxianus abundances per plot at the organogenic reference sites increased from pre-restoration (7.3%) into Year 3 (10.7%) (Figure 4.24-B). By Year 5, abundances of *S. michauxianus* decreased 6.0% per plot and into Year 10+, abundances decreased an additional 2.4% (Figure 4.24-B). At the minerogenic reference sites, *S. michauxianus* abundances per plot increased overtime from pre-restoration to Year 10+ post-restoration; abundances pre-restoration were 4.7% and 8.5% in Year 10+ (Figure 4.24-B). When comparing the organogenic restoration and reference sites, the restoration sites had higher abundances of *S. michauxianus* in both pre-restoration and Year 5 post-restoration (Figure 4.24). This is the opposite at the minerogenic sites where the reference sites had higher abundances of *S. michauxianus* in both pre-restoration and Year 10+ post-restoration than the restoration sites (Figure 4.24).

A mixed linear model with random effects of site and plot nested within site was used to analyse the interactions between sediment type (sms) and year. A post-hoc comparison test was conducted following the ANOVA to explore which group means differ from each other (Table F-6; Table F-12). There was a significant difference between pre-restoration *S. michauxianus* abundances at the minerogenic restoration sites (group = a, d) and Years 3 / 5 (group = c, f) and Year 10+ (group = b, c, e, f) post-restoration (Figure 4.24; Table F-6). At the organogenic restoration sites, *S. michauxianus* abundances in Year 5 (group = d, e, f) were significantly different than those pre-restoration, in Year 1 and in Year 3 (group = a, b, c) (Figure 4.24; Table F-6). These differences indicate a group interaction between sediment type and year. At the reference sites, the shared group numbers indicate there are no significant differences between sediment type and year (Figure 4.24; Table F-12).

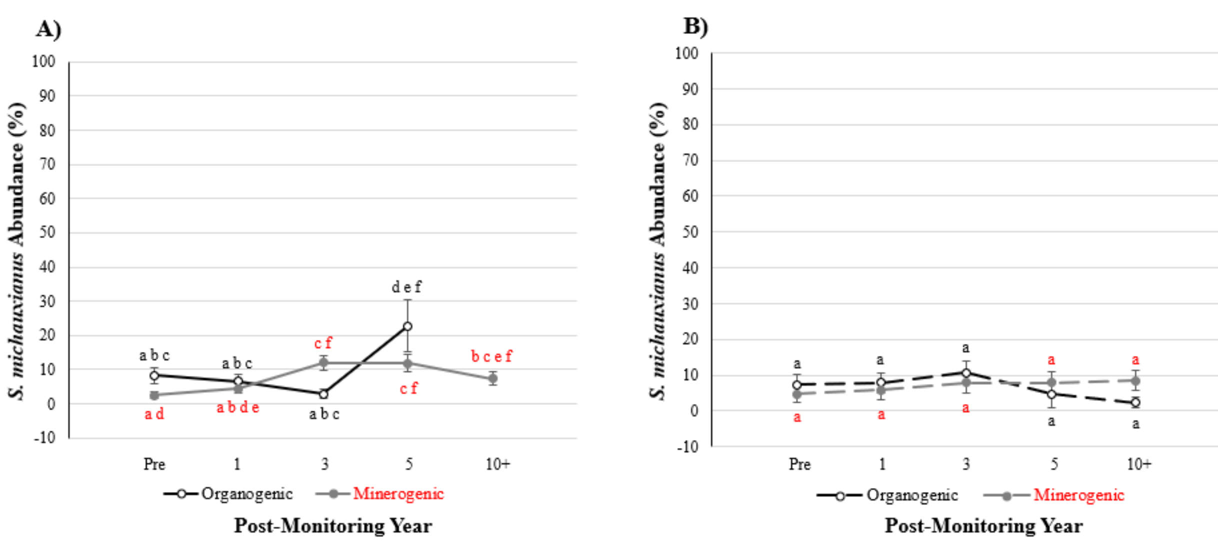


Figure 4.24. *The abundance of Sporobolus michauxianus pre-restoration and years 1, 3, 5, and 10+ post-restoration of the organogenic and minerogenic tidal marshes within this research, divided as A) restoration sites and B) reference sites. Error bars in standard error.*

Chapter 5 – Discussion

The purpose of this research was to determine whether intentionally restored tidal marshes could be characterized by their similarities and differences pre-restoration and to investigate the trajectory of the selected restored and natural tidal marshes given the environmental response variables. Further, this research aimed to determine whether the pre-condition of intentionally restored tidal marshes influenced the restoration trajectory. Data from the original monitoring programs along with a present-day field collection of data was compiled into a principal component analysis to explore pre-restoration characterization and used for graphing scatterplots of each variable independently to examine restoration trajectory. A repeated measure ANOVA was used to explore the influence of sediment type on site and year. This research provides results which can assist restoration practitioners in both the pre-restoration/baseline phase of tidal marsh restoration and post-restoration monitoring. Additionally, it provides considerations for future work and next steps for research.

5.1 Exploring Pre-Restoration Characterization Using a Principal Component Analysis

The characterization of tidal marshes pre-restoration is possible at select sites. While the PCA yielded groupings of sites with clusters of environmental variables to consider, not all groupings were well-suited and differed based on other environmental variables. BEL and SCP were grouped with SCW along with pasture species and SSC (mh); this group was fitting. Within the literature, tidal river channels with high SSCs that are re-introduced to fallow agricultural lands with low elevations have the potential for high sedimentation at newly restored sites (van Proosdij et al., 2006). Additionally, SSCs within estuarine systems have been shown to increase with increasing tidal range (Allen and Duffy, 1998; Parry et al., 2001; van Proosdij et al., 2006). Research conducted along the Tantramar Marshes found that with the higher the tidal range, the more suspended sediment available to be brought onto the marsh (Parry et al., 2001). All three of these sites were dykelands until their restoration and are within the Bay of Fundy located high in the tidal frame. In addition, they were dominated by pasture and brackish plant species pre-restoration and had high net accretion at the MHs in Year 1; their agricultural history caused subsidence given their high accretion rates within the first-year post-restoration (Roman et al., 1984; Roman et al., 2002; Bowron et al., 2015a; Kutcher and Raposa, 2023).

Converse (CON) and the Walton restoration site (WS) were grouped with Cheverie Creek (CHV), as well as with elevation, tidal range, inundation time, bulk density, and salt marsh vegetation. Within the literature, barriers to tidal river channels may be fully restricted, partially restricted, or have no restriction to tidal flow (Wells, 1999) which makes the grouping of these sites interesting as pre-restoration, their tidal restrictions were very different. CHV was a partially restricted system due to a causeway and an undersized culvert (Bowron et al., 2013a), whereas, WS was only dyked in 1990 to create a freshwater impoundment for waterfowl (Neatt, 2013); CON was a managed dyke realignment project (fully restricted) due to erosion occurring along the foreshore marsh and the susceptibility of breach or failure of the dyke in the face of climate change and sea-level rise (Bowron et al., 2019). Tidal restrictions which impact tidal inundation and therefore, salinity, can be resolved through restoration, however, the length of time required for a site to restore can vary depending on the severity and type of restriction that was in place (U.S. Environmental Protection Agency, 2020). When considering the environmental variables, there is only some overlap. All three sites are megatidal, however, CHV and WS had much lower pre-restoration platform elevations than CON. Only CHV had salt marsh vegetation present prior to restoration; WS was fresh and CON had pasture species present. Following restoration, CON and WS had similar inundation times, whereas, the inundation time at CHV was higher. Bulk densities were similar, ranging from 0.49 $g \cdot cm^{-3}$ to 0.60 $g \cdot cm^{-3}$. This grouping of sites and variables was not clarified when exploring the first and third principal components (PC1 vs. PC3), nor the first and fourth principal components (PC1 vs. PC4). The sediments of this grouping, as well as the previous group of sites, are minerogenic, whereas, all but one site in the following clusters have organogenic sediments.

TFH was grouped by itself with OM content within PC1 vs. PC2; this site grouping alone was expected. TFH had the highest OM content compared to all other restoring sites and was a freshwater site pre-restoration. Unlike the other restoring sites, TFH was a bog and therefore, its condition pre-restoration was different than most other sites. Lastly, ABR, MAV, and COG were grouped with salinity and brackish vegetation; ABR is located on the Atlantic coast, whereas, COG and MAV are located in the Bay of Fundy. There is brackish vegetation at COG along the treeline, similar to the brackish vegetation at ABR and MAV. OM content was also close to these site groupings—COG had the highest OM content of all the Bay sites in the Minas Basin pre-restoration and had values similar to those at ABR and MAV. Exploring the first and third component (PC1 vs. PC3) did not clarify the grouping of sites and variables however, the first and fourth component (PC1 vs. PC4) did show OM content grouping with COG, ABR, and MAV with salinity and brackish vegetation.

5.2 The Influence of Sediment Type

Groupings of sites and environmental response variables initially identified by the PCA appeared to be sorting by geography. Between New Brunswick and Nova Scotia, twenty-three distinct physiographical coastline segments were classified within three larger coastlines: the Nova Scotian Atlantic coast, the Bay of Fundy, and the Southern Gulf of St. Lawrence (Greenlaw et al., 2013). While the Gulf of St. Lawrence does not pertain to the sites within this research, sites included in this research are located within the Bay of Fundy and the Atlantic coast. Rather than a division based on coastline, clusters largely formed around the sediment type of the tidal marsh—whether the tidal marsh accreted vertically through external inorganic materials or internal organic materials. Within the literature, there is a push to consider whether a site is minerogenic or organogenic prior to determining methods for sampling within research as certain methods may work differently at each type of site (Nolte, 2013). While both types have mineral sediment supply and organic sediment supply, the long-term sediment composition of a tidal marsh appeared to have more bearing on the environmental response variables than their respective coastline (Allen, 1990). Organogenic versus minerogenic sediment type (sms) was added to the original PCA to explore whether sediment type would clarify any of the clusters identified in the previous analysis. Groups clustered in the same manner as in the original PCA and sediment type grouped with TFH.

Sediment type appears to influence OM content and bulk density—minerogenic tidal marshes had lower OM content and higher bulk densities than the organogenic tidal marshes. The repeated measures ANOVA showed the importance of year on elevation at both types of restoring sites and at the minerogenic reference sites in the final post-monitoring years (Year 5 and 10+). Abundances of *S. alterniflorus*, *S. pumilus*, and *S. michauxianus* appear to be impacted by year and sediment type at the restoring sites—this was not observed at the reference sites. Restored tidal marshes often have similar halophytic species composition to their reference sites however, their plant community composition remained different from the reference site (dominated by early successional species) (Mossman et al., 2012). North American Atlantic marshes with low diversity may reach species richness equivalence to their reference site within 10 years (Lasalle et al., 1991; Morgan & Short, 2002; Mossman et al., 2012) while it took 50 to

100 years in other areas for vegetation of restored marshes to be similar to the reference site (Mossman et al., 2012) and decades for stem density (Zedler, 1993) and carbon sequestration (Craft et al., 1999, Morgan & Short, 2002; Burden et al., 2013) to reach equivalence. A study observing stages of restoration in Aulac, New Brunswick anticipated that it could take 10+ years post-restoration for plant communities, especially the dominant grasses such as *Sporobolus sp.*, to establish their zones on the marsh platform, typically by high marsh species encroaching on the low marsh species which have established (Virgin et al., 2020). The changes in *Sporobolus* abundances at the restoration sites within this study, especially across pre- and post-monitoring year, is expected as the landscape undergoes physical and biological changes compared to the reference sites where changes often occur over a longer time scale.

5.3 Restoration Trajectory of the Sites Within This Study

Exploration of trajectory within this study showed that many of the tidal marshes within this study are threatened by the projections for sea-level rise by the Geological Survey of Canada (James et al., 2021); a low emission scenario projects 80 cm of sea-level rise whereas 140 cm of sea-level rise is projected under a high emission scenario. However, outside of these projections, vegetated area per plot remained high for sites into Year 10+—except at LTR—as did halophytic cover per plot. Abundances of *S. michauxianus* dropped at all the reference sites except WRS in Year 10+ and remained low at most restoring sites except SCP and SCW—not all sites have *S. michauxianus* as their dominant high marsh species. Decreases in the low marsh zone (*S. alterniflorus*) and increases in the mid-marsh zone (*S. pumilus*) at some sites show a transition from the early colonizer species to zonation which supports the establishment of higher marsh species. These are all indicators of resiliency and perseverance despite the threat of rising water levels.

Tidal marshes in Nova Scotia, between 2022-2100, should accrete approximately 1.03 cm per year with 80 cm of projected sea-level rise and 1.79 cm per year with 140 cm of projected sea-level rise (James et al., 2021). Cumulative accretion was used as a proxy for net accretion as it does include the measured net accretions from the MH data during the original monitoring program and uses a present data measured elevation which can be compared to the pre-restoration elevation to infer the present-day cumulative accretion. At the restoring sites, cumulative accretion decreased between the end of the original monitoring program and the 2022 sampling at CHV, COG and WS (Figure 4.8). Of all other restoring sites, only ABR, BEL, CON, SCP, and SCW have cumulative accretions (based on Year 1 values to 2022 values) per year that indicate potential resiliency to sea level rise based on the low and high emission scenarios for 2100. MAV and TFH, while cumulative accretion has continued to increase, are not accreting at a rate that would sustain their platform elevations above rising water levels by 2100. At the reference sites, BAS is the only reference site which has a cumulative accretion rate that is higher per-year accretion rate for the 2100 projections (Figure 4.8). While all other reference sites in this study have increased overtime, their accretion rates are much lower than that of the restoration sites. This is not unexpected—a study by Pethick (1981) found accretion rates of 1.7 $cm \cdot year^{-1}$ on 10-year old marshes and less than 0.002 $cm \cdot year^{-1}$ on marshes over 500 years old. When comparing the mean water level (MWL) and higher high water large tide (HHWLT) values provided by the Canadian Hydrographic Service (CHS) (Appendix G), marsh platform elevations of all sites from 2021-2022 were below both the MWL and HHWLT values.

In the literature, Bay of Fundy tidal marshes have been described as resilient to sea-level rise due to low population density, protected dykelands which are underused, and high suspended sediment concentrations (SSC) in the tidal water (Singh et al., 2007). Given these characteristics, tidal marshes along the Bay of Fundy—newly restored or natural—have enough available sediment arriving within the water column to sustain a vertical elevation above that of sea-level rise (Ollerhead, 2008) or are in equilibrium with sea-level rise (Chmura et al., 2001a). Larger tidal ranges and higher SSC associated with sea level rise can help macrotidal marshes, such as those along the Bay of Fundy, weather climate change (Kirwan et al., 2010; Poirier et al., 2017). Increasing sea levels, however, will increase inundation and may reduce the time between flooding events which has the potential to impact the subsurface processes and alter groundwater resources through salinization (Tackley et al., 2023). A study by French (2006) found high SSC may offset increasing hydroperiod and inundation and allow for migration of community zones into a broad vertical niche into the upper intertidal zone—sites where this is observed are likely to be more resilient.

Not all sites along the Bay of Fundy are the same. Sites in the lower Bay of Fundy experience a lower tidal range than those found in the upper Bay of Fundy (Bowron et al., 2011; Tiner, 2013; Slaymaker and Catto, 2020). Sediment accretion at tidal marshes found in the outer Bay of Fundy may be more sensitive to changes in mean sea level (Chmura et al., 2001a). Chmura et al. (2001a) found evidence of ice rafting within their study of outer Bay of Fundy sites which may contribute to marsh accretion—with climate change, accretion rates may decrease without the contribution of sediment from ice at the sites. MAV and MAV-R, located in the lower Bay of Fundy, may be experiencing the effects of increasing water levels as despite increases in sediment accretion, there has been loss of high marsh plant communities and areas once vegetated have become bare ground, standing water, or low marsh plant communities (Bowron et al., 2022a).

Rates of sedimentation, and thereby accretion, fluctuate seasonally within Nova Scotia's tidal marshes. In the spring, melting ice blocks and particles settling out of the water column contribute to sediment deposition (Christiansen et al., 2000; van Proosdij et al., 2006). The growth of vegetation in the summer becomes an important sediment input, particularly in the low marsh where wave activity allow sediment to settle out in the vegetation (van Proosdij et al., 2006). Sediment input in the fall is low in the low marsh due to increases in wave and storm activity however, higher high tides and wave activity can increase sediment deposition in the high marsh (van Proosdij et al., 2006). In the winter, ice rafting may bring course sediment onto a marsh while ice blocks and particle settling would contribute fine material (Ollerhead et al., 1999; van Proosdij et al., 2006). It is during the winter months that SSCs are highest; this sediment can adhere to ice blocks and be distributed across a marsh or along channel banks (van Proosdij, 2001; van Proosdij et al., 2006). Elevations surveyed in 2022 that were used to determine cumulative accretion were measured in the spring whereas net accretions measured during the original monitoring programs were carried out in the fall which could impact the calculated cumulative accretions.

It is important to consider temporal variability of sedimentation and elevation at each site, particularly under 18.6 nodal tidal modulation[16] which can influence variation in sea-level on short-term scales (French, 2006). As tide gauge is not typically used within monitoring or for research due to the limited duration of the projects, nodal tidal effects on the variation of sedimentation are often not explored (French, 2006). A study by Ray (2006) found tidal modulations in the Gulf of Maine experienced linear long-term increases during the 20th century with a drop in the 1980's; Halifax (and the Atlantic coast) experienced a similar drop in the

[16] the period in which the plane of the Earth's equator and the incline of the moon change; the inclination modulates the tides and therefore, impacts coastal processes (Thiébot et al., 2020).

1980’s but without the long-term increase in the tide. Under higher tidal ranges, sedimentation rates may vary substantially over decades when considering additional sedimentation relative to sea-level rise (French, 2006). There is not adequate data temporally among the sixteen sites considered in this study to explore long-term trends of sedimentation and accretion with regards to nodal tidal cycles. This may impact the comparisons made between cumulative accretion, the relative sea-level projections for 2100, and the tide data from CHS.

Within the literature, there is evidence to support that fluctuating sea levels can influence the predominant method of accretion (largely impacting minerogenic marshes) (Allen, 2000) whereas organogenic marshes may be at a greater risk for subsidence, causing compaction and decomposition of material (Nolte, 2013). Tidal marshes in low tidal ranges or along estuaries with low suspended sediment concentration, “will likely submerge in the near future, even for conservative projections of sea-level rise,” (Kirwan et al., 2010). A site of particular concern is the Lawrencetown Reference site (LTR) which is located on the Atlantic coast of Nova Scotia, a ‘drowned’ coastline which has been subsiding for 7000 years (Fensome and Williams 2001; Hanson, 2004). While cumulative accretion has increased since the end of the original monitoring program (2012) from 2.12 cm to 6.75 cm, elevations from the low marsh plots remain below sea-level (-0.07 m). However, an average of all the sampling stations at LTR yielded an elevation above sea-level (+0.05 m). While halophytic species and cover remain high at LTR, the mean number of species per plot, organic matter content, and vegetated area have decreased between Year 5 and Year 15. LTR is also undergoing a form of ‘coastal squeeze’ (Doody, 2004; Valiela et al., 2018) due to a roadway which separates beach and dune from the marsh, preventing migration of the beach-dune system and the sediment which would help the marsh accrete. In the coming years, LTR should be observed to understand how coastal squeeze and increasing sea levels will impact vulnerable sites along the Atlantic coast of Nova Scotia.

5.4 Impacts of Pre-Conditions on Restoration Trajectory

Pre-conditions may influence the restoration trajectory of some restoring tidal marshes (Janousek et al., 2021; Cai et al., 2022). BEL, CON, SCP, SCW were all former agriculture sites prior to restoration. As mentioned, reclaimed agricultural land is often subsided leading to high rates of sediment deposition early within restoration (Bowron et al., 2015a), which was observed at all four sites. In addition, BEL, CON, SCP, and SCW similarities in their trajectories with regards to OM content, bulk density, *S. pumilus* abundance, and halophytic cover per plot. The similarities between BEL, SCP, and SCW pre-restoration into post-restoration were explored by van Proosdij et al. (2023) and found sediment accretion was rapid early on, burying old vegetation to create a blank canvas for colonization of tidal species—elevation change was linked predominantly to allochthonous sources. While CON did not have high cumulative accretion rates compared to BEL, SCP, and SCW, there was enough sediment in Year 1 to cover the agricultural species, resulting in bare ground with sparse colonization; there was also die back of agricultural species (Bowron et al., 2020a). CON is located within the Upper Bay of Fundy and is part of the broader Tantramar Marsh system on the Chignecto Isthmus (Bowron et al., 2019). Tidal marshes in this area are exposed to high concentrations of suspended sediment (Gordon et al., 1985; van Proosdij et al., 1999; van Proosdij et al., 2006), similar to the Jijuktu'kwejk (Cornwallis) River near BEL (van Proosdij et al., 2023) and the St. Croix River (Lemieux, 2012; van Proosdij et al., 2023). Abundances of *S. michauxianus* were similar at BEL, SCP, and SCW; colonization has been slow at CON and vegetated area remained low in Year 3.

COG and WS were both impoundments pre-restoration and share similarities in their trajectories with regards to OM content and plant communities post-restoration; abundances of both *S.pumilus* and *S.michauxianus*, the mean number of plant species, halophytic species, halophytic cover, and vegetated area per plot were similar by Year 10+. At WS, it was determined that the pattern and rate of plant colonization were driven by the sediment characteristics, consolidation, and dewatering of sediments (van Proosdij et al., 2010). *S. pumilus* was slow to colonize at WS by Year 5 (van Proosdij et al., 2010), however, this changed by the 2022 survey; this was similar at COG.

Other pre-conditions did not appear to influence the trajectories. Three sites—CHV, ABR, and MAV—underwent infrastructure development projects; they had tidal flow pre-restoration however, it was restricted due to the undersized structures in place which limited hydrology. Similarities between ABR and MAV are more likely to be associated with sediment type—organogenic—than with pre-condition. There were similarities between ABR and CHV with respect to the mean number of species, halophytic species, and halophytic cover per plot however, all other environmental variables differed between these sites. TFH had a unique pre-condition within the selected sites as it was a freshwater bog. It appears that rather than the pre-condition influencing the restoration trajectory, sediment type is more likely the influencing factor given TFH shared many similarities to ABR and MAV (OM content, bulk density, vegetated area, and marsh platform elevation).

5.5 Research Limitations and Future Work

A limitation of this research was with the data itself—with the data collected during the original monitoring period, the data used from 2021 and the data collected during the 2022 season. Data collected within the early restoration projects and within the original monitoring program was limited to the data that was collected at the time and in the manner in which it was collected—if data was missing, not collected, or collected in an incompatible way, there was no way to access or have that data to apply within this study (e.g., elevations not being taken at the MHs pre-restoration because the GNSS technology was not available at the time). In addition, not all the data was collected the same across years as procedures often change overtime, especially between 2004 and 2022. Examples would be the length of time the water level loggers are left out to collect data (ex., 14 days at the older sites versus 29 days at the newer restoration sites) or the time in the muffle furnace to determine organic matter content (2 hours versus 4 hours). For ABR, ABR-R, BEL, CON, MAV, and MAV-R, Year 5 was being collected during the 2023-2024 field season. Exploring site similarities and differences, as well as restoration trajectory, for these sites was much more limited given the available data to compare with the other sites.

All data collected in 2022 was collected in a way that would allow for a comparison to the old data, which included continuing with older methods where needed—for example, loss on ignition (LOI) is the most common method used for determining organic matter content however, there is no standard procedure for this method (Hoogsteen et al., 2015). In addition, research suggests sediment core samples used for determining bulk density, water content and organic matter content determined through LOI may be overestimating the OM content of the sample (Frangipane et al., 2009; Farmer et al., 2014; Sampson, 2023). Instead of attempting to determine a new standard procedure for OM content, samples in this research were analyzed using the LOI method which had been used for processing previous samples. There was also limited time for analyzing data and some collected data could not be included in this thesis (e.g., grain size samples and elemental analysis[17] data to compare with the LOI results).

[17] Method used for determining organic and inorganic contents in a sample using a CHNS/O Analyzer (Carbon, Hydrogen, Nitrogen, Sulfur, and Oxygen).

Another limitation within this study was with the reference sites. Not all paired sites used within the original monitoring program were used within this study—there were two that were not used. The reference site for the St. Croix sites, SCR, and the Belcher St. reference, BEL-R, were not included in this study. SCR was not the best fit to the restoration sites due to its small size, location on a different branch of the river, and not being within the same tidal range as the restoring sites. As for BEL-R, it is located across the river from the restoration site but does not have RSETs or MHs installed and therefore, was not used; BEL has an RSET on part of the fringe marsh to act as a reference condition (Graham et al., 2021).

Lastly, as with many cases, time was a limiting factor. Due to the large amount of data that needed to be collected in during the 2022 field season, the RSETs and MHs could not be sampled as originally intended. Without present-day net accretion values, cumulative accretion was used instead as elevations of the MHs were collected in 2022. Had time permitted, the deployment of water level loggers would have been beneficial as it would have provided a better understanding of present-day site hydrology and inundation times, especially for the older restoration sites. Flight data that was collected could have also been used for habitat mapping paired with the vegetation data but this required too much time for preparation and there was no adequate method for comparing new maps to those in the original monitoring reports. Despite the difficulties, data from 250+ vegetation plots, 95 sediment cores, and 16 sites was collected and incorporated into this research.

Chapter 6 – Conclusion

Low-lying coastal ecosystems, such as tidal wetlands, are vulnerable to degradation or loss due to climate change and anthropogenic influences. Accelerated changes in vegetation distribution and pattern, vertical accretion, and erosion along the marsh edge have called into question the sustainability of these ecosystems into the future. There are few remaining untouched, natural tidal marshes in Nova Scotia, therefore, ecosystem restoration has been an important avenue for rehabilitating previously damaged or destroyed tidal marshes. However, despite the successful restoration of over 400 ha of tidal wetland habitat throughout the province since 2005, questions remain. Questions such as: are there are different classes or ways to classify NS tidal marshes; does pre-condition influence these classifications; and are there specific or characteristics restoration trajectories for each class?

In summary, a PCA identified three groupings along with environmental variables and some ungrouped sites and variables; one grouping—BEL, SCP, and SCW—shared similarities both pre- and post-restoration. Clusters identified during subsequent analysis were by sediment type—whether a site is organo- or minerogenic—rather than by geography. Cumulative accretion estimates show only six of the sixteen sites within this study are keeping pace with IPCC sea-level projections and identified one site of particular concern (LTR). Despite the concerning threats to the selected sites based on the IPCC sea-level rise projections, tidal marshes have been adapting to changing water levels for millennia (Singh et al., 2007); storm activity, tidal nodal oscillations, and seasonal variation can all impact sedimentation and accretion rates. Pre-conditions may influence the restoration trajectory of certain sites, particularly former agricultural lands and impoundments.

Future work should be undertaken to explore the present-day accretion levels the sites within this study for comparison to the cumulative accretion values, and to confirm whether this is a good proxy for net accretion. There should also be expansion of restoration projects into other areas of the province, such as the Northumberland Strait and Cape Breton. This expansion could allow for the identification of sites of potential concern, like LTR. Lastly, once available, Year 5 data should be incorporated into the results for ABR, ABR-R, BEL, CON, MAV, and MAV-R for comparison with the other sites.

This study emphasizes the importance of long-term data collection within tidal wetland restoration to allow for monitoring of ongoing processes and to determine whether their restoration trajectory is as anticipated, especially in light of climate change and sea-level rise. It highlights differences between minerogenic and organogenic tidal marshes in Nova Scotia which are important for not only ongoing restoration projects but future projects. As tidal wetland restoration expands to sites outside of the Bay of Fundy, methods and data collection techniques may need to be adjusted to best capture the changes occurring pre-and post-restoration. Lastly, while future projections threaten several tidal marshes in this study, they are continuing to accrete—even if only by millimeters—with each day and each tide, showing their ongoing resiliency to the threats they face.

"The environment was lost by increments. It can be saved by increments."

[Wendi Goldsmith, in Ghost Nets, Unraveling the Trap of the Familiar, an earth art project by Aviva Rahmani, at the International Landscape Conference on Site Technologies, Harvard Graduate School of Design, April 1998]

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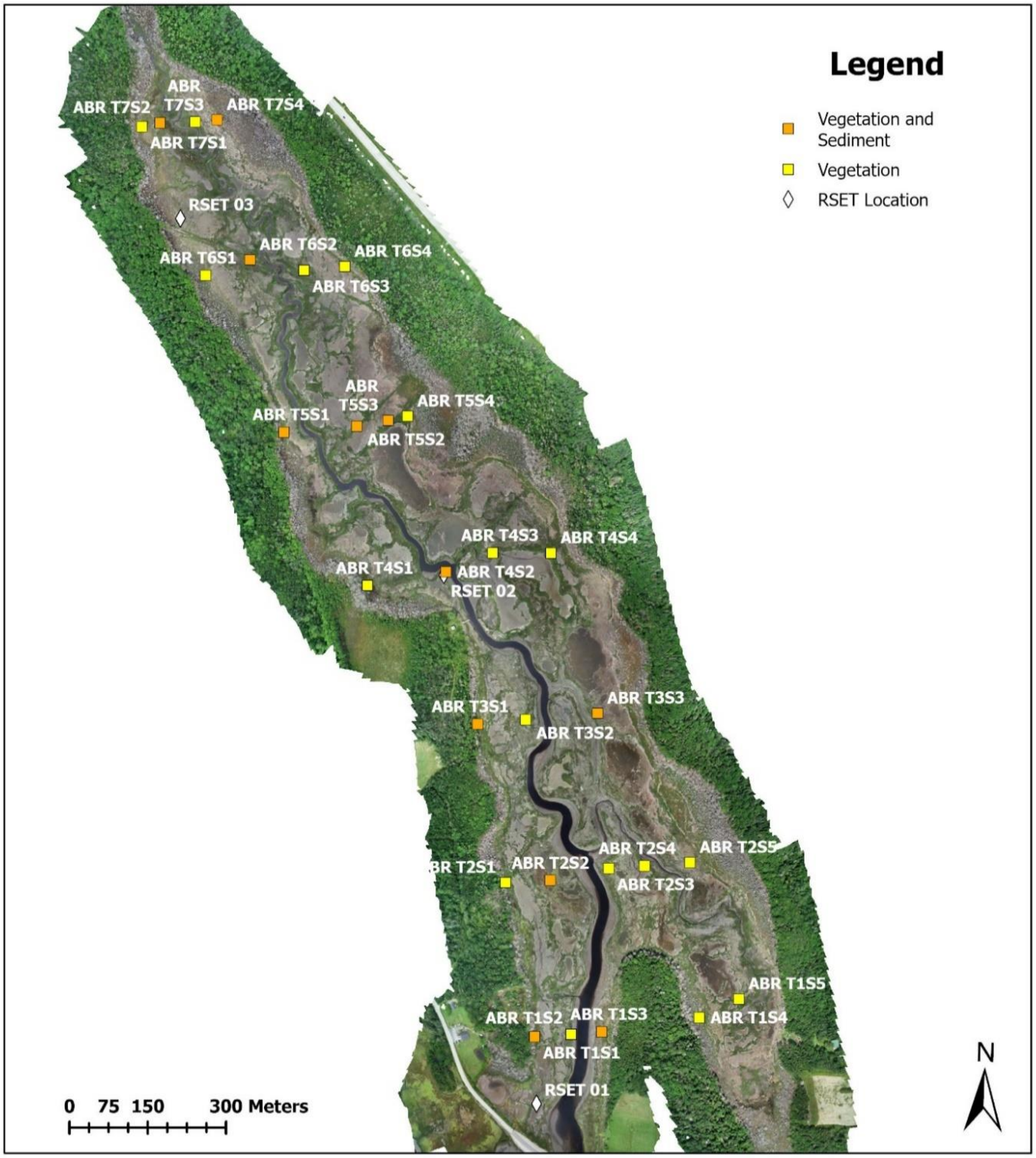
Appendices

Appendix A – Site Maps



Abrams River Restoration Sample Station Layout

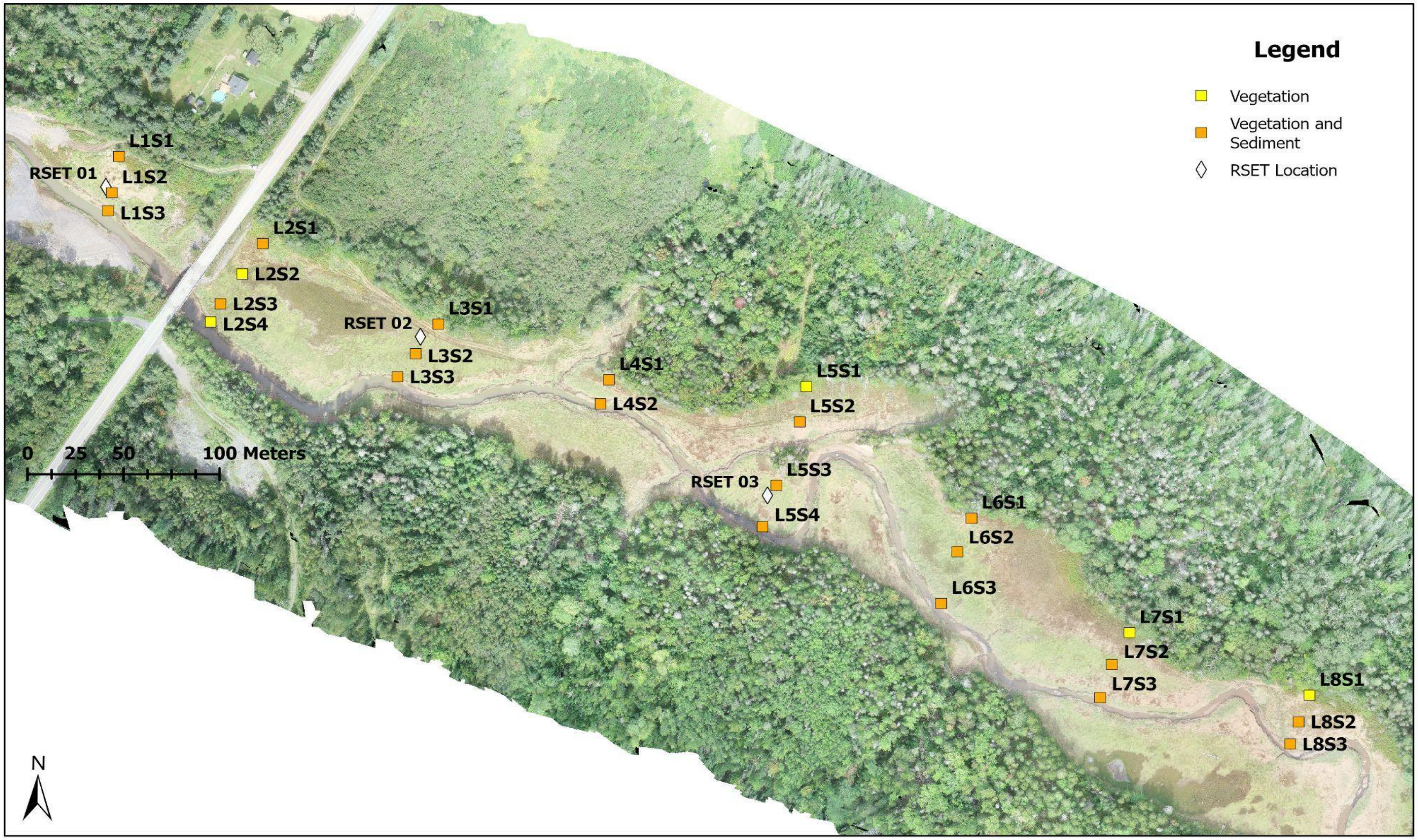
Kayla Williams, MSc.

Datum: UTM Zone 20N, NAD83 [CSRS]
Date: Aug 12, 2022
Data: Surveyed between May & Sept 2021
Orthomosaic: CBWES, Sept 1, 2021

Abrams River Reference Sample Station Layout

Kayla Williams, MSc.

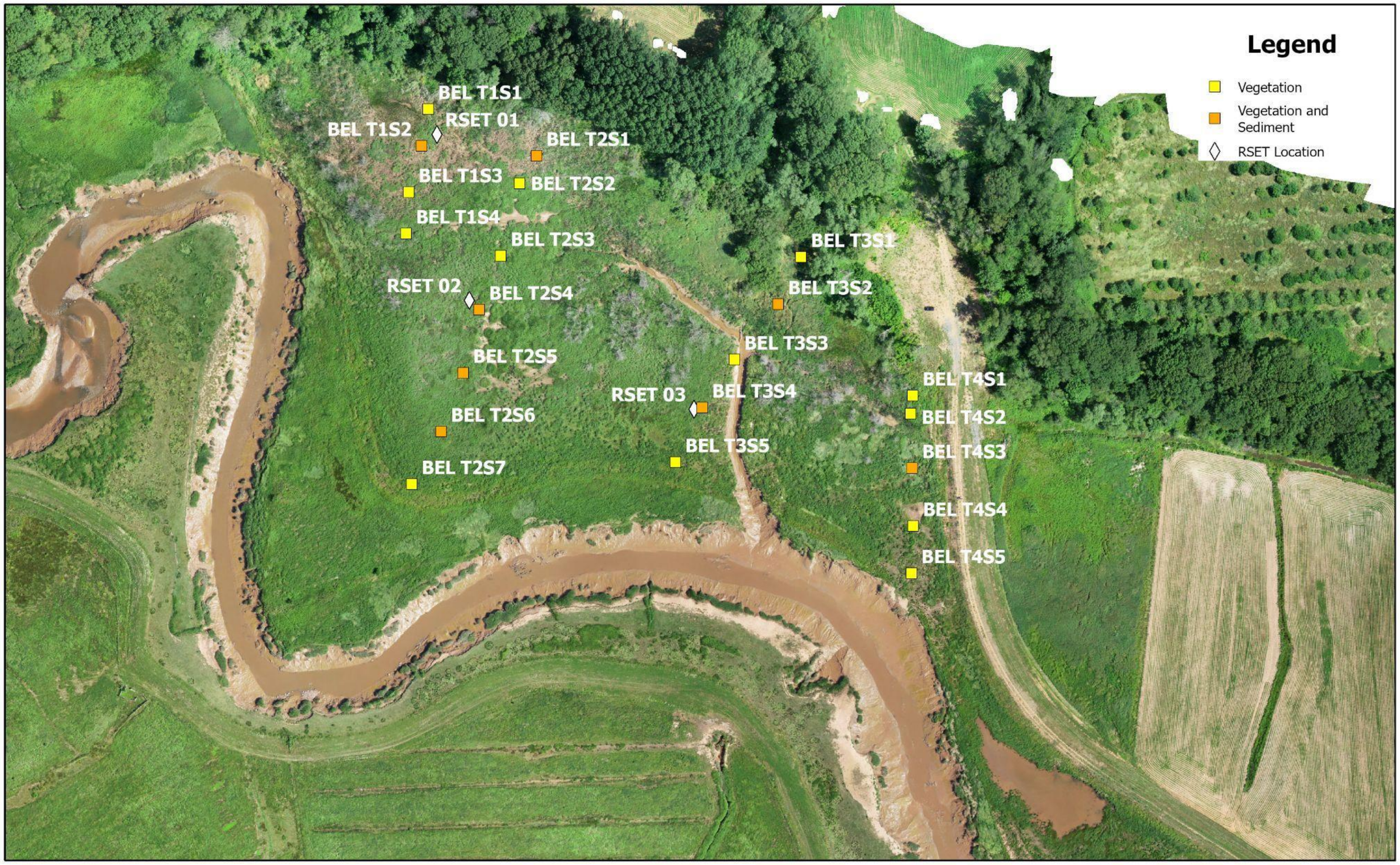
Datum: UTM Zone 20N, NAD83 [CSRS]
Date: Aug 12, 2022
Data: Surveyed between May & Sept 2021
Orthomosaic: CBWES, Sept 1, 2021



Bass Creek Sample Station Layout

Kayla Williams, MSc.

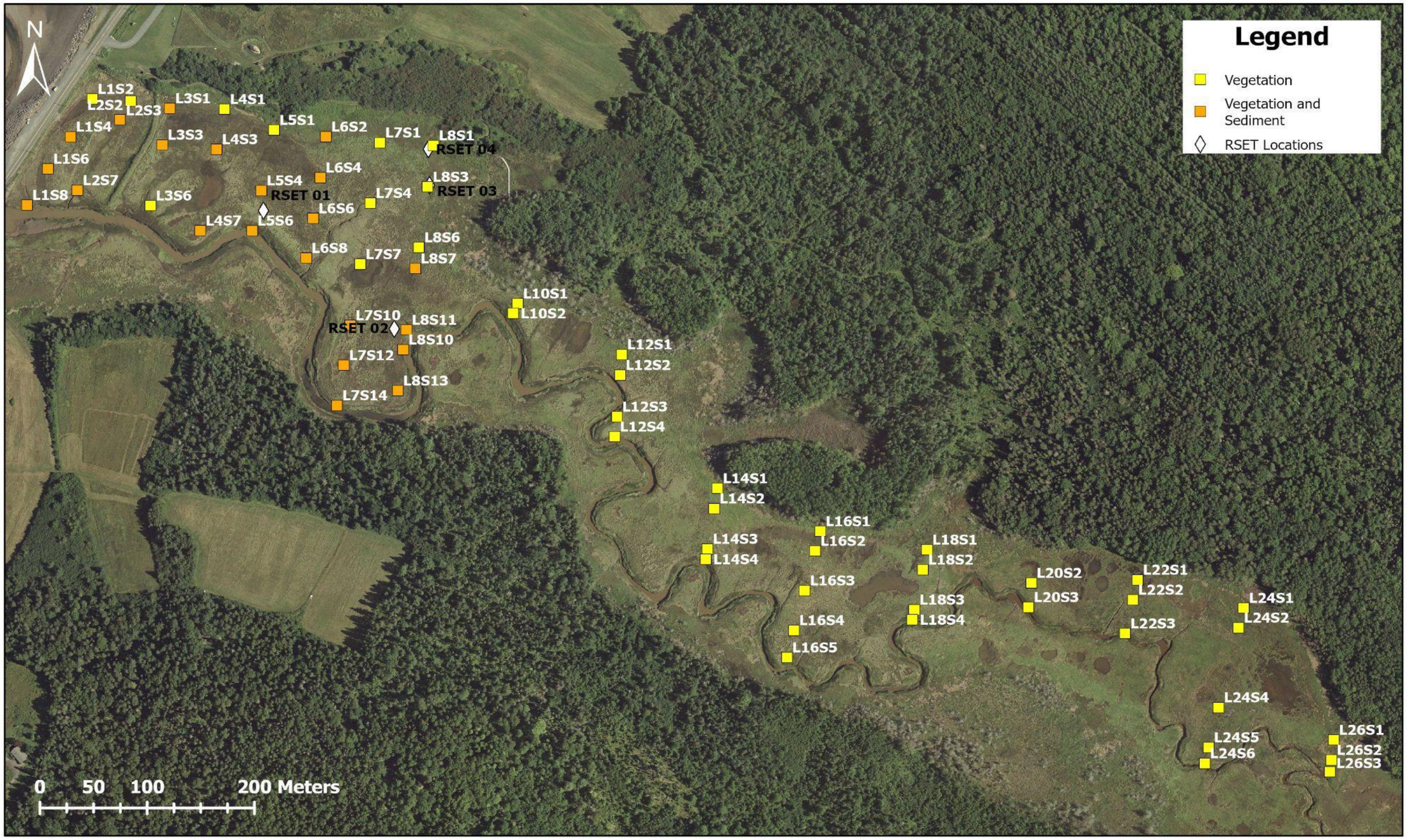
Datum: UTM Zone 20N, NAD83 [CSRS]
Date: Sept 21, 2022
Data: Surveyed between April & September 2022
Orthomosaic: Maritime Provinces Spatial Analysis Research Centre, Sept 6, 2022



Belcher Street Restoration Sample Station Layout

Kayla Williams, MSc.

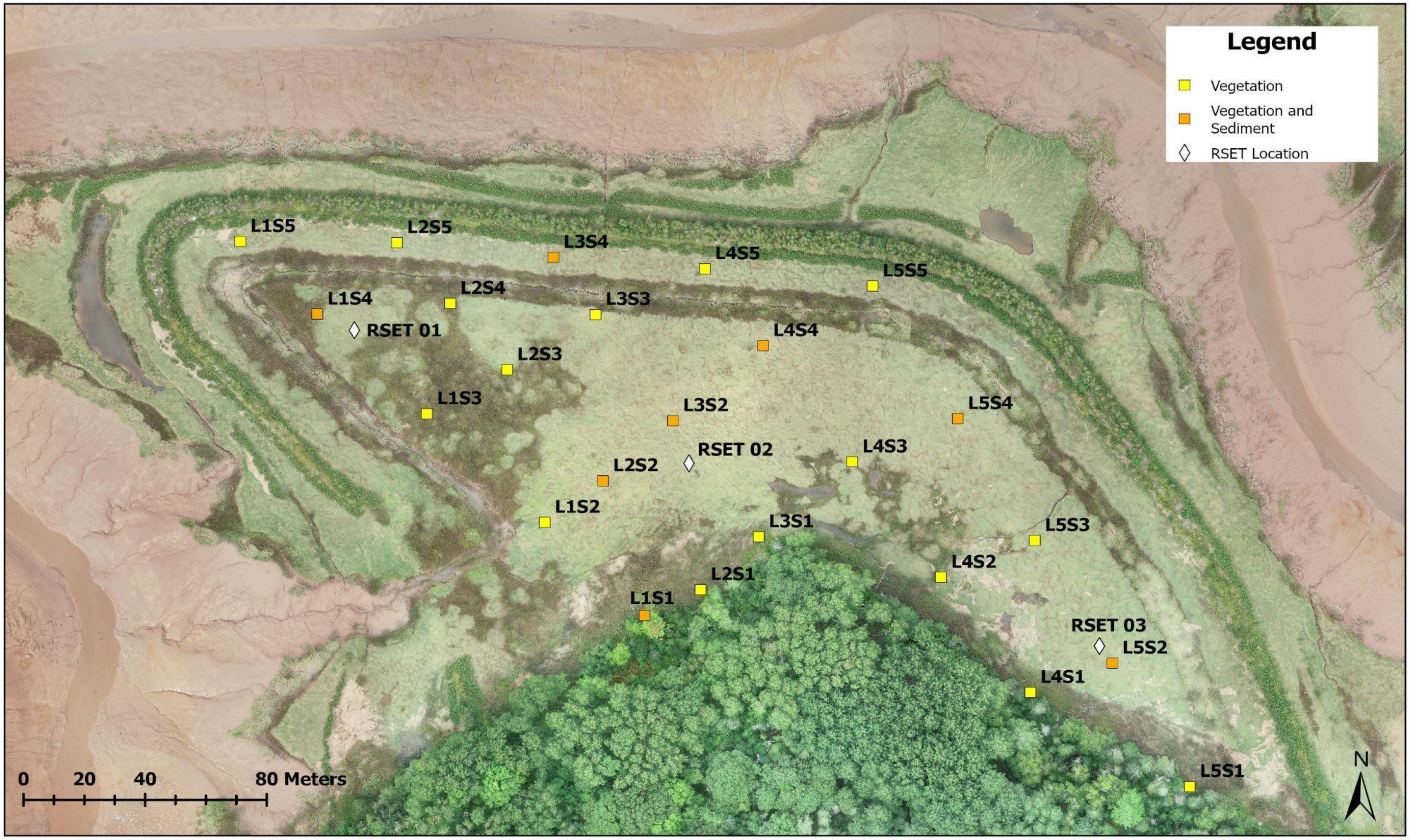
Datum: UTM Zone 20N, NAD83 [CSRS]
Date: Aug 12, 2022
Data: Surveyed between May & Oct 2021
Orthomosaic: CBWES, July 13, 2021



Cheverie Creek Restoration Sample Station Layout

Kayla Williams, MSc.

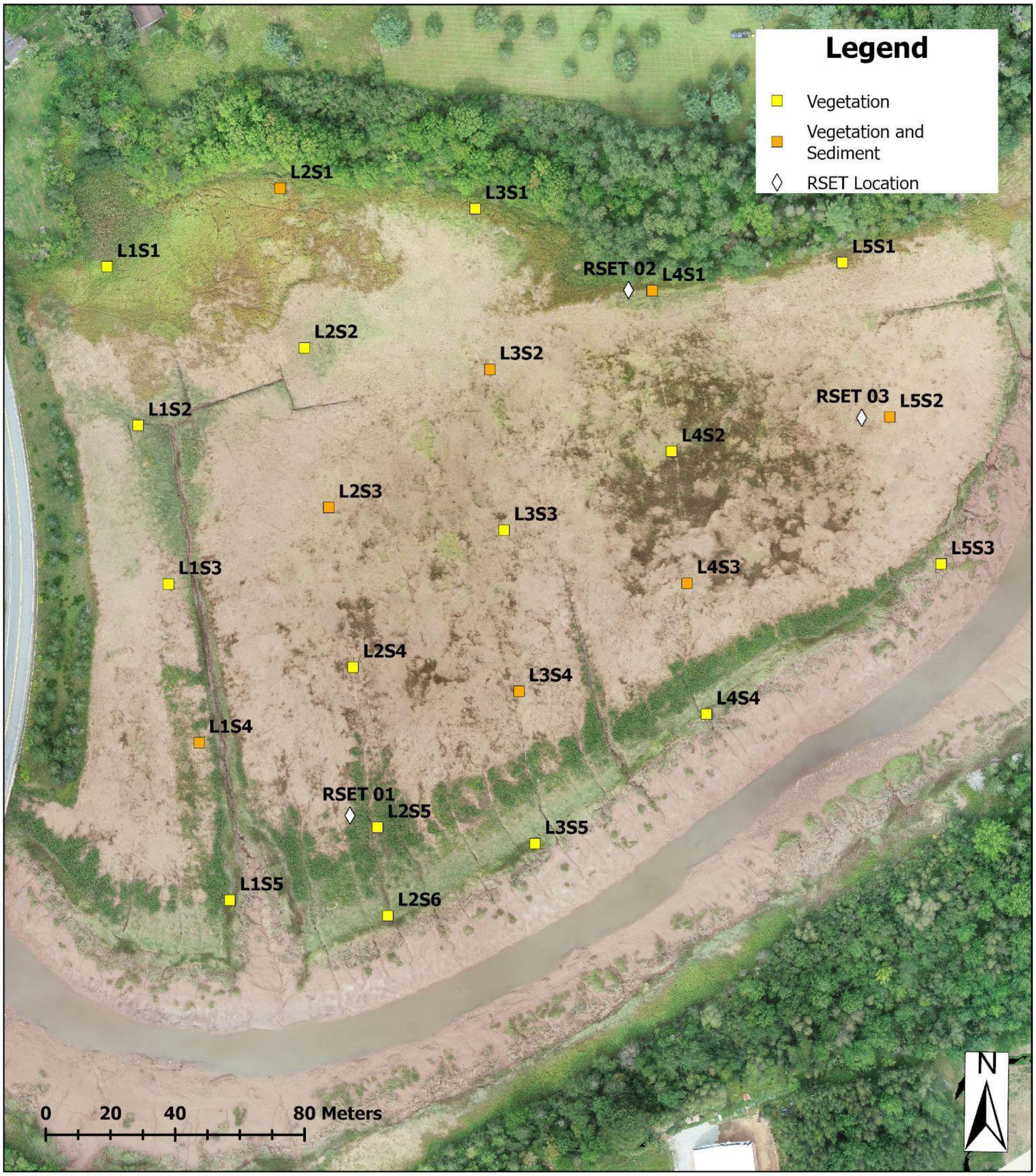
Datum: UTM Zone 20N, NAD83 [CSRS]
Date: Aug 11, 2022
Data: Surveyed between April & Oct 2022
Orthomosaic: Province of Nova Scotia, 2012



Cogmagun Restoration Sample Station Layout

Kayla Williams, MSc.

Datum: UTM Zone 20N, NAD83 [CSRS]
Date: Sept 21, 2022
Data: Surveyed between April & September 2022
Orthomosaic: Maritime Provinces Spatial Analysis Research Centre, Sept 5, 2022



Cogmagun Reference Sample Station Layout

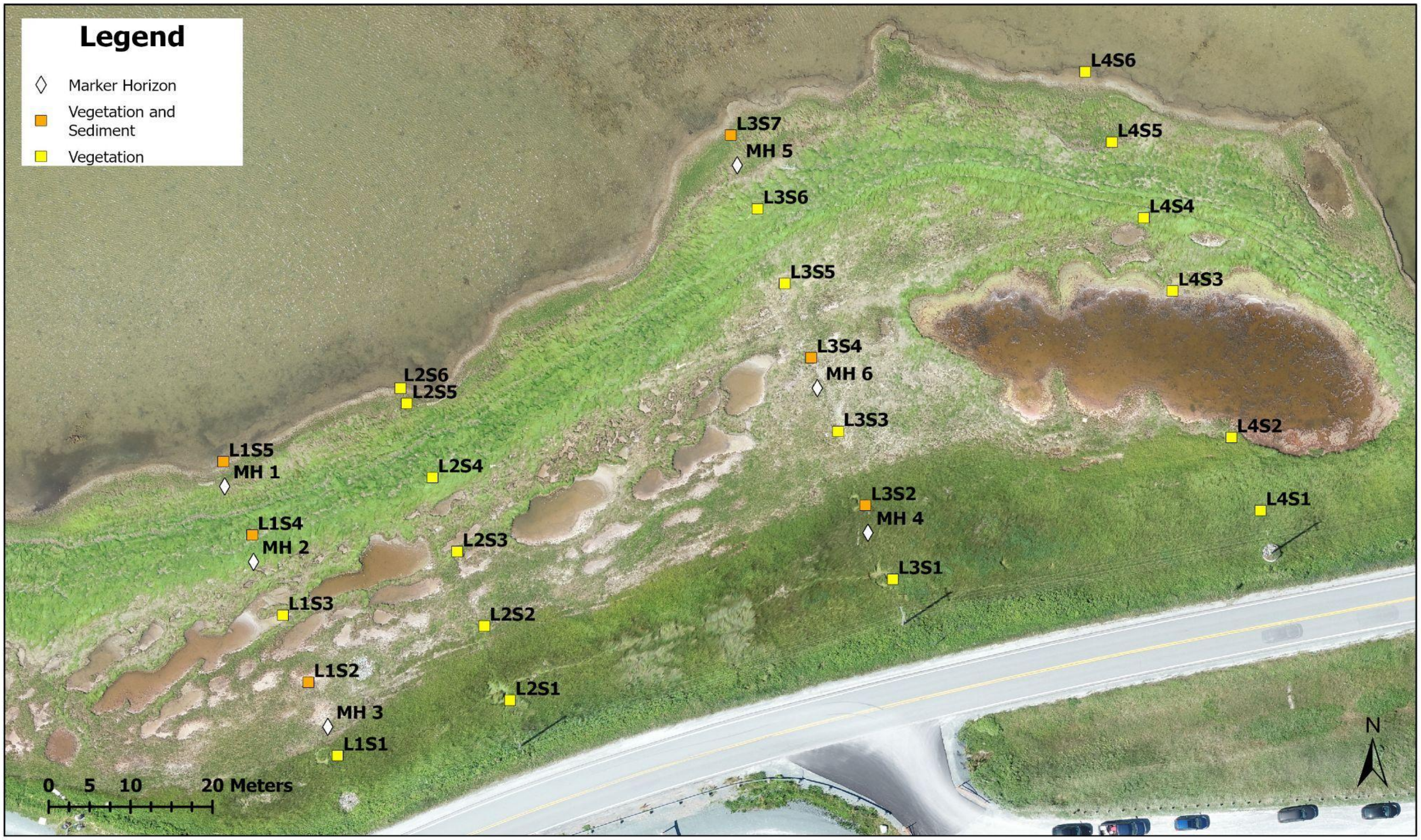
Kayla Williams, MSc.

Datum: UTM Zone 20N, NAD83 [CSRS]
Date: Sept 21, 2022
Data: Surveyed between April & September 2022
Orthomosaic: Maritime Provinces Spatial Analysis Research Centre, Sept 5, 2022

Converse Salt Marsh Restoration Sample Station Layout

Kayla Williams, MSc.

Datum: UTM Zone 20N, NAD83 [CSRS]
Date: Aug 29, 2022
Data: Surveyed between May - Oct 2021
Orthomosaic: CBWES, July 25, 2021



Lawrencetown Reference Sample Station Layout

Kayla Williams, MSc.

Datum: UTM Zone 20N, NAD83 [CSRS]
Date: Aug 11, 2022
Data: Surveyed between April & Oct 2022
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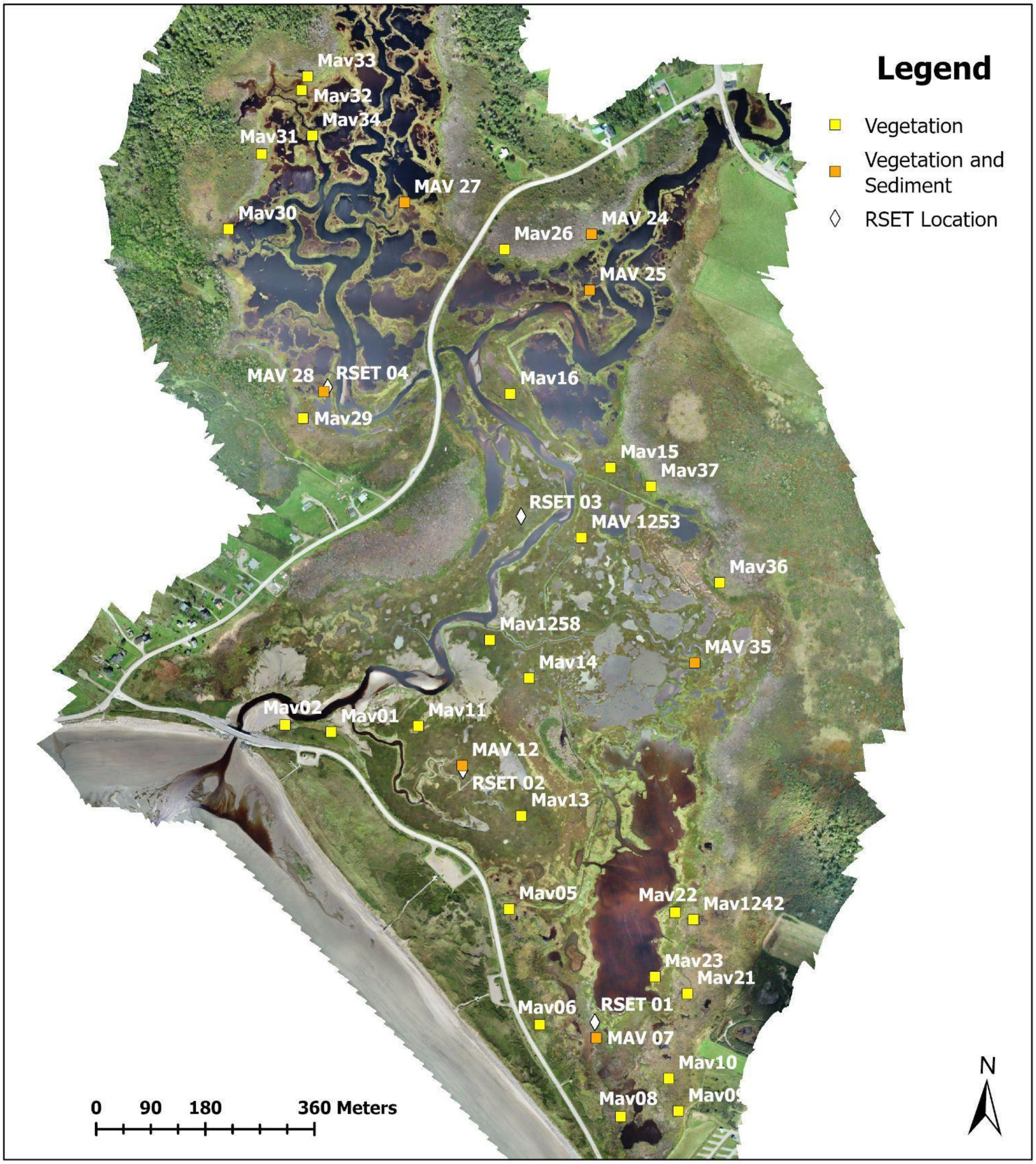


Mavillette Restoration Sample Station Layout

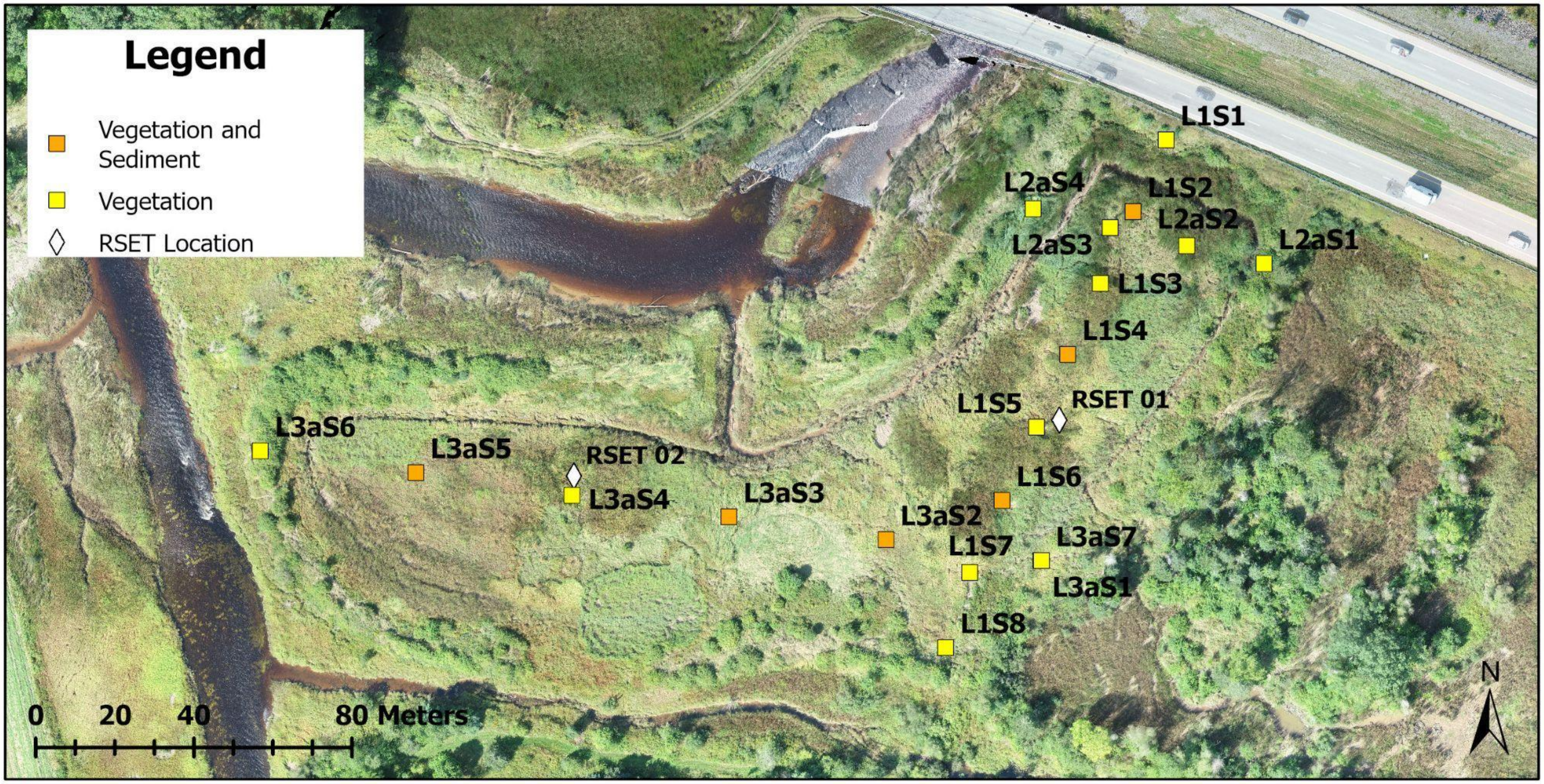
Kayla Williams, MSc.

Datum: UTM Zone 20N, NAD83 [CSRS]
Date: Aug 16, 2022
Data: Surveyed between May - Sept 2021
Orthomosaic: CBWES, Sept 28, 2021

Mavillette Reference Sample Station Layout

Kayla Williams, MSc.

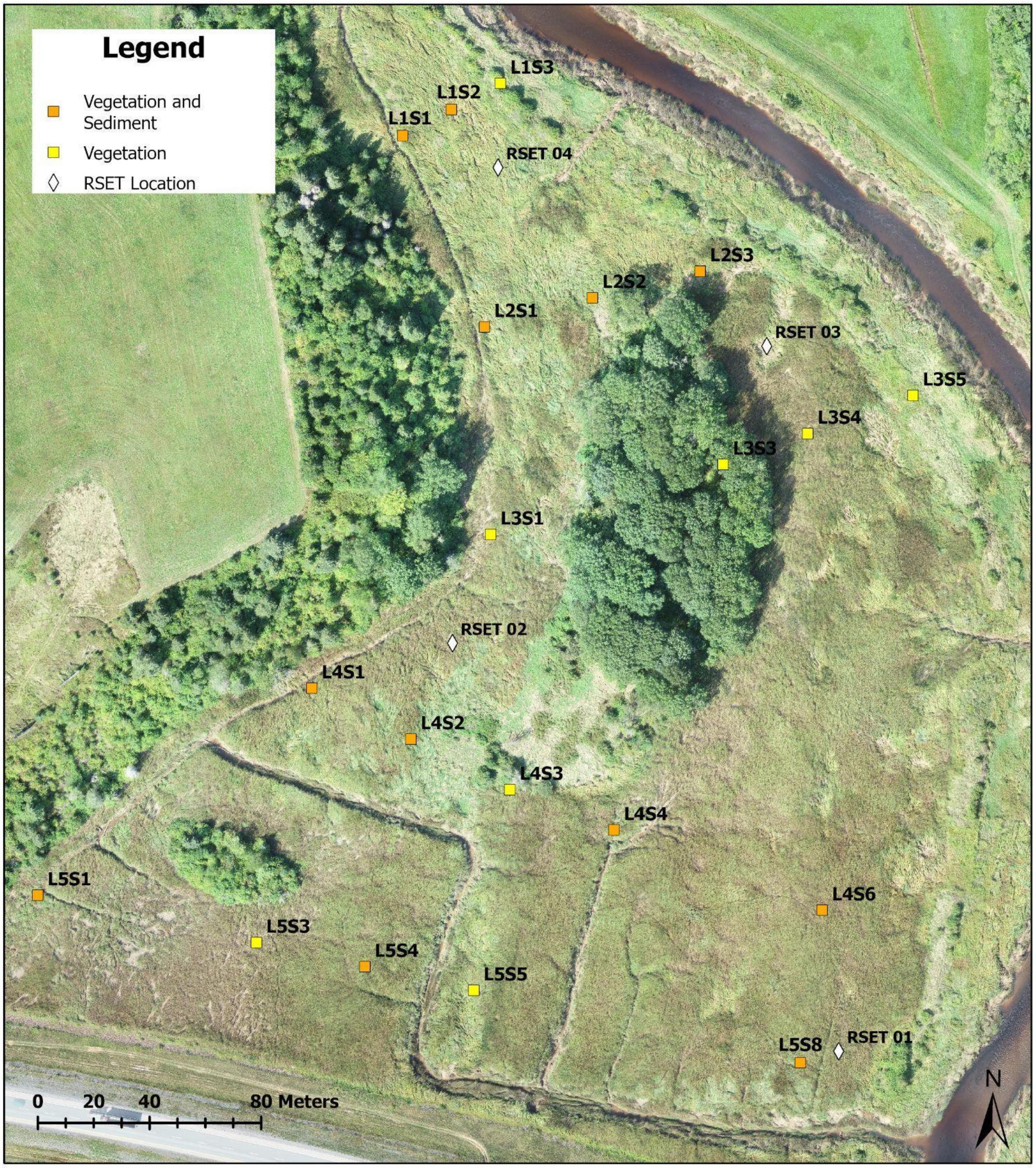
Datum: UTM Zone 20N, NAD83 [CSRS]
Date: Aug 16, 2022
Data: Surveyed between May - Sept 2021
Orthomosaic: CBWES, Sept 27, 2021



St. Croix South-East Sample Station Layout

Kayla Williams, MSc.

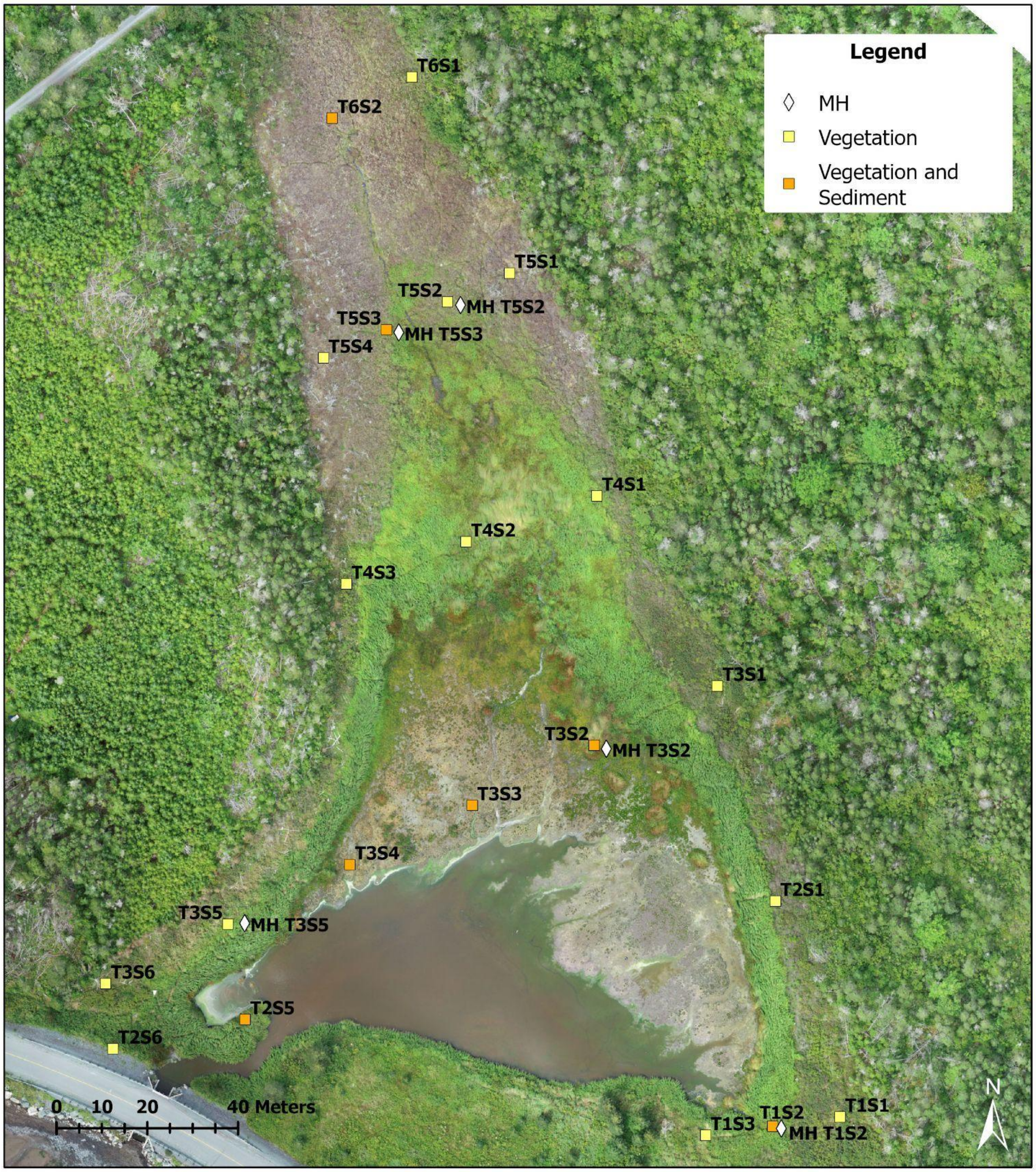
Datum: UTM Zone 20N, NAD83 [CSRS]
Date: Sept 19, 2022
Data: Surveyed between April & Oct 2022
Orthomosaic: Maritime Provinces Spatial Analysis Research Centre, Sept 7, 2022



St. Croix West Sample Station Layout

Kayla Williams, MSc.

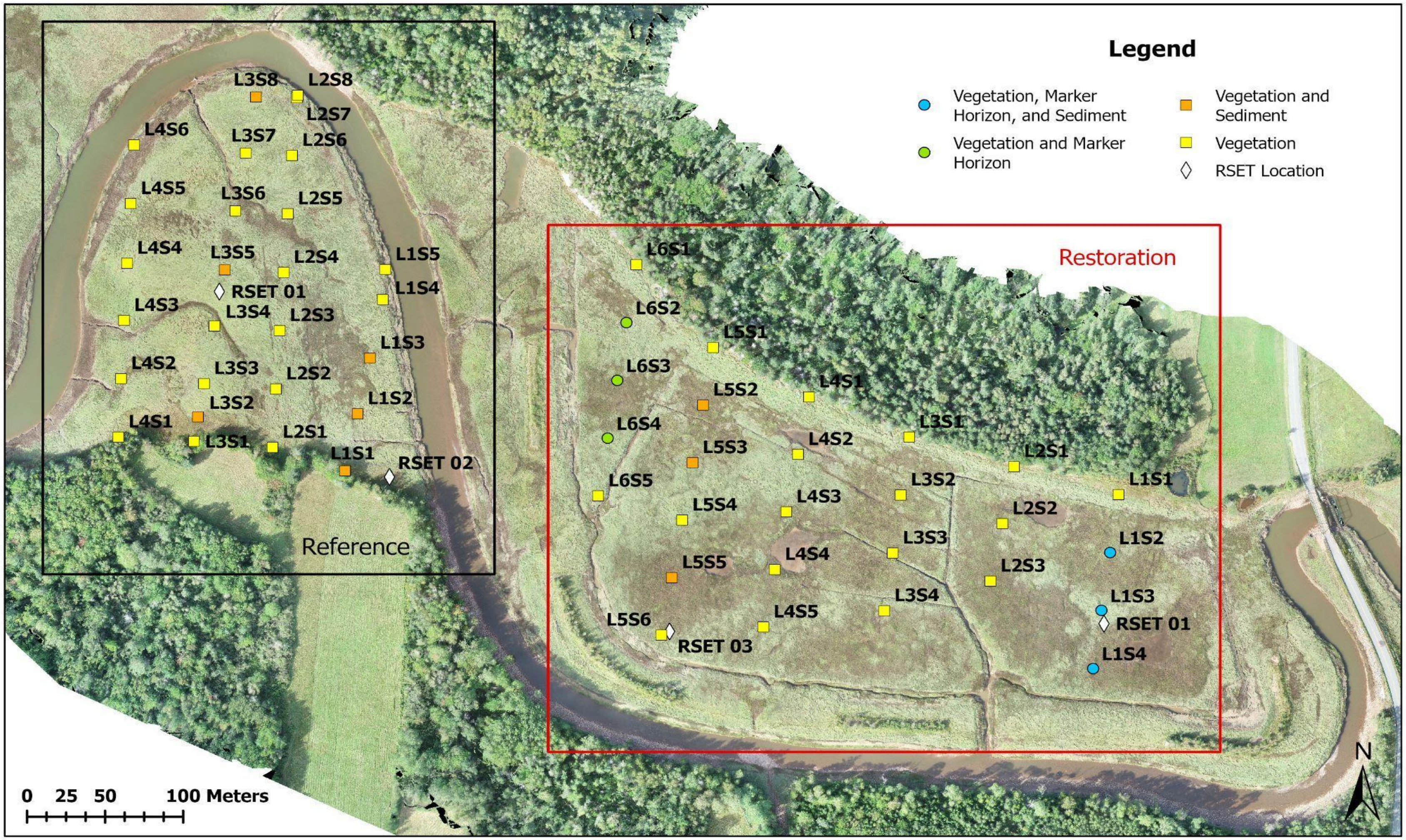
Datum: UTM Zone 20N, NAD83 [CSRS]
Date: Sept 19, 2022
Data: Surveyed between April & Oct 2022
Orthomosaic: Maritime Provinces Spatial Analysis Research Centre, Sept 7, 2022



Three Fathom Harbour Sample Station Layout

Kayla Williams, MSc.

Datum: UTM Zone 20N, NAD83 [CSRS]
Date: Aug 8, 2022
Data: Surveyed between April & Oct 2022
Orthomosaic: CBWES, Sept 2, 2020



Walton River Sample Station Layout

Kayla Williams, MSc.

Datum: UTM Zone 20N, NAD83 [CSRS]
Date: Sept 21, 2022
Data: Surveyed between April & September 2022
Orthomosaic: Maritime Provinces Spatial Analysis Research Centre, Sept 6, 2022

Appendix B– Mean Abundance and Frequency Tables

Table B-1. Vegetation plot data summaries from the Abrams River restoration showing mean abundance, frequency (no. plots), and percent cover for species present. Table modified from the ABR Year 3 monitoring report by CBWES Inc (Graham et al. 2022).

Species Names	Abrams River Restoration					
	pre		1		3	
	abun.	freq.	abun.	freq.	abun.	freq.
Sporobolus alterniflorus	31.1	18	38.7	19	72	25
Sporobolus pumilus	42.9	13	29	20	17.8	10
Sporobolus michauxianus	15.0	7	7.7	8	0	0
Juncus gerardii	0	0	1.1	2	0.03	1
Limonium carolinianum	0.1	1	0	0	0.1	1
Salicornia depressa	0	0	0	0	2.5	8
Solidago sempervirens	0	0	0	0	0.8	2
Algae	0	0	1.5	2	1.2	1
Alnus incana	1.1	1	0	0	0	0
Aster sp.	0.3	2	0	0	0	0
Betula populifolia	1.4	1	0	0	0	0
Bolboschoenus maritimus	2.6	1	3.5	3	0.3	1
Calystegia sepium	0.4	1	0	0	0	0
Carex sp.	3.5	1	0	0	0	0
Distichlis spicata	0	0	0.3	1	0.1	1
Elymus repens	0.4	1	0	0	0.3	1
Anthoxanthum nitens	1.0	2	0	0	0	0
Juncus balticus	20.7	8	1.3	2	0	0
Morella pensylvanica	3.6	3	0	0	0	0
Moss	6.9	2	0	0	0	0
Myrica gale	2.5	1	0	0	0	0
Picea glauca	0.1	1	0	0	0	0
Poa palustris	0.6	1	0	0	0	0
Poa sp.	1.4	1	0	0	0	0
Rhododendron groenlandicum	1.1	1	0	0	0	0
Rosa virginiana	0.9	4	0	0	0	0
Rubus strigosus	0.03	1	0	0	0	0

Ruppia maritima	3.3	2	0	0	7.6	3
Salicornia maritima	0.6	6	1.3	5	0	0
Schoenoplectus acutus	1.5	1	0	0	0	0
Schoenoplectus americanus	0	0	3.3	1	3.2	1
Scirpus sp.	3.3	1	0	0	0	0
Sphagnum moss	1.7	2	0	0	0	0
Suaeda maritima spp maritima	0.03	1	0.03	1	0.3	4
Symphyotrichum novi-belgii	0.4	4	0	0	0	0
Thelypteris noveboracensis	0.1	1	0	0	0	0
Triglochin maritima	2.6	5	1.9	4	0	0
Typha angustifolia	6.0	5	0	0	0	0
Unknown grass	0	0	0.9	1	0	0

Table B-2. Vegetation plot data summaries from the Abrams River reference showing mean abundance, frequency (no. plots), and percent cover for species present. Table modified from the ABR Year 3 monitoring report by CBWES Inc (Graham et al. 2022).

Species Names	**Abrams River Reference**					
	pre		**1**		**3**	
	abun.	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**
Agalinis maritima	1.67	1	0.83	2	0.38	2
Agrostis stolonifera	4.54	3	2.33	2	5.17	3
Aster sp.	0	0	0	0	0.04	1
Atriplex glabriuscula	0	0	0	0	0.17	1
Atriplex prostrata	0	0	0.83	1	0	0
Atriplex sp.	0	0	0	0	0.21	2
Distichlis spicata	8.67	3	6.67	2	8.5	3
Elymus virginicus	0	0	0	0	0.04	1
Festuca rubra	1.33	1	3.67	1	9	5
Juncus balticus	4.17	1	4.83	2	4.17	1
Juncus gerardii	8.33	4	13	5	8.5	4
Limonium carolinianum	0.54	3	0.21	2	0.46	8

Lysimachia maritima	4.17	2	3.67	2	4.33	3
Plantago maritima	0	0	3.83	2	2.5	3
Poa.sp	0	0	0.04	1	0	0
Ruppia maritima	0	0	0	0	4.17	1
Salicornia depressa	0	0	0	0	14.46	15
Salicornia maritima	0.04	1	2.29	10	0	0
Schoenoplectus americanus	4	1	4.17	1	4	1
Solidago sempervirens	2.83	3	1.67	3	4.88	6
Sporobolus alterniflorus	35.33	10	26.5	10	29.17	13
Sporobolus michauxianus	3	2	2.17	2	5.33	2
Sporobolus pumilus	53.33	15	57.83	15	68.38	20
Suaeda maritima spp maritima	0	0	0	0	3.33	1
Triglochin maritima	7.17	3	8.17	3	5.33	4
Unknown grass	0	0	5.83	2	0	0

Table B-3. Vegetation plot data summaries from Bass Creek showing mean abundance and frequency for present species.

	Bass Creek													
	pre		1		2		3		5		7		17	
Species Names	**abun.**	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**
Agrostis stolonifera	0	0	0.0	1	1.5	3	3.4	3	6.2	4	2.2	2	1.9	2
Ammophila breviligulata	0.1	2	5.3	4	0	0	0	0	0	0	0	0	0	0
Anthoxanthum nitens	0	0	0	0	0	0	2.4	4	4.6	3	0.8	2	0	0
Ascophyllum nodosum	0	0	0.3	1	0	0	0	0	0	0	0	0	0	0
Atriplex glabriuscula	0.1	1	0.3	4	0.4	4	1.8	7	0.9	4	1.1	3	0.8	4
Calystegia sepium	0	0	0.3	1	0.0	1	0.3	1	0.3	1	0.9	1	0	0
Carex paleacea	2.3	5	4.6	3	9.7	4	8.9	5	15.4	6	13.5	5	20	6
Distichlis spicata	0	0	4.5	4	1.7	2	4	2	4	2	4.7	3	5.8	2
Elymus repens	0	0	0	0	0	0	0	0	0	0	0.9	2	0	0
Elymus trachycaulus	0	0	1	2	1.4	1	1.9	1	0	0	0	0	0	0
Euthamia graminifolia	0	0	1.6	2	0	0	3.7	2	0	0	0	0	0	0
Festuca rubra	0	0	0.6	3	0	0	9.1	4	5.38	2	4.96	3	1.9	4

Juncus arcticus	0	0	2.4	1	0	0	0	0	0	0	0	0	0	0
Juncus articulatus	0	0	2.6	1	0	0	0	0	0	0	0	0	0	0
Juncus balticus	0	0	0	0	4.6	2	5.9	2	6	2	4.46	2	3.4	1
Juncus brevicaudatus	0	0	0.3	1	0	0	0.04	1	0	0	0	0	0	0
Juncus effusus	0.0	1	3.7	1	0	0	0	0	0	0	0	0	0	0
Juncus gerardii	10.3	4	20.8	10	29.3	12	17.4	6	25.5	8	18.8	10	31.0	8
Limonium carolinianum	0.5	5	0.7	4	0.2	2	0.2	2	3.6	7	0.2	2	1.0	2
Lysimachia maritima	0.1	4	1.8	3	1.7	4	0.3	2	1.4	2	0.1	2	4.3	2
Plantago major	0	0	0	0	0	0	0	0	0.2	1	0	0	0	0
Plantago maritima	0.61	3	6.7	5	7.38	4	0	0	6.5	4	4.2	4	0	0
Poa palustris	0.0	0	0	0	0	0	0	0	0	0	0	0	0.04	1
Potentilla anserina	0	0	0	0	0	0	1.92	4	0	0	0	0	0.04	1
Salicornia depressa	0.1	4	0.1	2	0.46	1	0.5	2	1.69	3	0	0	0.04	1
Salicornia maritima	0	0	0	0	0	0	0	0	0	0	0.19	2	0	0
Schoenoplectus tabermontanii	0	0	0	0	0	0	1.9	1	0	0	0	0	0	0
Solidago sempervirens	0.3	6	10.4	10	6.7	9	5.9	6	12.2	10	8.2	11	3.2	6
Sporobolus alterniflorus	12.1	10	25.0	10	25.6	12	22.0	11	26.5	13	27.0	12	23.7	11
Sporobolus michauxianus	0.2	1	0	0	8.3	5	6.4	4	6.8	3	6.8	6	3.7	2
Sporobolus pumilus	35.9	16	38.2	16	42.3	15	52.2	18	38.3	16	47.2	16	39.4	11
Suaeda maritima spp maritima	0.1	2	2.2	3	2.3	3	2.2	3	0	0	1.4	5	0.8	4
Symphyotrichum lanceolatus	0	0	0	0	2.3	2	0	0	0	0	0	0	0	0
Symphyotrichum novi-belgii	0	0	0	0	0	0	2.0	2	1.4	2	0.5	2	0	0
Triglochin maritima	0	0	0	0	1.2	2	0	0	0.3	1	0.4	2	0.8	2
Unknown seedling	0	0	0	0	0.0	0	0	0	0	0	0	0	0.5	1

Table B-4. Vegetation plot data summaries from Belcher Street showing mean abundance and frequency for present species. Table modified from the BEL Year 3 monitoring report by CBWES Inc (Graham et al., 2021).

Species Name	**Belcher Street Restoration**									
	pre		**1**		**2**		**3**		**4**	
	abun.	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**

Agrostis stolonifera	5	1	0	0	2.6	4	3.24	3	3.8	1
Alopecurus geniculatus	0	0	0	0	0	0	0	0	0.2	1
Ambrosia artemisiifolia	0	0	0	0	0.1	1	0	0	0	0
Anthoxanthum nitens	1.2	1	0	0	0	0	0	0	0	0
Aster sp.	0	0	0	0	0.1	1	0	0	0	0
Atriplex glabriuscula	0	0	0	0	0	0	0	0	13.6	11
Atriplex patula	0	0	0	0	2.8	2	0	0	0	0
Atriplex prostrata	0	0	0	0	0.6	1	0	0	0	0
Atriplex sp.	0	0	0	0	2.3	3	3.1	4	0	0
Bidens cernua	3.7	3	0	0	0	0	0	0	0	0
Bolboschoenus maritimus	0	0	0	0	0	0	3.6	1	8.8	4
Calamagrostis canadensis	14.8	5	1.8	1	4.6	1	2.3	2	0.2	1
Calystegia sepium	0	0	0.2	1	0.1	1	0.2	1	0.8	2
Carex paleacea	0	0	0	0	0	0	0	0	1.5	2
Carex scoparia	15	3	0	0	0	0	0	0	0	0
Carex sp.	2.6	1	1.4	1	5	1	2.3	2	0	0
Carex spicata	0.4	1	0	0	0	0	0	0	3.4	1
Carex stipata	11.4	3	9.8	2	0	0	1.3	1	2.9	1
Chenopodium album	0	0	0	0	1.8	2	7.1	3	0	0
Chenopodium sp.	0	0	0	0	0	0	4	3	0	0
Cicuta bulbifera	0	0	0	0	0.2	1	0	0	0	0
Cicuta maculata	0	0	0	0	0.6	1	0	0	0	0
Doellingeria umbellata	5	2	0	0	0	0	0	0	0	0
Duckweed	10	2	0	0	0	0	0	0	0	0
Echinochloa crus-galli	0	0	0	0	3.4	2	0	0	0	0
Elymus repens	0	0	0.4	1	4.2	2	6.9	2	11.1	5
Elymus virginicus	0	0	0	0	0	0	1.7	2	0.1	1
Epilobium palustre	2.2	2	0	0	0	0	0	0	0	0
Equisetum	1.5	3	0.4	1	1.6	1	0.1	1	0	0
Equisetum arvense	0	0	0	0	1.4	2	0	0	0	0
Eupatorium maculatum	0	0	0	0	0	0	0	0	1.5	1
Galeopsis bifida	0	0	0	0	0	0	0	0	0.2	1
Galium asprellum	0	0	0	0	0	0	0	0	0.1	1
Galium palustre	5.8	3	0	0	0	0	0	0	0	0
Impatiens capensis	0.3	2	3.2	1	4.8	1	1.7	2	3.6	1
Juncus gerardii	0.2	1	0	0	0.1	1	1.3	1	0.6	1
Leersia oryzoides	1.8	1	0	0	1.6	1	3.1	1	0	0
Lycopus uniflorus	0	0	0	0	0	0	0.2	1	0	0
Lysimachia terrestris	0.2	1	0	0	0	0	0	0	0	0
Onoclea sensibilis	5	2	0	0	0	0	0	0	0	0
Oxybasis glauca	0	0	0	0	18.5	9	1.3	2	0	0
Panicum dichotomiflorum	0	0	0	0	3.2	1	0	0	0	0
Persicaria hydropiper	0	0	0	0	1	1	0	0	0	0
Persicaria sagittata	4.7	5	0	0	0.8	2	0	0	0	0

Persicaria sagittata	0	0	0	0	0	0	0	0	0.1	1
Phalaris arundinacea	19.3	5	13	3	10	2	9.5	2	10.7	4
Plantago major	0	0	0	0	0.5	2	0	0	0	0
Poa palustris	12.6	4	0	0	0	0	0.4	1	0.2	1
Poa sp	0	0	0	0	0	0	0	0	0.6	1
Polygonum fowleri	0	0	0	0	0.8	2	3.1	2	0.2	1
Polygonum persicaria	0.2	1	0	0	3.2	2	0	0	0	0
Polygonum punctatum	0	0	0	0	1.8	1	0.1	1	0	0
Polygonum sp.	0	0	0	0	0	0	0	0	1.3	1
Ranunculus repens	1	2	0	0	0	0	0	0	0	0
Rosa virginiana	4.4	2	1.5	2	0	0	0	0	0	0
Rubus idaeus	6	2	0	0	0	0	0	0	0	0
Rumex crispus	0	0	0	0	0	0	0	0	0.2	1
Schoenoplectus acutus	0.6	1	0	0	0	0	0	0	0	0
Scirpus cyperinus	7	3	0	0	0	0	0	0	0	0
Scirpus microcarpus	8	2	0	0	0	0	0	0	0	0
Solanum dulcamara	0.6	1	0	0	0	0	0	0	0	0
Solidago canadensis	5	2	0	0	0	0	0	0	0	0
Solidago sempervirens	0.8	1	0	0	0.5	3	2.3	4	3.2	1
Solidago sp.	0.1	1	0	0	0	0	0	0	0	0
Sonchus arvensis	0	0	0	0	0.1	1	0	0	1.4	2
Sparganium americanum	0	0	0	0	0	0	0	0	5.0	3
Sparganium eurycarpum	13	4	7.4	3	8.0	4	10.5	4	0	0
Spergularia salina	0	0	0	0	0.4	1	0.2	1	0	0
Sphagnum moss	0.9	3	0	0	0	0	0	0	0	0
Sporobolus alterniflorus	0	0	0	0	3.1	3	14.3	7	32.1	9
Sporobolus michauxianus	2.3	3	0	0	7.8	7	33.7	12	39.2	14
Suaeda maritima spp maritima	0	0	0	0	0	0	0	0	3.3	4
Suaeda sp.	0	0	0	0	0	0	0.2	1	0	0
Symphyotrichum novi-belgii	1.4	3	0	0	1.6	2	5.5	2	8.1	4
Taraxacum officinale	0.4	1	0	0	0.4	1	0	0	0	0
Trifolium sp.	0	0	0	0	0.6	1	0	0	0	0
Typha angustifolia	0	0	0	0	14.8	4	0	0	0	0
Typha latifolia	10.3	6	8.3	4	7.3	5	13.2	9	4.8	4
Unknown grass	0	0	0	0	1.8	1	0	0	0	0
Unknown seedling	0	0	0.1	1	0	0	0	0	0	0
Vicia sp.	2.3	3	0	0	0.2	1	0	0	3.4	1

Table B-5. Vegetation plot data summaries from Cheverie Creek showing mean abundance and frequency for present species.

Species Name	Cheverie Creek						
	pre	1	2	3	5	7	17

	abun.	freq.	abun.	freq.	abun.	freq.	abun.	freq.	abun.	freq.	abun.	freq.	abun.	freq.
Agrostis stolonifera	0	0	0.2	1	0.0	1	0.0	0	0	0	0	0	0	0
Algae	0	0	0.4	1	0.8	2	0.9	1	0.0	1	0	0	2.3	2
Ammophila breviligulata	3.5	2	1.0	1	0	0	0	0	0	0	0	0	0	0
Ascophyllum nodosum	0	0	0	0	0.2	1	0	0	0	0	0	0	0	0
Atriplex glabriuscula	0.1	3	0.1	1	0.4	4	0.3	4	0.2	3	0.3	3	0.0	1
Carex paleacea	1.1	1	2.9	6	8.6	9	3.5	6	4.8	3	5.8	6	4.4	5
Daucus carota	0.4	1	0	0	0	0	0	0	0	0	0	0	0	0
Distichlis spicata	0	0	1.7	1	0.8	3	0.1	1	1.26	3	4	7	6.7	10
Festuca rubra	0	0	0	0	0.2	1	0	0	0	0	0.1	1	0	0
Juncus balticus	0	0	0	0	0.6	1	0	0	0	0	0	0	0	0
Juncus gerardii	0	0	11.7	9	6.6	7	2.1	4	4.3	3	3.2	2	0.0	0
Lathyrus japonicus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Limonium carolinianum	0.04	1	1.1	3	0.9	5	0.4	3	1.0	6	0.3	4	0.3	5
Lysimachia maritima	0	0	0.02	1	0	0	0	0	0	0	0	0	0	0
Mentha arvensis	0.2	1	0	0	0	0	0	0	0	0	0	0	0	0
Plantago maritima	0	0	0	0	0.1	1	0.1	1	0.4	3	0.4	2	0.1	1
Poa palustris	0	0	0	0	0.02	1	0	0	0	0	0	0	0	0
Potentilla anserina	0	0	0	0	0	0	0	0	0	0	0	0	0.02	1
Potentilla simplex	1.1	1	0	0	0	0	0	0	0	0	0	0	0	0
Rosa virginiana	0.9	1	0	0	0	0	0	0	0	0	0	0	0	0
Rubus strigosus	0.2	1	0	0	0	0	0	0	0	0	0	0	0	0
Ruppia maritima	0	0	0.3	1	0	0	0	0	1.7	2	0	0	0	0
Salicornia depressa	0.2	5	0	0	0.7	8	2.2	13	0.6	6	0	0	0.9	1
Salicornia maritima	0	0	0	0	0	0	0	0	0	0	0.07	1	0	0
Schoenoplectus acutus	1.7	1	0	0	0	0	0	0	0	0	0	0	0	0
Solidago sempervirens	1.1	1	2.2	6	1.0	5	0.0	1	0.1	1	0	0	1.5	1
Sporobolus alterniflorus	18.5	9	27.0	23	33.5	25	33.8	25	37.1	32	34.1	28	35.1	30
Sporobolus michauxianus	0	0	0	0	3.0	3	2.0	2	1.7	2	2.3	3	1.2	1
Sporobolus pumilus	39.1	13	49.7	32	54.5	40	56.6	37	62.3	42	58.2	36	60.8	45
Suaeda maritima spp maritima	0.1	2	0.02	1	0.5	8	4.0	12	0.4	3	0.1	3	0.1	1

Symphyotrichum novi-belgii	0.2	1	0	0	0.02	1	0	0	0	0	0	0	0	0
Trifolium sp.	0.1	1	0	0	0	0	0	0	0	0	0	0	0	0
Triglochin maritima	0	0	0	0	0.2	2	0	0	0	0	0	0	0	0
Typha latifolia	0	0	0	0	2.2	3	0.6	2	0.4	1	0.5	1	0	0
Typhaceae sp	0	0	2.0	3	0	0	0	0	0	0	0	0	0	0
Unk.sp A 04	0.4	1	0	0	0	0	0	0	0	0	0	0	0	0
Unknown grass	0.4	1	0	0	0	0	0	0	0	0	0	0	0	0
Zostera marina	0	0	0	0	0	0	0	0	0	0	0	0	3.0	2

Table B-6. Vegetation plot data summaries from Cogmagun Restoration showing mean abundance and frequency for present species.

	Cogmagun Restoration													
	pre		**1**		**2**		**3**		**4**		**5**		**13**	
Species Names	**abun.**	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**
Agrostis stolonifera	6.5	3	5.7	3	6	3	7.3	3	2.5	2	0.9	3	0.1	2
Algae	4.3	3	0.2	2	7.0	4	0	0	0	0	0	0	0	0
Anthoxanthum nitens	1	3	0.2	1	7.7	4	2.3	2	2.7	2	3.8	1	5	2
Aster sp.	0	0	0	0	0.5	2	0	0	0	0	0	0	0	0
Atriplex glabriuscula	0.5	2	3.9	4	2.6	6	1.2	1	0	0	0	0	0.1	3
Betula sp.	0.2	2	0	0	0	0	0	0	0	0	0	0	0	0
Bolboschoenus maritimus	8.8	4	0	0	9.5	8	3.7	1	2.3	3	1	1	0	0
Calamagrostis canadensis	0.04	1	4.8	3	0.2	1	1.8	2	1.2	1	0	0	0	0
Calystegia sepium	0.04	1	0	0	0	0	0	0	0	0	0	0	0	0
Carex gynandra	0	0	0	0	0.3	1	0	0	0	0	0	0	0	0
Carex paleacea	0	0	0	0	0	0	0.04	1	0.7	1	2.7	1	1.3	1
Carex pseudocyperus	0	0	0.7	1	0	0	0	0	0	0	0	0	0	0
Carex stipata	5.2	3	3	3	0	0	0	0	0	0	0	0	0	0
Distichlis spicata	0	0	0	0	0	0	3.3	1	2.2	1	29.7	11	21.5	11
Elymus repens	0	0	0.8	1	0	0	0.3	1	0.9	2	0	0	5.2	3
Equistum	2	2	0	0	0.04	1	0	0	0	0	0	0	0.5	1
Festuca rubra	0	1	0	0	0	0	0	0	6	3	0	0	0	0
Galium palustre	4	4	0	0	0.04	1	0	0	0	0	0	0	0	0
Impatiens capensis	6	4	0	0	0.04	1	0	0	0	0	0	0	0	0
Iris versicolor	0	0	0	0	0	0	0.2	1	0	0	0	0	0	0

Juncus effusus	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Juncus gerardii	0.2	1	1.5	2	8.7	3	3.8	2	4	2	4.7	2	2.3	1
Lemna sp.	4.2	1	0	0	0	0	0	0	0	0	0	0	0	0
Limonium carolinianum	0	0	0	0	0.1	3	0.04	1	0.4	4	0.4	3	0.4	2
Lycopus americanus	0.2	2	0.04	1	0	0	0	0	0	0	0	0	0	0
Lycopus uniflorus	0.8	2	0	0	0	0	0	0	0	0	0	0	0	0
Lysimachia terrestris	0.7	1	0.8	1	0	0	0	0	0	0	0	0	0	0
Moss	3.2	1	0	0	0	0	0	0	0	0	0	0	0	0
Myosotis laxa	0.8	1	0	0	0	0	0	0	0	0	0	0	0	0
Onoclea sensibilis	1.5	2	0.2	1	0.04	1	0	0	0	0	0	0	0	0
Oxalis sp	4.2	3	0	0	0	0	0	0	0	0	0	0	0	0
Persicaria sagittata	0.8	3	0	0	0.2	1	0	0	0	0	0	0	0	0
Phragmites australis	0	0	0	0	0	0	0	0	0	0	2.5	1	4.2	1
Poa palustris	2	1	4.5	2	0	0	3	1	0	0	1	1	0	0
Ranunculus cymbalaria	3	1	0	0	0	0	0	0	0	0	0	0	0	0
Ranunculus repens	2	1	0.2	2	0.5	1	0	0	0	0	0	0	0	0
Rorippa palustris	0	0	0	0	0.3	1	0	0	0	0	0	0	0	0
Ruppia maritima	0.3	1	0	0	0	0	0	0	0	0	0	0	0	0
Salicornia depressa	0	0	0.3	2	4.9	15	0	0	0	0	0	0	0.3	2
Salicornia maritima	0	0	0	0	0	0	5.7	10	26.0	16	14.2	6	0	0
Schoenoplectus tabermontanii	12.7	7	0.7	2	0	0	0	0	0	0	0	0	0	0
Scirpus cyperinus	2.5	1	0.7	3	0	0	0	0	0	0	0	0	0	0
Scutellaria galericulata	2	3	0	0	0	0	0	0	0	0	0	0	0	0
Solidago rugosa	0.5	1	0	0	0	0	0	0	0	0	0	0	0	0
Solidago sempervirens	0	0	0	0	0	0	0	0	0	0	0.04	1	3.8	1
Solidago tenuifolia	0.2	1	0	0	0	0	0	0	0	0	0	0	0	0
Sporobolus alterniflorus	0.0	0	1.54	3	11.75	9	34.58	17	62.71	20	72.5	18	18.83	6
Sporobolus michauxianus	1.5	1	4.2	1	4	2	7.7	3	2.2	1	1.2	2	3.3	1
Sporobolus pumilus	0	0	0	0	3.2	3	10.6	9	24.7	10	18.8	5	62	17
Suaeda maritima	0	0	1.0	4	17.5	15	7.3	8	11.4	13	5.4	6	5.2	3
Symphyotrichum lanceolatus	0	0	0	0	0	0	0.3	1	0	0	0	0	0	0
Symphyotrichum lateriflorum	0.3	1	0.2	1	0	0	0	0	0	0	0	0	0	0

Symphyotrichum novi-belgii	0	0	0.4	3	1	1	0	0	0.04	1	2.5	1	0	0
Symphyotrichum spp.	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Taraxacum officinale	0	0	0	0	1.5	1	1.2	1	0	0	0	0	0	0
Thelypteris palustris	0.04	1	0.3	1	0	0	0	0	0	0	0	0	0	0
Triglochin maritima	0	0	0	0	0	0	0	0	0	0	0.2	1	0	0
Typha angustifolia	26.8	10	0	0	9.5	6	0	0	8.5	3	14	4	0	0
Typha latifolia	6.5	3	8.3	10	5.1	7	3.5	1	3	1	2.5	1	8.5	4
Typha sp.	0	0	0	0	0	0	5.2	3	0	0	0	0	0	0

Table B-7. Vegetation plot data summaries from Cogmagun Reference showing mean abundance and frequency for present species.

	Cogmagun Restoration													
	pre		**1**		**2**		**3**		**4**		**5**		**13**	
Species Names	**abun.**	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**
Anthoxanthum nitens	0	0	0	0	0	0	0.4	1	2.3	2	0	0	0	0
Atriplex glabriuscula	4	11	0.5	6	1.2	2	0.8	4	1.4	5	5.7	6	0.8	3
Carex paleacea	8.4	3	13.0	5	15.8	5	15.1	5	7.0	3	14.4	5	18.7	5
Distichlis spicata	4.5	3	6.4	4	9.9	4	8.9	5	7.8	6	8.7	4	1.5	2
Elymus repens	4.4	1	3.5	1	4	1	4	1	0	0	2.4	1	0	0
Festuca rubra	4.2	2	4.2	1	2.4	2	4.4	2	0.2	1	0	0	1.8	1
Hordeum jubatum	0	0	0	0	0.5	1	0.2	1	0	0	0	0	0	0
Iva frutescens	0	0	0	0	0	0	0	0	0	0	0	0	1.6	1
Juncus gerardii	51.5	13	52.7	13	56.2	16	52.2	12	52.2	12	54.6	13	54.6	12
Limonium carolinianum	0.2	2	0.04	1	0.4	1	0	0	0.5	1	0.5	1	0.9	1
Polygonum sp.	0.04	1	0	0	0	0	0	0	0	0	0	0	0	0
Potentilla anserina	0.04	1	0.2	1	1.2	1	0.2	1	0	0	0	0	0.4	1
Puccinellia maritima	0	0	0	0	0	0	0.7	1	0	0	0	0	0	0
Salicornia maritima	0	0	0	0	0	0	0	0	0	0	2.6	4	0	0
Solidago sempervirens	4.9	3	4.9	5	5.2	4	1.7	3	2.4	6	5.2	3	5.0	4
Sporobolus alterniflorus	24.7	8	29.9	9	23.0	7	25.8	9	23.8	10	23.7	9	18.7	7
Sporobolus michauxianus	13.4	4	12.9	4	13.2	4	15.3	5	13.0	3	12.5	3	9.3	4
Sporobolus pumilus	9.7	6	13.1	6	15.0	6	12.2	5	29.7	9	24.2	8	17.9	6

Suaeda maritima	0	0	0.04	1	0.4	2	0.2	2	2.8	2	0.6	4	0.6	1
Symphyotrichum novi-belgii	0	0	0.9	1	0	0	0.2	1	0	0	0	0	0	0
Triglochin maritima	0.7	1	0	0	0	0	0.2	1	0.5	1	0.2	1	0	0
Typha angustifolia	0	0	0	0	0	0	0	0	3.3	1	0	0	0	0
Unknown seedling	0	0	0	0	0	0	0	0	0	0	0	0	1.3	1

Table B-8. Vegetation plot data summaries from Converse showing mean abundance and frequency for present species. Table modified from the CON Year 3 monitoring report by CBWES Inc (Bowron et al., 2022).

Species Names	**Converse**							
	pre		**1**		**2**		**3**	
	abun.	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**
Acer rubrum	0	0	0	0	0	0	0	0
Achillea millefolium	2.8	1	0	0	0	0	0	0
Agrostis sp.	0	0	0	0	0	0	0	0
Agrostis stolonifera	10.6	4	0	0	0	0	0.4	1
Alopecurus pratensis	35	7	0	0	0	0	0	0
Ambrosia artemisiifolia	0	0	0	0	0.1	1	0.8	1
Symphyotrichum sp.	0.9	2	0	0	0	0	0	0
Atriplex glabriuscula	0	0	0	0	0	0	0.4	1
Atriplex littoralis	0	0	0	0	0	0	0	0
Atriplex sp.	0	0	0	0	0	0	0	0
Bromus inermis	5	1	0	0	0	0	0	0
Calamagrostis canadensis	9.4	3	0	0	0	0	0	0
Calystegia sepium	0	0	0	0	0	0	0	0
Carex hormathodes	0	0	0	0	0	0	0	0
Carex lenticularis	9.8	2	0	0	0	0	0	0
Carex nigra	0.1	2	1.7	1	0	0	0	0
Carex paleacea	0	0	0	0	0	0	0	0
Carex scoparia	0.4	1	0	0	0	0	0	0
Carex sp.	1.4	2	0	0	0	0	0	0
Cerastium fontanum	0	0	0	0	0.2	1	3	1
Chenopodium album	0	0	0	0	0	0	0.2	1
Cirsium arvense	0	0	0	0	0	0	2.4	1
Daucus carota	1.8	1	0	0	0	0	0	0
Distichlis spicata	0	0	0	0	0	0	0	0
Eleocharis tenuis	0	0	0	0	0	0	0	0
Elymus repens	0	0	2.4	4	0.6	1	1	2

Elymus trachycaulus	0	0	0	0	0	0	0	0
Elymus virginicus	0	0	0	0	0	0	0	0
Epilobium palustre	1	1	0	0	0	0	0	0
Euthamia graminifolia	0	0	0	0	0.1	1	1	1
Festuca rubra	5	1	0	0	0	0	0	0
Galium mollugo	0.8	1	0	0	0	0	0	0
Lysimachia maritima	0	0	0	0	0	0	0	0
Anthoxanthum nitens	29.8	9	0	0	0	0	0	0
Hordeum jubatum	0	0	0	0	0	0	0	0
Juncus balticus	0	0	0	0	0	0	0	0
Juncus brevicaudatus	3	1	0	0	0	0	0	0
Juncus canadensis	0	0	0	0	0	0	0	0
Juncus gerardii	0	0	0	0	2.2	1	2	1
Juncus tenuis	0	0	0	0	0	0	0.2	1
Scorzoneroides autumnalis	0	0	0	0	0.2	1	0.4	1
Limonium carolinianum	0	0	0	0	0	0	0	0
Lotus corniculatus	0	0	0	0	1.4	1	3.2	1
Lycopus americanus	0.8	1	0	0	0	0	0	0
Lysimachia terrestris	0	0	0	0	0	0	0	0
Morella pensylvanica	0	0	0	0	0	0	0	0
Oxybasis glauca	0	0	0	0	0	0	0	0
Pasture grasses	20	4	0	0	0	0	0	0
Picea mariana	0	0	0	0	0	0	0	0
Phleum pratense	0	0	0	0	0	0	0.4	1
Plantago major	0	0	0	0	0	0	0.2	1
Plantago maritima	0	0	0	0	0	0	0	0
Poa palustris	3.8	3	0	0	0	0	0.4	1
Poa pratensis	1.6	1	0	0	0	0	1.8	1
Poa sp.	0	0	0.1	1	0	0	0	0
Polygonum aviculare	0	0	0	0	0	0	0	0
Polygonum ramosissimum	0	0	0	0	0	0	0	0
Polygonum sagittatum	4.1	5	0	0	0	0	0	0
Potentilla anserina	0	0	0	0	0	0	0	0
Potentilla norvegica	0	0	0	0	0.4	1	0.6	1
Potentilla simplex	2.8	1	0	0	0	0	0	0
Ranunculus repens	0.1	1	0	0	0.2	1	1.4	1
Rosa virginiana	0	0	0	0	0	0	0	0
Rubus idaea	0	0	0	0	0	0	0	0
Rumex acetosella	0	0	0	0	0	0	1.4	1

Salicornia maritima	0	0	0	0	0	0	0	0
Schoenoplectus americanus	0	0	0	0	0	0	0	0
Scirpus cyperinus	10.8	5	0	0	0	0	0	0
Bulboschoenus maritima	0	0	0.2	1	0	0	0	0
Solidago canadensis	0	0	0	0	0	0	1	1
Solidago sempervirens	0	0	0	0	0	0	0	0
Solidago sp.	0.1	1	0	0	0	0	0	0
Sonchus arvensis	0	0	0.4	1	0.1	1	0.2	1
Sporobolus alterniflorus	0	0	0.2	1	0.1	1	5.6	3
Sporobolus pumilus	0	0	0.4	1	0.1	1	0	0
Sporobolus michauxianus	5	1	5.3	1	4.7	2	8.6	5
Spergularia canadensis	0	0	0	0	0	0	0	0
Spergularia salina	0	0	0	0	0	0	1.2	1
Spiraea alba var. latifolia	3	1	0	0	0	0	0.2	1
Stellaria sp.	4	4	0	0	0	0	0	0
Suaeda maritima spp maritima	0	0	0	0	0	0	19.4	9
Suaeda sp.	0	0	0	0	0	0	0	0
Symphotrichum novi-belgii	3.1	6	3.4	1	1.2	1	2.6	1
Taraxacum officinale	1.9	5	0	0	0	0	0	0
Thalictrum pubescens	0	0	0	0	0	0	0	0
Toxicodendron radicans	0	0	0	0	0	0	0	0
Triglochin maritima	0	0	0	0	0	0	0	0
Trifolium pratense	0	0	0	0	0	0	4.6	1
Trifolium sp.	0.1	1	0	0	0	0	0	0
Typha latifolia	2.5	2	0	0	1	1	0	0
Grass sp.	0	0	0	0	0	0	0	0
Seedling sp.	0	0	0.1	1	0	0	0	0
Vaccinium macrocarpon	0	0	0	0	0	0	0	0
Vaccinium oxycoccus	0	0	0	0	0	0	0	0
Vicia sp.	7.5	12	0	0	1	1	1.8	1

Table B-9. Vegetation plot data summaries from Lawrencetown showing mean abundance and frequency for present species.

Species Names	**Lawrencetown Reference**													
	Pre		**1**		**2**		**3**		**4**		**5**		**15**	
	abun.	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**
Agrostis stolonifera	8.7	5	11	7	8.7	6	13	7	7.5	7	6.67	5	0.04	1
Algae	0	0	0	0	0	0	0	0	6.7	2	0	0	0.04	1

Anthoxanthum nitens	12.9	10	14.8	11	9.3	7	17.2	9	11.9	6	8.5	7	9.2	8
Atriplex glabriuscula	0.38	3	0	0	1.7	2	1.6	5	0.25	3	0.9	5	0	0
Cakile edentula	0	0	0	0	0.2	1	0	0	0	0	0	0	0	0
Calamagrostis canadensis	0	0	0	0	0.8	1	0	0	0	0	0	0	0	0
Calystegia sepium	0.88	2	0.33	1	0.04	1	0.8	1	0.7	2	0.5	1	2	2
Carex hormathodes	0	0	0	0	1.0	2	0.5	2	0.04	1	2.7	2	1.0	2
Carex nigra	0	0	0	0	0	0	0	0	0	0	0	0	1.3	1
Carex paleacea	24.7	10	26.5	10	29.0	12	25.3	9	21.4	9	22.8	7	19.7	6
Distichlis spicata	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Elymus repens	0	0	0	0	0	0	0	0	0	0	0.17	1	0	0
Equisetum	0	0	0.04	1	0.2	1	0	0	0	0	0	0	0.04	1
Festuca rubra	30	10	33.8	11	36.7	9	39.7	11	26.2	7	27.3	8	19.8	6
Galium palustre	1.2	1	0.8	5	0.04	1	0	0	1.5	3	0.5	5	0.1	2
Impatiens capensis	0	0	0	0	0.04	1	0	0	0	0	0	0	0.04	1
Juncus balticus	17.5	7	18.1	8	18.3	6	21	7	18.5	5	18.3	6	19.2	5
Juncus effusus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Juncus gerardii	0	0	0	0	0	0	0.8	1	1.3	1	0	0	4.2	2
Lathyrus japonicus	0	0	0	0	0	0	0	0	0	0	3.8	3	0	0
Lathyrus palustris	0	0	0	0	0	0	0	0	0	0	0	0	1.7	1
Limonium carolinianum	0	0	0	0	0	0	0	0	0.04	1	0	0	0	0
Lycopus americanus	0.2	1	0	0	0	0	0	0	0	0	0	0	0	0
Lycopus uniflorus	0	0	0	0	0.3	1	1.3	2	0	0	0	0	0	0
Lysimachia terrestris	0	0	0	0	0.5	1	0.2	1	0	0	0	0	0	0
Maianthemum stellatum	0	0	0.04	1	0.2	1	0.04	1	0	0	0	0	0	0
Mentha arvensis	0.4	3	0.8	2	0	0	0	0	0	0	0.7	2	0	0
Myrica gale	1.8	2	1.3	3	0.5	2	1.8	2	0	0	0	0	0	0
Persicaria sagittata	0.04	1	0.2	1	0.04	1	0	0	0	0	0	0	0	0
Plantago major	0	0	0	0	0	0	0	0	0	0	0.2	1	0	0

Poa palustris	0	0	0	0	0	0	0	0	4.7	2	3.2	3	1.1	5
Potentilla anserina	2.6	6	0.5	5	0.5	4	1.2	3	0.04	1	0.71	2	0.92	4
Potentilla palustris	4.8	4	3.4	4	3.8	4	6.7	4	4.7	4	3.2	4	0.3	1
Rosa virginiana	0	0	0	0	0	0	0	0	0	0	0	0	0.04	1
Rubus pubescens	0	0	0.2	1	0	0	0	0	0	0	0	0	0	0
Rubus strigosus	0	0	0	0	0	0	0.04	1	0	0	0	0	0	0
Ruppia maritima	0	0	0	0	0	0	0	0	1.3	1	0	0	0	0
Salicornia depressa	0	0	0	0	0.5	1	0.2	1	0.04	1	0	0	0.04	1
Salicornia maritima	0	0	0	0	0	0	0	0	0	0	0.4	2	0	0
Schoenoplectus acutus	1.2	1	0.2	1	0	0	0	0	0	0	0	0	0	0
Schoenoplectus americanus	0	0	0	0	0	0	0	0	0	0	0	0	0.2	1
Schoenoplectus tabermontanii	0	0	0	0	0.3	1	0.2	1	0	0	0	0	0	0
Scutellaria galericulata	2.7	4	3.7	5	2.7	5	5.2	5	0.3	1	0	0	1.7	2
Solidago rugosa	0	0	0	0	0	0	0.04	1	0	0	0	0	0	0
Solidago sempervirens	1.2	3	0	0	0.3	1	0	0	0.2	2	1.54	4	0	0
Spiraea latifolia	0	0	0	0	0.04	1	0	0	0	0	0	0	0	0
Sporobolus alterniflorus	27	8	24.0	10	20.5	7	24.5	11	24.8	13	16.6	13	27.2	13
Sporobolus michauxianus	4.2	1	4.92	5	5.5	3	4.2	1	6.5	2	4.7	4	2.3	3
Sporobolus pumilus	27.5	8	32	9	30.2	8	31.4	10	32.8	12	39.6	14	40.2	13
Symphyotrichum lanceolatus	0	0	0.1	2	0.1	2	4.2	5	0	0	1.8	2	0	0
Symphyotrichum lateriflorum	0	0	0.2	2	0	0	0	0	0	0	0	0	0	0
Symphyotrichum novae-angliae	0	0	0	0	0	0	0	0	1.3	1	0	0	0	0
Symphyotrichum novi-belgii	3.5	6	1.0	2	0.1	2	0	0	2.3	3	1.3	3	0	0
Symphyotrichum spp.	0	0	0	0	0	0	0	0	0	0	0	0	1.4	2

Taraxacum officinale	0	0	0	0	0	0	0	0	0.04	1	0	0	0	0
Thalictrum pubescens	0	0	0	0	0	0	0	0	0.04	1	0	0	0	0
Triglochin maritima	0.7	2	0	0	0.7	3	0	0	0.04	1	0.5	1	0	0
Typha latifolia	0.04	1	0	0	0.04	1	0.3	1	0.2	1	0.2	2	0	0
Unknown seedling	0	0	0	0	0	0	0	0	0	0	0	0	0.04	1
Vaccinium macrocarpon	0	0	0.5	1	1.3	1	1.5	1	0.5	1	1.5	1	0	0
Vaccinium myrtilloides	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vicia sp	6.5	6	4.7	4	0.9	5	1.7	4	2.5	3	0.3	1	2.3	4

Table B-10. Vegetation plot data summaries from Mavillette restoration showing mean abundance and frequency for present species. Table modified from the MAV Year 3 monitoring report by CBWES Inc (Bowron et al., 2022a).

Species Names	**Mavillette Restoration**					
	pre		**1**		**3**	
	abun.	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**
Achillea millefolium	1.11	2	0	0	0.03	1
Agrostis stolonifera	1.3	2	1.06	3	0.12	1
Algae	0	0	0.03	1	2.94	1
Alnus sp.	0.11	1	0	0	0	0
Alopecurus pratensis	0	0	0	0	0	0
Amelanchier sp.	0.11	1	0.34	1	0	0
Ammophila breviligulata	4.11	2	0	0	0	0
Anthoxanthum nitens	2	7	3.54	2	1.18	1
Aronia prunifolia	2.81	4	0	0	0	0
Atriplex glabriuscula	0	0	0	0	5.47	10
Atriplex sp.	0	0	0.37	3	0	0
Cakile edulenta	0	0	0	0	2.85	2
Calamagrostis canadensis	4.43	3	2.74	1	0	0
Calystegia sepium	4.86	4	0.11	1	2.47	2
Carex echinata	0.22	1	0.26	2	0	0
Carex exilis	1.41	1	0	0	0.12	1
Carex folliculata	0.11	1	0	0	0	0
Carex leptalea	0.54	1	1.26	1	0	0
Carex nigra	0.03	1	0	0	0	0
Carex paleacea	2.54	4	1.71	1	0.24	1
Carex rostrata	1.19	2	0	0	0	0
Carex scoparia	1.73	3	0.11	1	0	0
Carex sp.	2.81	2	3.2	2	0	0
Carex stricta	0	0	0	0	0	0
Carex viridula	0.11	1	0	0	0	0
Centauria nigra	0	0	0	0	0	0
Cerastium vulgatum	0	0	0	0	0	0
Chamaedaphne calyculata	5.51	4	0.11	1	0.35	1
Chelone glabra	0	0	0	0	0	0
Chenopodium album	0	0	0	0	2	3
Cirsium arvense	0	0	0	0	0	0
Dactylis glomerulata	0	0	0	0	0	0
Daucus carota	0.22	2	0	0	0	0
Decodon verticillatus	0.11	1	0	0	0	0
Deschampsia cespitosa	0	0	0	0	0.94	2

Doellingeria umbellata	0.11	1	0	0	0	0
Drosera rotundifloia	0.05	2	0.46	1	0	0
Dryopteris cristata	0	0	0.11	1	0	0
Eleocharis palustris	0.76	1	0	0	0	0
Eleocharis sp.	0	0	0	0	0	0
Elymus repens	0.65	1	1.06	3	3.53	4
Empetrum nigrum	1.62	3	0.46	1	0.12	1
Epilobium ciliatum	0	0	0	0	0	0
Epilobium palustre	0.43	2	0	0	0	0
Equisetum sp.	1.62	1	0	0	0	0
fern sp.	0	0	0	0	0	0
Festuca filliformis	0	0	0	0	0	0
Festuca rubra	8.03	10	7.46	8	6.82	6
Filipendula ulmaria	3.89	5	0	0	0	0
Fragaria virginiana	1.19	2	0	0	0	0
Galeopsis bifida	0	0	0.03	1	0	0
Galeopsis tetrahit	0	0	0	0	0.24	1
Galium palustre	0.68	2	0.03	1	0	0
Glyceria canadensis	0	0	0.69	1	0	0
Glyceria sp.	0	0	2.06	1	0	0
Glyceria striata	0	0	0	0	0	0
grass sp.	0	0	1.94	2	0.59	1
Impatiens capensis	0.22	1	0	0	0	0
Juncus balticus	12.78	10	13.51	8	6.62	4
Juncus canadensis	0.22	1	0.03	1	0	0
Juncus effusus	0.22	1	0	0	0	0
Juncus gerardii	6.3	4	5.71	2	2.94	1
Juniperus communis	1.73	1	0	0	0	0
Kalmia polifolia	0.76	1	0	0	0	0
Lathyrus japonicus	2.08	2	0	0	0	0
Lathyrus palustris	0	0	0	0	0	0
Leersia oryzoides	0	0	0	0	0.24	1
Ligusticum scoticum	0	0	0	0	0	0
Limonium carolinianum	0	0	0	0	0	0
Lycopus americanus	0.03	1	0	0	0	0
Lycopus uniflorus	0	0	0	0	0	0
Lysimachia maritima	7.14	4	1.83	2	0.82	1
Lysimachia terrestris	1.57	6	0.91	2	0.47	2
Lythrum salicaria	0	0	0	0	0	0
Malus floribunda	0.11	1	0	0	0	0
Menyanthes trifoliata	2.27	2	0.03	1	0	0
Moehringia lateriflora	0	0	1.14	1	0	0
Morella pensylvanica	4	5	3.09	4	0.35	1
Muhlenbergia glomerata	0.03	1	0	0	0	0
Myrica gale	12.32	10	2.29	3	1.18	1
Oclemena nemoralis	0	0	0.03	1	0	0
Osmundastrum cinnamomeum	0.11	1	0	0	0	0
Oxybasis glauca	0	0	0	0	0	0
Persicaria sagittata	0.24	2	0.23	1	0	0
Phalaris arundinacea	0	0	0	0	0	0
Plantago maritima	2.38	2	1.94	2	2.59	2
Poa palustris	5.76	5	0	0	0	0
Poa pratensis	3.46	2	0	0	0	0
Poa sp.	0	0	0	0	0	0
Potentilla anserina	1.73	3	0	0	0	0
Ranunculus cymbalaria	0	0	0	0	0	0
Ranunculus repens	0	0	0	0	0	0
Rhododendron canadense	2.62	4	0	0	0	0
Rhododendron groenlanicum	4.57	6	1.14	1	0.24	1
Rhynchospora alba	0.03	1	0	0	1.18	1
Rosa carolina	4.22	6	0	0	1.29	1

Rosa nitida	0	0	0	0	0.03	1
Rosa palustris	0	0	0	0	0.35	1
Rosa rugosa	2.27	1	1.14	1	0	0
Rosa sp.	0	0	0.69	1	0	0
Rosa virginiana	0	0	2.63	3	0.59	2
Rubus allegheniensis	0	0	0	0	0	0
Rubus canadensis	0.76	1	0	0	1.18	1
Rubus hispidus	6.81	7	0.69	1	0	0
Rubus pubescens	0	0	0.91	1	0.03	1
Rubus sp.	0	0	0.03	1	0	0
Rumex crispus	0.05	2	0	0	0	0
Rumex sp.	0.03	1	0	0	0	0
Salicornia maritima	0.14	2	1.6	2	2.88	6
Sarracenia purpurea	0.54	2	0.11	1	0.03	1
Schoenoplectus acutus	0	0	1.26	1	0	0
Schoenoplectus americanus	0	0	0	0	0	0
Schoenoplectus tabernaemontani	2.7	1	0	0	0	0
Scutellaria galericulata	0.03	1	0	0	0	0
sedge sp.	0	0	0	0	0	0
seedling sp.	0	0	0.14	2	0	0
Solidago canadensis	0.05	2	0	0	0	0
Solidago rugosa	1.51	3	1.37	2	0.94	1
Solidago sempervirens	2.7	3	0.23	2	0	0
Solidago uliginosa	0	0	2.63	3	2.47	2
Sonchus arvensis	0	0	0	0	0	0
Sparaea alba var. latifolia	0	0	0	0	0.59	1
Sphagnum sp.	16.54	11	10.97	4	6.71	4
Spiraea alba	0	0	0.11	1	0	0
Sporobolus alterniflorus	19.68	13	27.77	12	32.26	17
Sporobolus michauxianus	4.84	6	5.37	2	4.59	2
Sporobolus pumilus	24.22	9	17.14	7	24.03	12
Stellaria sp.	0.89	4	0	0	0.12	1
Suaeda maritima	0.32	5	1.2	5	3.59	11
Symphyotrichum novae-angliae	0.11	1	0	0	0	0
Symphyotrichum novi-belgii	6.49	9	3.11	7	0.47	1
Symplocarpus foetidus	0.11	1	0	0	0	0
Synphyotrichum sp.	2.92	4	0	0	0	0
Taraxacum officinale	0	0	0	0	0	0
Thalicrum pubescens	0.54	1	0	0	0	0
Thelypteris noveboracensis	0	0	0	0	0	0
Thelypteris palustris	1.41	2	0	0	0	0
Trifolium pratense	0.76	1	0	0	0	0
Triglochin maritima	3.68	3	1.83	2	1.06	3
Typha angustifolia	4.11	4	0	0	0	0
Typha latifolia	0.11	1	3.11	4	1.65	3
Typha sp.	0	0	0	0	0	0
Vaccinium angustifolium	0.65	1	0.03	1	0	0
Vaccinium macrocarpon	5.43	5	4.14	5	1.06	1
Vaccinium oxycoccus	0	0	1.14	1	0	0
Viburnum nudum	0.43	1	0	0	0	0
Vicia sp.	0.05	2	0	0	0.03	1
Viola macloskeyi ssp. *pallens*	0	0	0.03	1	0	0
Zostera maritma	0	0	0	0	0.24	1

Table B-11. Vegetation plot data summaries from Mavillette reference showing mean abundance and frequency for present species. Table modified from the MAV-R Year 3 monitoring report by CBWES Inc (Bowron et al., 2022a).

Species Names	Mavillette Reference

	pre		1		3	
	abun.	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**
Achillea millefolium	1.33	2	0	0	0	0
Agrostis stolonifera	6.4	4	4	3	8.4	4
Alopecurus pratensis	0	0	2.96	1	2.93	1
Ammophila breviligulata	10	3	10.96	3	10	3
Potentilla anserina	0.97	3	1.93	3	0.97	3
Synphyotrichum sp.	2.57	6	0	0	0	0
Atriplex sp.	0.03	1	0	0	0.53	2
Calamagrostis canadensis	9.73	3	10.67	5	1.07	1
Calystegia sepium	4.83	6	10.11	8	6.4	7
Carex paleacea	8.47	7	20.3	8	17.07	7
Carex sp.	0	0	3.7	1	0	0
Carex stricta	3.07	1	0	0	0	0
Centauria nigra	1.47	1	1.04	1	0	0
Cerastium vulgatum	1.6	2	0	0	0.13	1
Chelone glabra	0	0	1.48	1	0	0
Cirsium arvense	0	0	0.04	1	2.8	1
Dactylis glomerulata	0.13	1	1.04	3	1.47	2
Eleocharis palustris	0	0	1.48	2	0	0
Eleocharis sp.	0.57	2	0	0	0	0
Elymus repens	0.63	4	2.81	4	4.53	5
Empetrum nigrum	0	0	0	0	0	0
Epilobium ciliatum	0	0	0.33	2	0.03	1
Equisetum sp.	0	0	3.74	2	1.47	1
Fern sp.	0.27	1	0	0	0	0
Festuca filliformis	0	0	0.89	1	0	0
Festuca rubra	9.2	5	12.74	5	4.97	6
Filipendula ulmaria	4	2	0	0	0	0
Fragaria virginiana	0	0	0.15	1	0	0
Galeopsis bifida	0.17	2	1.04	2	0.13	1
Galium palustre	0.67	1	0.44	1	0	0
Glyceria canadensis	0	0	2.22	1	0.03	1
Glyceria sp.	0	0	0.74	1	0	0
Glyceria striata	1.07	1	0	0	0	0
Anthoxanthum nitens	0.8	1	4.3	2	0	0
Impatiens capensis	3.33	2	1.04	1	0.4	2
Juncus balticus	0	0	4	4	9.07	4
Juncus gerardii	3.6	2	4.3	3	6	3

Lathyrus japonicus	3.33	3	0	0	2.4	3
Lathyrus palustris	0	0	3.56	3	0	0
Ligusticum scoticum	0	0	0.44	1	0.53	2
Limonium carolinianum	0	0	0	0	0.13	1
Lycopus uniflorus	0.4	1	1.04	1	0	0
Lysimachia maritima	0.43	2	0.3	1	3.87	3
Lysimachia terrestris	2.8	3	1.63	3	1.33	3
Lythrum salicaria	0	0	2.07	1	0	0
Menyanthes trifoliata	0.27	1	0	0	0	0
Morella pensylvanica	1.73	1	0	0	0.67	1
Muhlenbergia glomerata	0.53	1	0	0	0	0
Myrica gale	0	0	0	0	1.2	1
Osmundastrum cinnamomeum	0	0	0	0	0.03	1
Oxybasis glauca	0	0	2.56	2	0	0
Phalaris arundinacea	0	0	1.04	1	0	0
Plantago maritima	0.7	3	0.74	3	2.53	5
Poa palustris	2	1	0	0	0	0
Poa pratensis	0.57	3	0	0	0	0
Poa sp.	0	0	0.59	2	7.87	5
Ranunculus cymbalaria	0.13	1	0	0	0	0
Ranunculus repens	0.13	1	0	0	0	0
Rosa carolina	3.6	3	0	0	0	0
Rosa palustris	0	0	1.93	1	0	0
Rosa virginiana	0	0	2.52	2	2.8	3
Rubus allegheniensis	1.73	1	0	0	0	0
Rumex sp.	0.03	1	0	0	0	0
Salicornia maritima	3.37	6	0.48	2	1.73	7
Schoenoplectus americanus	1.73	1	1.33	1	0.67	1
Scutellaria galericulata	0	0	0.78	2	0.67	1
Solidago canadensis	0.13	1	0	0	0	0
Solidago rugosa	1.73	2	2.7	2	1.73	1
Solidago sempervirens	4.17	6	5.81	4	6.8	5
Sonchus arvensis	0	0	2.22	2	0.4	2
Sporobolus alterniflorus	24.57	10	24.96	12	27.33	11
Sporobolus pumilus	31.2	10	29.48	9	36.4	14
Sporobolus michauxianus	13.33	6	16.59	8	20.7	10
Sphagnum sp.	0	0	0	0	0.13	1
Spiraea alba	0	0	2.22	1	3.33	2
Sparaea alba var. latifolia	0	0	0	0	0.4	1

Stellaria sp.	0	0	0.44	2	0	0
Symplocarpus foetidus	0.03	1	0.15	1	0.93	2
Symphyotrichum novi-belgii	1.73	2	11.41	6	14	9
Taraxacum officinale	0.67	2	0	0	0	0
Thalicrum pubescens	1.07	1	0	0	0.13	1
Thelypteris noveboracensis	0	0	0.15	1	0.4	1
Triglochin maritima	3.2	4	2.37	3	4.67	5
Typha angustifolia	1.87	1	0	0	0	0
Typha latifolia	0	0	2.81	1	0	0
Typha sp.	0	0	0	0	2	1
grass sp.	0	0	4.59	3	0	0
sedge sp.	0	0	0	0	2.53	1
seedling sp.	0	0	0	0	0.13	1
Vicia sp.	0.83	4	7.85	4	1.07	3

Table B-12. Vegetation plot data summaries from St. Croix South-East restoration showing mean abundance and frequency for present species.

Species Names	**St. Croix South-East**											
	pre		**1**		**2**		**3**		**4**		**13**	
	abun.	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**
Achillea millefolium	1.2	3	1.3	1	0.4	1	0.1	1	0	0	0	0
Agrostis gigantea	0	0	0	0	0	0	0	0	0.4	1	0	0
Agrostis stolonifera	0	0	0.6	1	3.8	1	2.2	2	2.1	3	0	0
Alopecurus pratensis	0	0	27.0	11	33.3	11	7.8	7	11.6	4	10.3	3
Amphicarpaea bracteata	0	0	0	0	0	0	0.6	1	0	0	0	0
Anthoxanthum nitens	0	0	0	0	0	0	1.1	1	0	0	0	0
Aster spp.	0	0	0.6	1	1.7	4	0	0	0	0	0	0
Atriplex glabriuscula	0	0	0	0	0	0	0	0	0	0	0.3	1
Atriplex hastata	0	0	0	0	2.1	1	0	0	0	0	0	0
Atriplex sp.	0	0	0	0	0	0	0	0	0.1	1	0	0
Bidens cernua	0	0	0	0	0	0	0	0	0	0	5.8	2
Bromus inermis	7.3	2	6.0	3	6.7	2	2.7	1	9.5	2	0	0
Calamagrostis canadensis	2	1	4.6	1	4	1	4.4	1	5.3	1	1.8	1

Calystegia sepium	0	0	0	0	0.4	1	1.1	1	0	0	0	0
Carex gynandra	0	0	0.1	1	2.7	1	0	0	0.2	1	0	0
Carex paleacea	0	0	0	0	0	0	0	0	0	0	4.8	1
Carex pseudocyperus	0.4	1	0	0	0	0	0	0	0	0	0	0
Carex scoparia	1.3	2	5.6	8	4.5	3	4.6	4	3.4	3	1.3	2
Carex sp.	0	0	0	0	0.1	1	3.8	3	0	0	10.3	2
Carex stipata	0	0	0	0	0	0	0	0	0	0	0.5	1
Carex stricta	0	0	0	0	0	0	0	0	0	0	6.8	2
Centauria nigra	8.4	4	4.2	3	1.3	1	1.3	1	1.1	2	0	0
Cicuta bulbifera	0	0	0.1	1	0	0	0	0	0	0	0	0
Cirsium arvense	0	0	0	0	0.8	1	0.5	2	0.4	1	7.9	5
Cirsium vulgare	0.2	1	0	0	0	0	0	0	0	0	0	0
Daucus carota	2.9	4	0.2	1	0.1	1	0.1	1	0	0	0	0
Elymus repens	46.4	10	24.4	5	2.7	2	1.1	4	0.3	3	0.3	1
Epilobium ciliatum	1.1	2	0	0	0	0	0	0	0	0	0	0
Epilobium palustre	0	0	0.2	1	0	0	0	0	1.3	1	0	0
Equisetum	0	0	3.4	1	7.8	2	1.1	1	0	0	0	0
Eupatorium maculatum	0	0	0	0	2.1	1	0.8	1	0	0	0	0
Euthamia graminifolia	0	0	0	0	2.0	3	0	0	2.1	2	5.3	3
Galeopsis tetrahit	0	0	0	0	0.2	1	0	0	0	0	0.5	1
Galium mollugo	0	0	5.3	2	0	0	0	0	0	0	0	0
Galium palustre	1	6	14.2	10	13.1	10	9.1	13	5.1	6	3.3	5
Impatiens capensis	4.3	3	1.1	3	3.3	4	0	0	0	0	1.4	5
Iris versicolor	0.1	1	1.1	2	1.9	2	1.3	1	1.1	1	0	0
Juncus effusus	0	0	0.6	1	0.8	1	5.1	4	4.9	3	0.1	1
Juncus sp.	0	0	0	0	1.5	1	0	0	0	0	0	0
Late danelion	0	0	0.8	1	0.2	1	0	0	0	0	0	0
Leersia oryzoides	0	0	0	0	0	0	1.3	2	3.4	1	6.3	1

Linaria vulgaris	0.7	2	0	0	0	0	0	0	0	0	0	0
Lycopus uniflorus	0.7	1	0	0	0	0	0	0	0	0	0	0
Lysimachia terrestris	3.3	3	5.9	5	4.3	3	1.7	4	0.1	1	0.5	1
Persicaria hydropiper	0	0	0	0	2.1	2	1.5	3	2.7	2	0	0
Persicaria sagittata	10.2	6	2.6	4	4.5	5	1.1	3	2.6	4	10.1	7
Phalaris arundinacea	0	0	5.1	1	5.3	1	4.6	1	5.3	1	9.3	3
Phleum pratense	0	0	0.2	1	0	0	0.6	1	0	0	0	0
Plantago major	0	0	0	0	0	0	0.2	1	0	0	0	0
Poa palustris	0	0	0.6	3	2.3	1	22	9	4	4	0	0
Poa pratensis	0	0	25.7	8	26.3	9	2.5	2	5.3	2	0	0
Polygonum neglectum	0	0	0	0	0	0	0	0	1.1	1	0	0
Polygonum persicaria	0	0	0	0	1.1	2	0.6	1	0	0	0	0
Ranunculus repens	0	0	0.2	1	0.2	1	0.4	2	0.4	2	0.1	1
Rosa virginiana	0.5	2	3.4	2	5.7	2	4.3	2	5.3	3	3	2
Rumex crispus	0	0	0	0	0	0	1.1	1	0.8	1	0	0
Schoenoplectus tabermontanii	0.2	1	0	0	0	0	0	0	0	0	0	0
Scirpus atrovirens	10	5	13.1	6	17.1	6	30.6	10	25.5	8	0	0
Scirpus cyperinus	8.4	2	12	3	7.6	2	10.7	4	7.8	4	0	0
Scirpus microcarpus	0	0	0	0	0	0	0	0	0	0	11.8	2
Scutellaria galericulata	0	0	0	0	1.5	1	0	0	0	0	0	0
Solanum dulcamara	0.1	1	0.1	1	0.8	1	0.1	1	0	0	0	0
Solidago altissima	2.2	3	0	0	0	0	0.6	2	0	0	0	0
Solidago canadensis	1.6	4	1.7	4	0	0	0	0	0.1	1	0	0
Solidago gigantea	0	0	0	0	0	0	0.2	1	0	0	0	0
Solidago rugosa	0.7	1	0.2	1	0	0	0	0	0	0	0	0
Solidago tenuifolia	8.4	5	1.5	2	0	0	1.3	2	0	0	0	0
Sonchus arvensis	0	0	0	0	0	0	0	0	0	0	9.3	5

Sporobolus alterniflorus	0	0	0	0	0	0	0	0	0	0	0	0
Sporobolus michauxianus	13.1	4	30.5	9	31.6	10	41.7	12	50.1	10	34.5	8
Sporobolus pumilus	0	0	0	0	0	0	0	0	0	0	0	0
Stellaria graminea	0	0	0	0	0	0	0.2	1	0.4	1	0	0
Stellaria sp.	2.5	3	2.5	1	0.5	2	0	0	0	0	0	0
Symphyotrichum lanceolatus	0	0	0	0	0.2	1	1.7	3	0	0	0	0
Symphyotrichum lateriflorum	0	0	0.2	1	0.1	1	0.1	1	0.2	1	1.5	1
Symphyotrichum novae-angliae	0	0	0	0	5.3	3	0	0	0.6	1	0	0
Symphyotrichum novi-belgii	2	2	6.5	4	3.4	4	11.4	5	15.8	8	1.3	1
Symphyotrichum spp.	0	0	0	0	0	0	0	0	0	0	0.1	2
Taraxacum officinale	6.5	4	2.2	4	3.2	5	2.2	3	0.9	3	0	0
Tragopogon pratensis	0	0	0.2	1	0	0	0	0	0	0	0	0
Trifolium pratense	0	0	0.3	2	0	0	0	0	0	0	0	0
Trifolium repens	0	0	1.1	1	0.7	3	0	0	0	0	0	0
Trifolium sp.	0.1	1	0	0	2.7	2	0	0	0.1	1	0	0
Typha angustifolia	0	0	0	0	0	0	3.4	1	0.1	1	0	0
Typha latifolia	1.3	1	4.4	1	1.7	1	0	0	0	0	31.5	8
Unknown seedling	0	0	0	0	0	0	0	0	0.1	1	0.1	1
Vicia sp.	4.2	9	6.8	11	7.9	9	2.5	9	0.4	1	1.6	3

Table B-13. Vegetation plot data summaries from St. Croix West restoration showing mean abundance and frequency for present species.

Species Names	St. Croix West											
	pre		1		2		3		4		13	
	abun.	freq.	abun.	freq.	abun.	freq.	abun.	freq.	abun.	freq.	abun.	freq.
Achillea millefolium	1.1	1	5.4	2	0.3	1	0.3	1	0	0	0	0
Agrostis perennans	0	0	0	0	0	0	0	0	0	0	0.2	1
Agrostis stolonifera	3.7	1	17.7	5	16.7	3	23.7	7	50.3	7	1.1	1
Algae	0	0	9	3	0	0	0	0	1	1	0	0
Alisma triviale	0	0	0	0	3.1	4	1	1	0	0	0	0

Alopecurus geniculatus	0	0	35	6	42.3	8	29.1	6	8	1	0	0
Alopecurus pratensis	0	0	15.8	5	17.3	3	11	2	6	1	5.7	2
Atriplex glabriuscula	0	0	0	0	0	0	6.83	4	0.67	1	5.1	6
Atriplex hastata	0	0	0	0	11	3	0	0	0	0	0	0
Atriplex sp.	0	0	0	0	0.3	1	0	0	1.7	1	0	0
Bidens cernua	0	0	0	0	0.3	1	0	0	0	0	0	0
Bolboschoenus maritimus	0	0	0	0	0.7	1	0	0	0	0	0	0
Bromus inermis	0	0	0	0	0.3	1	0	0	0	0	0	0
Calamagrostis canadensis	0	0	1	1	0	0	0	0	0	0	0	0
Carex gynandra	0	0	0	0	7.7	1	0	0	0	0	0	0
Carex lurida	0.3	1	0	0	0	0	0	0	0	0	0	0
Carex paleacea	0	0	0	0	0	0	6	1	6.67	1	20.2	7
Carex scoparia	3.7	2	0	0	0	0	0	0	0	0	0	0
Carex sp.	0	0	0	0	2.3	1	0	0	0	0	0	0
Carex spicata	0	0	0	0	0	0	0	0	0	0	2.7	1
Cirsium arvense	0	0	0	0	0	0	0	0	0	0	0.2	1
Cirsium vulgare	1.1	1	0	0	0	0	0	0	0	0	0	0
Elymus repens	0	0	4.1	3	9	3	1.3	2	3.7	3	0	0
Filipendula ulmaria	1.1	1	0	0	0	0	0	0	0	0	0	0
Galium mollugo	2.4	1	0	0	0	0	0	0	0	0	0	0
Glyceria grandis	0	0	0	0	0	0	0	0	1	1	0	0
Gnaphalium uliginosum	0	0	0	0	2	1	0	0	0	0	0	0
Impatiens capensis	0	0	0	0	0	0	0	0	0	0	0.1	1
Iris versicolor	0	0	0	0	0	0	0.3	1	0	0	0	0
Juncus articulatus	0	0	0	0	4.4	3	6	2	4.3	1	0	0
Juncus brevicaudatus	0	0	1.3	1	0	0	0	0	0	0	0	0
Juncus bufonius	0	0	0	0	0.1	1	0	0	0	0	0	0
Juncus effusus	8	2	0.3	1	0	0	3.7	2	0.3	1	0	0
Juncus tenuis	0	0	0.1	1	0	0	0	0	0	0	0	0
Late danelion	0	0	2	1	6	2	0	0	0	0	0	0
Lythrum salicaria	0	0	0	0	0	0	0	0	0.7	1	0	0
Moss	0.3	1	0	0	0	0	0	0	0	0	0	0
Pasture grass	47.7	9	0	0	0	0	0	0	0	0	0	0
Persicaria hydropiper	0	0	0	0	3.3	2	2.1	4	5.3	1	0	0
Persicaria lapathifolia	0	0	0.1	1	3.4	3	0	0	0	0	0	0
Persicaria maculosa	0	0	0	0	1	1	0	0	0	0	0	0
Persicaria sp.	0	0	0	0	0	0	0	0	0	0	2.3	3

Phalaris arundinacea	0	0	0	0	0	0	0	0	2	1	14.3	3
Phleum pratense	0	0	0	0	3	1	0	0	0	0	0	0
Plantago major	0.1	1	1.3	1	0	0	0	0	0	0	0	0
Poa palustris	0	0	0	0	0	0	9.3	2	0	0	0	0
Poa pratensis	0	0	41.3	7	9	3	6.3	1	8.3	1	0	0
Polygonum hydropiper	0	0	0	0	0	0	0.1	1	0	0	0	0
Polygonum neglectum	0	0	1.7	2	20.75	8	0	0	2	1	0	0
Polygonum sp.	0	0	0	0	0	0	1.3	1	0	0	0	0
Ranunculus repens	0	0	0.1	1	0	0	0	0	0	0	0	0
Rosa virginiana	6.7	1	0	0	0	0	0	0	0	0	0.1	1
Rumex crispus	1.9	2	0	0	0	0	3	2	0.3	1	0.6	1
Schoenoplectus tabermontanii	0	0	1.7	1	1	1	3	4	9	2	0	0
Scirpus atrovirens	0	0	0	0	0.7	1	0	0	0.3	1	0	0
Solidago sempervirens	0	0	0	0	0	0	0	0	0	0	3.2	1
Sonchus arvensis	0	0	0	0	0	0	0	0	1	1	13.3	5
Sporobolus alterniflorus	0	0	1.1	2	29.7	5	34	6	31.3	5	0	0
Sporobolus michauxianus	0	0	2.3	2	7.7	4	24	5	28	6	28.8	11
Sporobolus pumilus	0	0	0	0	0	0	0	0	0	0	0.2	1
Stellaria sp.	0.1	2	0	0	0	0	0	0	0	0	0	0
Symphyotrichum spp.	0	0	0	0	0	0	0	0	0	0	0.9	2
Taraxacum officinale	13.2	9	4	1	1.1	2	1.5	3	0	0	0.2	1
Trifolium repens	0	0	2.7	2	2.3	2	0	0	0	0	0	0
Trifolium sp.	21.3	8	0	0	0.7	1	0	0	0	0	0	0
Typha angustifolia	0	0	0	0	0	0	0	0	8.3	1	0	0
Typha latifolia	0	0	0	0	0	0	3.3	1	11.7	2	68.2	14
Unknown grass	0	0	0	0	0	0	0	0	0	0	1.5	1
Unknown seedling	0	0	0	0	0	0	0	0	0	0	0.4	1

Table B-14. Vegetation plot data summaries from Three Fathom Harbour showing mean abundance and frequency for present species.

Species Names	Three Fathom Harbour									
	pre		1		3		5		7	
	abun.	freq.	abun.	freq.	abun.	freq.	abun.	freq.	abun.	freq.
Sporobolus alterniflorus	0	0	0	0	0	0	4.2	1	0	0
Sporobolus pumilus	0	0	0	0	0	0	0	0	0.8	1
Sporobolus michauxianus	4.3	6	7	5	4.3	4	23	8	34.8	11

Atriplex glabriuscula	0	0	2.2	2	0	0	0	0	4	2
Solidago sempervirens	0	0	0	0	0.2	1	0.2	1	0.2	1
Agrostis perennans	0	0	0	0	0	0	0.8	1	0	0
Agrostis stolonifera	0.7	2	1.3	1	9.0	5	0.3	1	2.9	2
Alnus sp.	0	0	0.2	1	0	0	0	0	0	0
Andromeda polifolia	0.3	1	4	2	0.5	2	2.2	1	0.5	1
Potentilla anserina	0	0	0	0	0	0	0	0	0.04	1
Aster sp.	0.2	2	0	0	0	0	0	0	0	0
Atriplex patula	0	0	0	0	0.1	2	0	0	0	0
Atriplex sp.	0	0	0	0	1	4	1.2	2	0	0
Bidens cernua	0.2	1	0	0	0	0	0	0	0	0
Bidens frondosa	0.5	3	0	0	0	0	0	0	0	0
Bolboschoenus maritimus	0.2	1	0	0	0	0	2.8	1	4.3	2
Calamagrostis canadensis	39.9	14	24.3	10	11	5	22	10	22.7	11
Calystegia sepium	0	0	0	0	2.7	1	0.04	1	1.7	1
Carex atlantica	12.5	10	9	7	0	0	0	0	0	0
Carex brunnescens	10.7	9	0	0	0	0	0	0	0	0
Carex echinata	0	0	0	0	11.8	6	8	5	16	6
Carex exilis	0	0	2.8	1	0	0	7	2	8	3
Carex hormathodes	0	0	0	0	1.3	2	2	3	3	5
Carex limosa	0	0	0	0	0.5	1	0	0	0	0
Carex magellanica	0	0	1.2	3	0	0	0	0	0	0
Carex nigra	0.04	1	1.3	1	0	0	0	0	0.3	1
Carex scoparia	5	9	0.9	4	0.8	1	0	0	0	0
Carex sp.	0.3	1	0	0	0	0	3.5	3	0.04	1
Carex stricta	0	0	1.0	3	0	0	0	0	0	0
Carex trisperma	0.2	1	0.3	1	0	0	0	0	0.04	1
Chamaedaphne calyculata	9	8	15.8	8	9.7	7	5	4	6.7	4
Chenopodium album	0	0	0	0	2.3	1	0	0	0	0
Eleocharis palustris	14	6	0	0	0	0	0	0	0	0
Eleocharis sp.	0	0	0	0	1	2	0	0	0	0
Elymus repens	0	0	0	0	0	0	0.7	1	0	0
Euthamia graminifolia	0	0	0	0	0	0	0	0	0.3	1
Fragaria virginiana	0	0	0	0	0	0	0.04	1	6.3	3
Galium mollugo	0.2	1	0	0	0	0	0	0	0	0
Galium palustre	0.7	7	0	0	1.5	4	0.7	3	0.8	4
Glyceria laxa	0.5	5	0	0	0	0	0	0	0.5	1
Glyceria striata	0.3	1	0	0	0.5	1	0	0	0.0	1
Anthoxanthum nitens	0	0	5.8	4	0	0	0	0	0.3	1
Hordeum jubatum	0	0	0	0	0	0	0.2	1	0	0

Iris versicolor	0	0	0.5	1	0	0	0	0	0	0
Juncus articulatus	0	0	0	0	0.2	1	0	0	0	0
Juncus balticus	0	0	0	0	0	0	0	0	0.04	1
Juncus brevicaudatus	0.3	1	0	0	0	0	0	0	0.2	1
Juncus canadensis	0.3	2	0	0	0	0	0	0	0	0
Juncus effusus	7.5	7	1.9	3	3.5	2	3.0	3	2.5	3
Juncus sp.	0.0	1	0	0	0	0	1	1	0	0
Leucanthemum vulgare	0	0	0	0	0	0	0	0	1.5	1
Lichen sp.	0	0	0	0	0.04	1	0	0	0	0
Lycopus americanus	0.5	1	0	0	0	0	0	0	0	0
Lycopus uniflorus	1.4	4	0	0	0.2	1	0	0	1.3	1
Lysimachia terrestris	4.0	7	0.5	3	0.4	2	0.1	2	1.5	4
Maianthemum stellatum	0	0	0	0	0	0	0.3	1	0	0
Maianthemum trifolium	0	0	0.3	1	0	0	0	0	0.2	1
Mentha arvensis	0	0	0.8	2	0	0	0	0	0	0
Morella pensylvanica	0.08	2	0	0	0	0	0	0	0	0
Moss	0	0	0	0	0	0	16.7	5	0	0
Muhlenbergia uniflora	0	0	0	0	4	1	0	0	0	0
Myrica gale	21.2	10	20	10	24	10	7.2	5	21.1	11
Oclemena nemoralis	0	0	0.04	1	4	1	0.8	1	3.8	1
Onoclea sensibilis	0	0	0.04	1	0	0	0	0	0	0
Persicaria hydropiper	0.04	1	0	0	0	0	0.3	1	0	0
Persicaria sagittata	1.2	4	0	0	0	0	0	0	0	0
Potentilla palustris	0.2	1	0	0	0	0	0	0	0	0
Potentilla simplex	0	0	0	0	0.2	1	0	0	0	0
Ranunculus repens	0.04	1	0	0	0	0	0	0	0	0
Rhododendron groenlandicum	0	0	0	0	0	0	0.5	1	0.04	1
Rorippa sylvestris	0	0	0	0	1.7	1	0	0	0	0
Rosa carolina	0	0	0	0	0	0	0.04	1	0	0
Rubus allegheniensis	0	0	0	0	0	0	1.2	1	0.2	1
Rubus hispidus	0	0	6	4	6	3	0	0	0	0
Rubus idaeus	0	0	0	0	2.2	2	0.2	1	0	0
Rubus pubescens	0	0	0	0	0	0	2.5	2	1.3	2
Rubus strigosus	0.04	1	0	0	0	0	0	0	0	0
Rumex crispus	0	0	0	0	0	0	0	0	0.2	1
Ruppia maritima	0	0	0	0	0.2	1	2.3	2	0	0
Sarracenia purpurea	0	0	0.2	1	0	0	0.3	1	0	0
Schoenoplectus americanus	4.7	5	9.2	4	7.2	2	6.8	3	3	1
Schoenoplectus tabermontanii	5.7	4	6.2	2	0.04	1	0	0	0.7	1
Scirpus cyperinus	9.5	6	0.2	2	0	0	0	0	0	0

Scutellaria galericulata	0.04	1	0	0	0	0	0	0	0.3	1
Solidago rugosa	0	0	0	0	0	0	0.04	1	0.7	1
Solidago sp.	0	0	0	0	0	0	0	0	0.2	1
Sonchus arvensis	0	0	0	0	0	0	1.8	2	0.2	1
Sphagnum moss	10.7	4	31.2	9	23.3	8	0	0	12.2	7
Spiraea alba	0	0	0	0	0	0	3	2	15.4	10
Spiraea latifolia	10.9	13	8.2	7	12.5	9	4.3	4	0	0
Spirea tomentosa	0	0	0.5	1	0.04	1	0.3	1	0	0
Stellaria sp.	0	0	0.2	1	0	0	0	0	0	0
Symphyotrichum lanceolatus	0.04	1	0	0	0	0	0	0	0	0
Symphyotrichum novi-belgii	0.3	1	3	6	10.3	8	16.4	11	12.5	12
Taraxacum officinale	0	0	0	0	1	1	0.3	1	0.3	1
Hypericum fraseri	3.2	11	0.4	2	0.4	2	0.2	1	0	0
Triglochin maritima	0	0	0	0	1.2	1	0	0	0	0
Tussilago farfara	0	0	0	0	0	0	0	0	0.2	1
Typha angustifolia	0	0	0.7	1	0	0	0	0	0	0
Typha latifolia	2	3	2	1	3.3	3	2.7	4	3.9	7
Unknown grass	0	0	0	0	0	0	0.2	1	0.3	1
Unknown seedling	0	0	0	0	0	0	0.5	2	0.2	1
Vaccinium macrocarpon	1.7	1	4.6	6	1.0	2	0	0	6.8	2
Vaccinium oxycoccos	0	0	0	0	2.7	2	7.5	3	1.5	2
Vicia sp.	0	0	0.3	1	0	0	0.04	1	0	0
Viola macloskeyi ssp. pallens	0	0	0.3	1	0	0	0	0	0.3	1

Table B-15. Vegetation plot data summaries from Walton River Study showing mean abundance and frequency for present species.

Species Name	Walton River Study															
	pre		1		2		3		4		5		7		17	
	abun.	freq.	abun.	freq.	abun.	freq.	abun.	freq.	abun.	freq.	abun.	freq.	abun.	freq.	abun.	freq.
Agrostis stolonifera	8.8	5	0.3	1	12.6	5	7.7	5	6.8	4	5.6	4	1.5	3	0	0
Algae	7.0	7	0	0	9.8	5	0	0	1.0	1	0	0	0	0	0	0
Ammophila breviligulata	1.0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Atriplex glabriuscula	0	0	0.04	1	0.5	4	0.33	3	0.8	4	0.2	2	0.04	1	0.1	3
Betula sp.	0.04	1	0	0	0.04	1	0	0	2.2	1	0	0	0	0	0	0
Bolboschoenus maritimus	0	0	0	0	0.9	2	4.6	5	0.9	4	1.5	2	1.4	4	0.3	1
Carex hormathodes	0	0	0	0	0	0	0.3	2	0	0	1.2	1	0	0	0	0
Carex paleacea	0	0	0	0	0.3	2	2.37	3	2.7	3	7.1	4	8.3	6	16.4	6
Carex scoparia	0	0	0.3	1	0	0	0	0	0.6	1	0	0	0	0	0	0
Distichlis spicata	0.2	1	1.5	2	0	0	0	0	0	0	0	0	0	0	0.2	1
Eleocharis parvula	0	0	1.2	2	0	0	0	0	0	0	0	0	0	0	0	0
Festuca rubra	0	0	0	0	0.6	2	2.4	1	2.8	1	2.1	1	0	0	0	0
Hydrocotyle americana	0.04	1	0.04	1	0	0	0	0	0	0	0	0	0	0	0	0
Juncus balticus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04	1
Juncus brevicaudatus	0	0	0	0	0	0	0	0	0	0	0	0	0.04	1	0	0
Juncus effusus	4.3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Juncus gerardii	5.6	3	4.3	4	8.6	5	8.89	4	4.8	5	11.9	6	12.2	6	5.3	4
Limonium carolinianum	0	0	0	0	0	0	0	0	0	0	0.3	2	0.04	1	0.9	2
Myosotis laxa	0.2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plantago maritima	0.2	1	0.3	1	0.7	3	0.04	1	0.3	2	0.04	1	0	0	3.4	1

Populus sp.	0	0	0.04	1	0	0	0	0	0	0	0	0	0	0	0	0
Puccinellia maritima	0	0	0	0	0.3	2	0.2	1	0	0	0	0	0	0	0.9	1
Ranunculus cymbalaria	0	0	0	0	1.0	1	3.0	1	1.5	1	2.4	1	1.5	1	0	0
Ruppia maritima	0	0	1.0	1	0	0	0	0	1.2	1	0	0	0	0	0	0
Salicornia depressa	0	0	0.4	4	0.9	8	1.7	5	0.2	3	0.2	1	0	0	0.7	3
Salicornia maritima	0	0	0	0	0	0	0	0	0	0	0	0	5.4	15	0	0
Schoenoplectus acutus	0.2	1	0.6	4	0	0	0	0	0.4	1	0	0	0	0	0	0
Schoenoplectus tabermontanii	0.3	1	0	0	2.8	1	1.8	2	3.4	1	1.8	1	1.3	3	0	0
Scirpus torreyi	0	0	0	0	0.3	1	0	0	0	0	0	0	0	0	0	0
Solidago gigantea	0.7	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solidago sempervirens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04	1
Sporobolus alterniflorus	0	0	21.7	21	58.7	25	74.07	24	72.3	22	75.3	22	77.4	26	52.9	18
Sporobolus michauxianus	0	0	0	0	1.0	1	2.37	1	3.9	2	3.1	2	1.9	3	0	0
Sporobolus pumilus	0	0	9.9	5	11.9	7	6.96	5	15.9	8	16.3	6	21.6	8	65.0	20
Suaeda maritima spp maritima	0	0	0.3	4	0.04	1	0.9	1	0.9	1	0.2	1	0.9	12	0	0
Submerged Aquatic Veg	41.2	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Triglochin maritima	0	0	0	0	0.04	1	0	0	0.4	2	0.6	1	0	0	0.5	2

Table B-16. Vegetation plot data summaries from Walton River reference showing mean abundance and frequency for present species.

Species Name	Walton Reference

	pre		1		2		3		4		5			7		17
	abun.	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**	**abun.**	**freq.**
Agrostis perennans	0.04	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agrostis stolonifera	0	0	1.2	1	0	0	0	0	0	0	0	0	0	0	0	0
Ammophila breviligulata	10.2	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anthoxanthum nitens	0	0	0	0	0	0	1.2	2	0.7	2	0.4	1	1.0	1	0.2	1
Atriplex glabriuscula	0.7	7	0.4	6	0.3	5	0.7	5	0.2	6	0.5	4	0.1	3	0	0
Calamagrostis canadensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	1
Carex paleacea	1.7	4	2.7	3	11.5	4	13.5	4	11.1	4	14.2	4	14.5	4	14.2	5
Distichlis spicata	6.7	2	7.5	2	7.4	2	7.3	2	7.3	2	6.8	2	5.8	2	4.7	3
Elymus virginicus	0	0	0.5	1	0	0	0	0	0	0	0.3	1	0	0	0	0
Juncus gerardii	0	0	0	0	0.8	1	0	0	3.7	1	0.4	1	0	0	0	0
Limonium carolinianum	0	0	0	0	0	0	0.04	1	0.04	1	0.04	1	3.9	3	0	0
Plantago maritima	0.2	2	0.5	3	0	0	0	0	0.04	1	0.9	1	0	0	0	0
Potentilla anserina	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04	1
Salicornia depressa	0	0	0	0	0	0	0.04	1	0.3	1	0	0	0	0	0.04	1
Salicornia maritima	1.3	7	0	0	0	0	0	0	0	0	0	0	0.3	4	0	0

Solidago sempervirens	3.4	3	3.1	3	2.0	3	0.7	3	0.7	3	2.2	3	0.6	2	2.5	3
Sporobolus alterniflorus	35.9	18	47.1	18	41.1	18	36.9	19	34.9	18	35.6	19	38.1	18	25.7	14
Sporobolus michauxianus	1.0	3	5.2	3	3.7	2	3.0	2	1.6	1	5.3	2	5.2	2	12.3	4
Sporobolus pumilus	59	19	62.6	18	63.9	19	74.1	21	71.3	21	66.2	20	70.2	20	67.0	19
Suaeda maritima spp maritima	1	4	1.2	1	0.04	1	0.3	1	0.04	1	0.04	1	0.78	2	0	0
Triglochin maritima	1.5	2	0.6	2	4.2	2	3.9	4	4.3	2	2.5	1	2.7	2	2.2	2
Unknown seedling	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.6	2

Appendix C – Vegetation Plot Data by Site

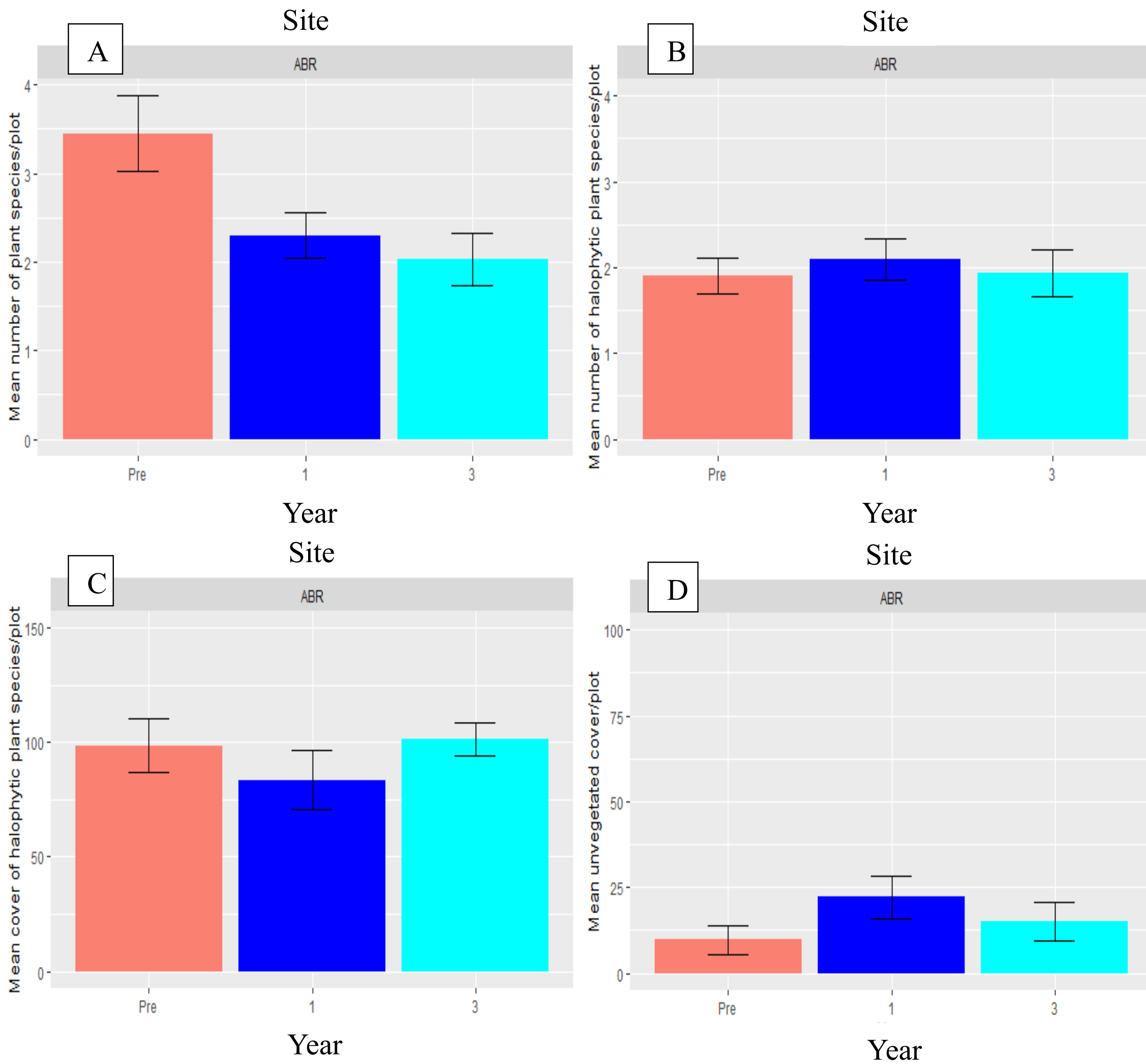


Figure C-1. *Vegetation plot data summaries from ABR from pre-restoration and years 1 and 3 post-restoration showing A) mean number of plant species, B) mean number of halophyte species, C) mean cover of halophytes, and D) mean unvegetated cover.*

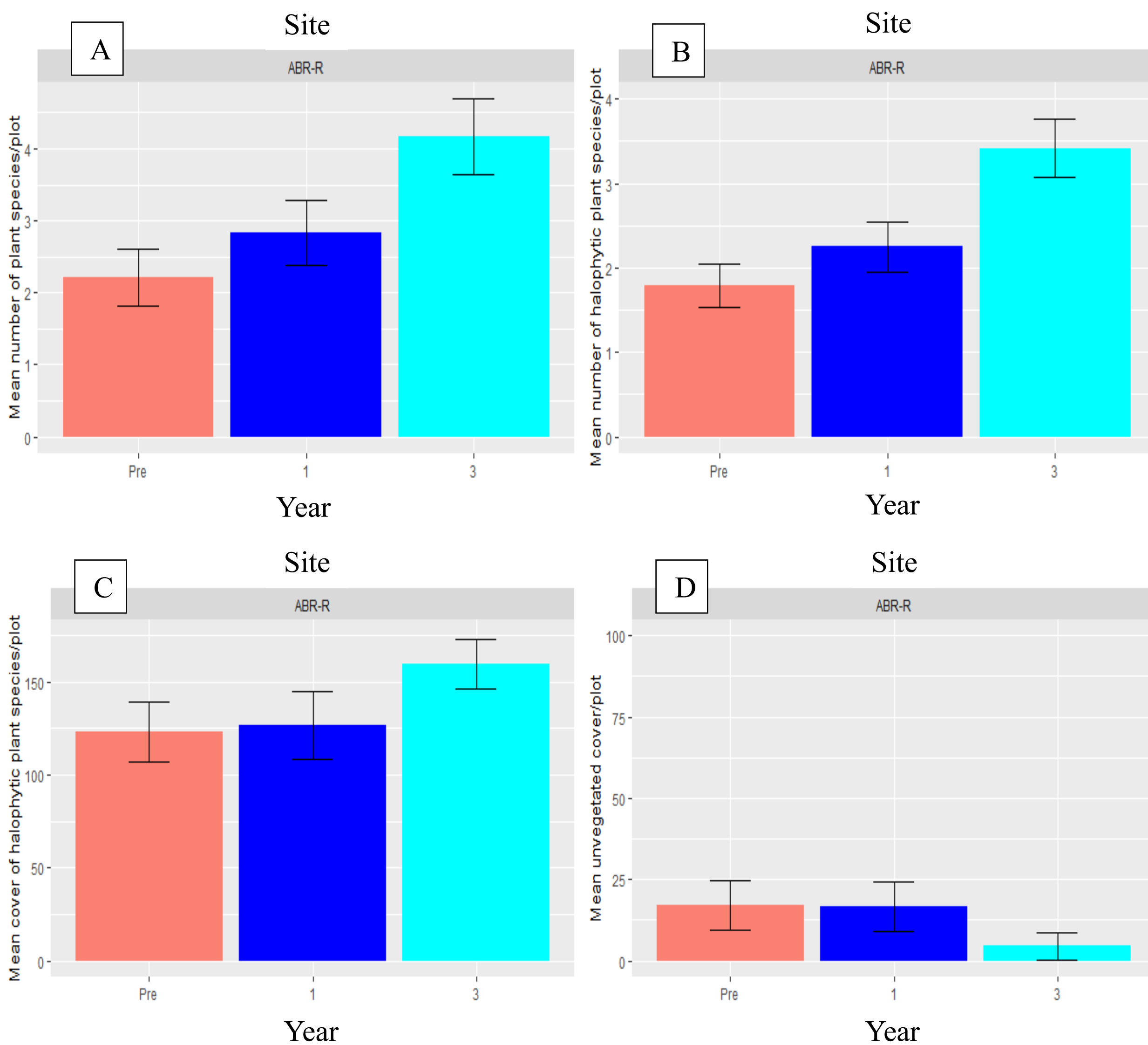


Figure C-2. *Vegetation plot data summaries from ABR-R from pre-restoration and years 1 and 3 post-restoration showing A) mean number of plant species, B) mean number of halophyte species, C) mean cover of halophytes, and D) mean unvegetated cover.*

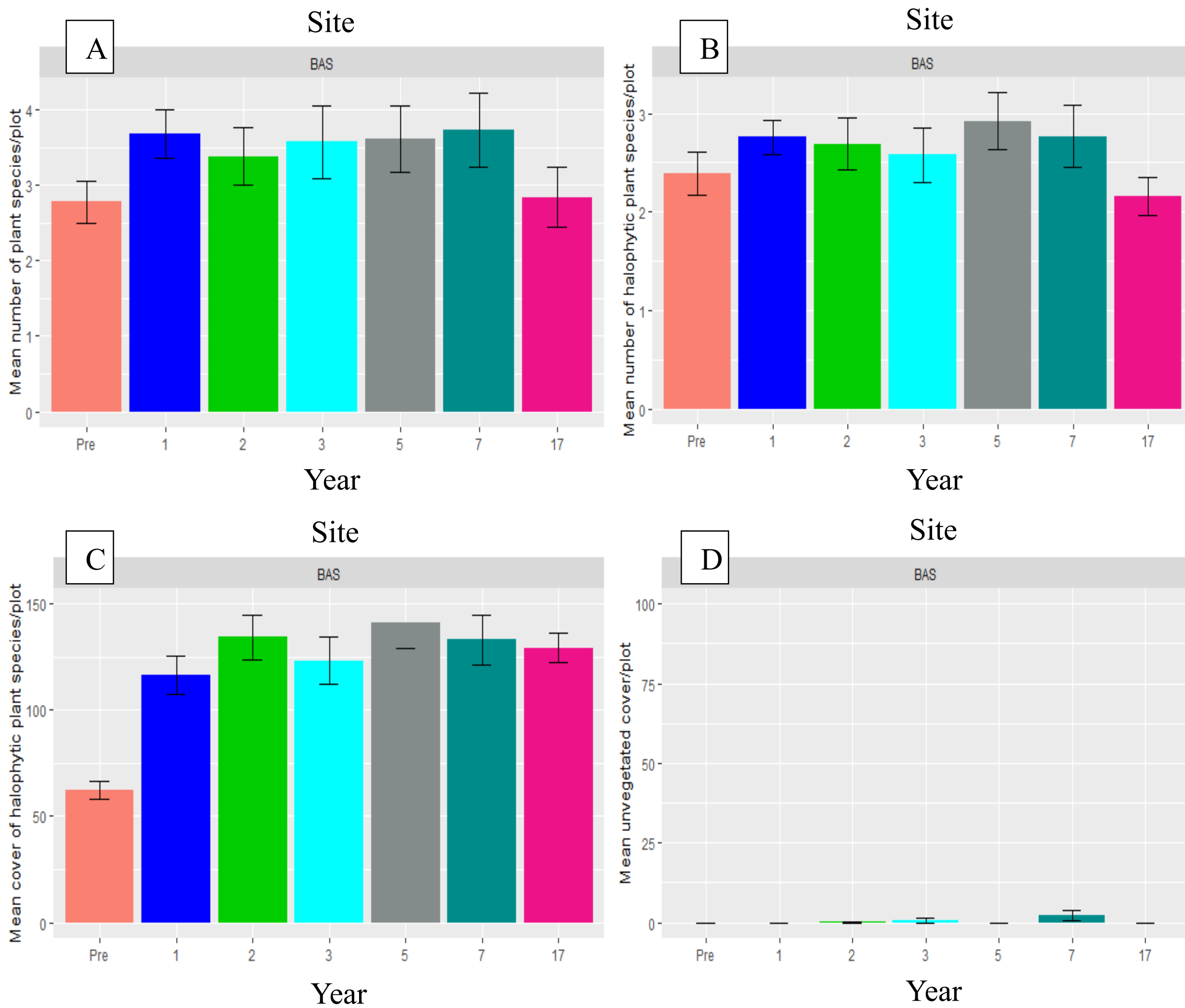


Figure C-3. *Vegetation plot data summary from BAS from pre-restoration and years 1, 3, 5, 7 and 17 post-restoration showing A) mean number of plant species, B) mean number of halophytic species, C) mean cover of halophytes, and D) mean unvegetated cover.*

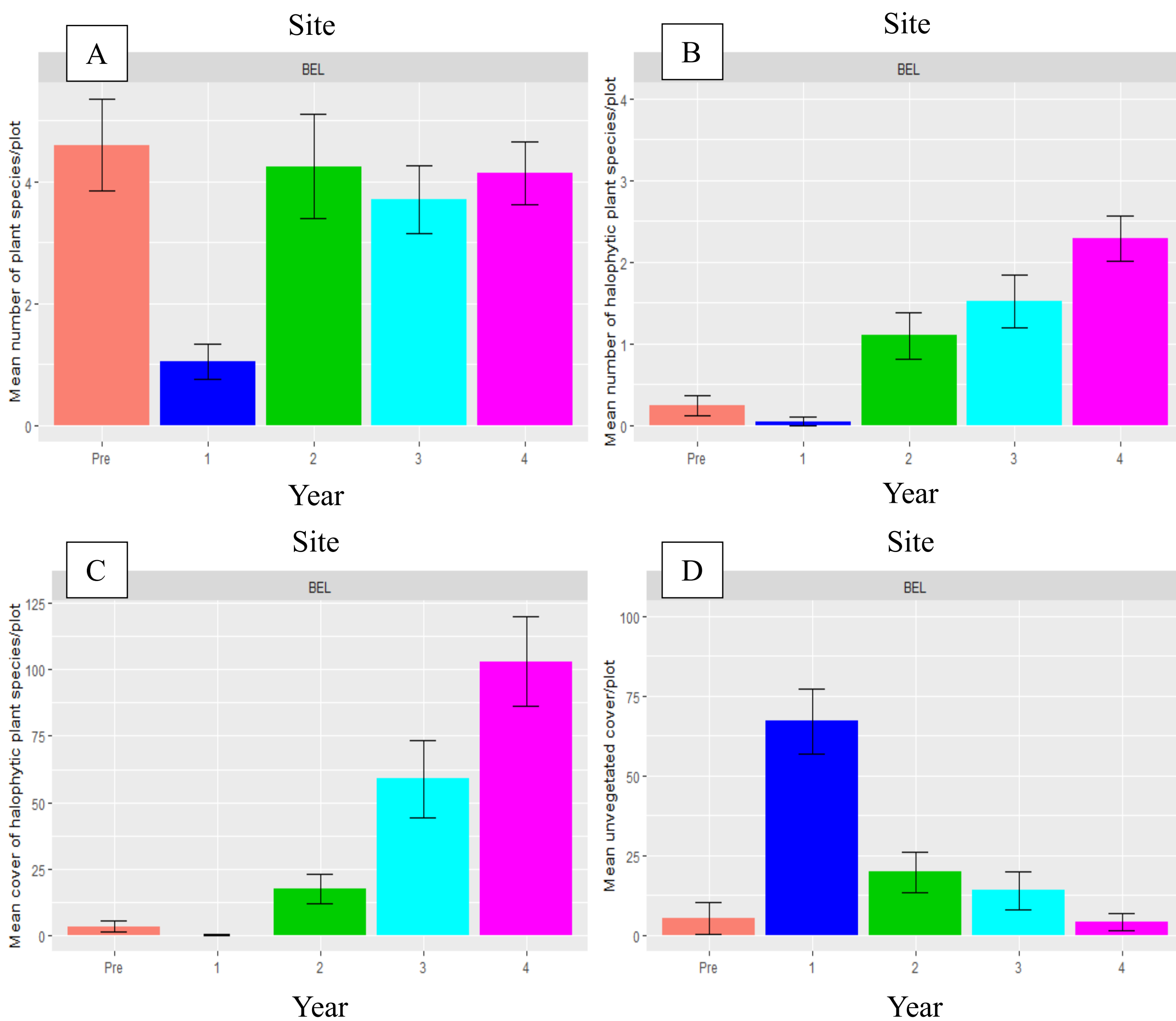


Figure C-4. *Vegetation plot data summary from BEL from pre-restoration and years 1, 2, 3, and 4 post-restoration showing A) mean number of plant species, B) mean number of halophytic species, C) mean cover of halophytes, and D) mean unvegetated cover.*

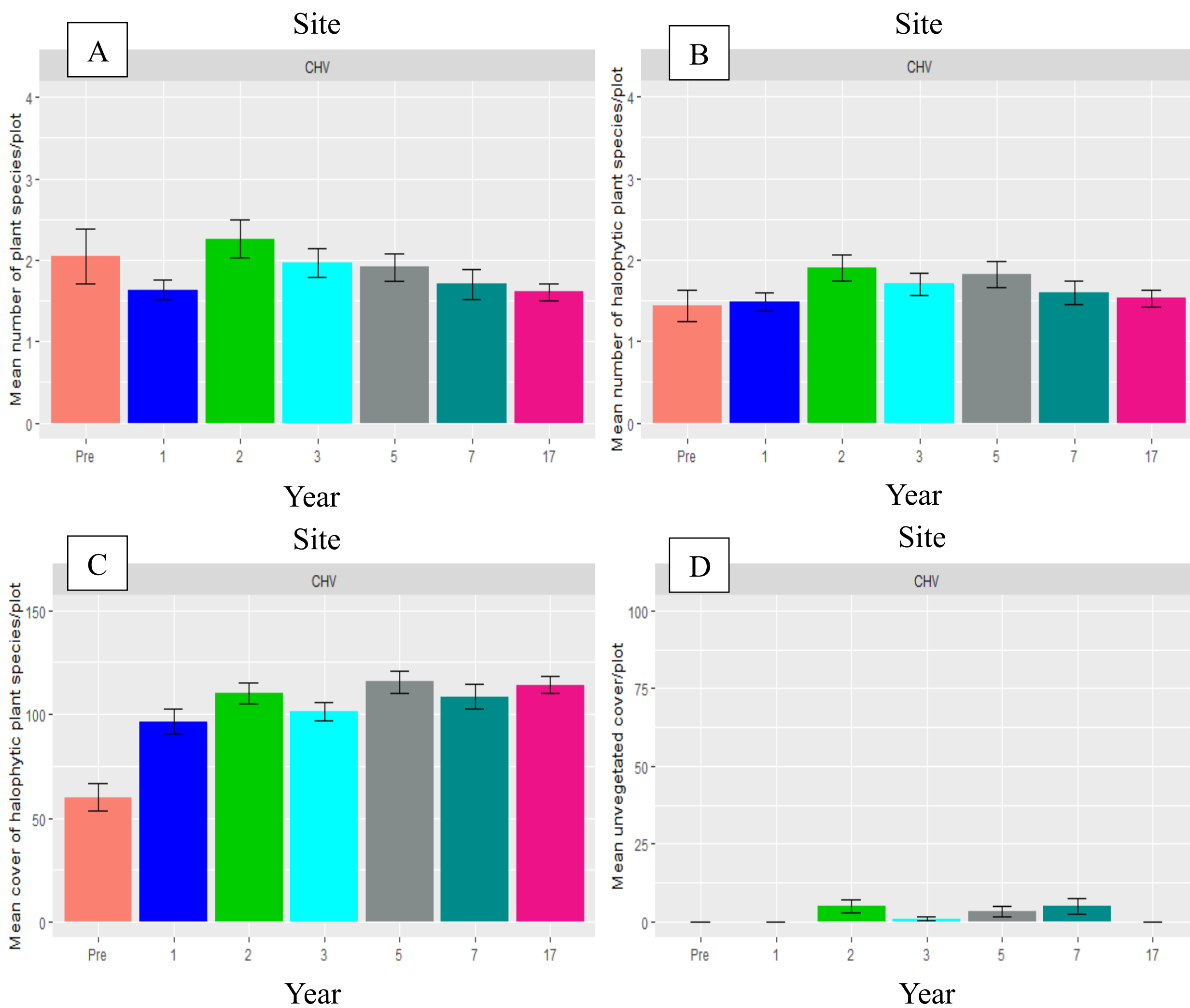


Figure C-5. *Vegetation plot data summary from CHV from pre-restoration and years 1, 2, 3, 5, 7 and 17 post-restoration showing A) mean number of plant species, B) mean number of halophytic species, C) mean cover of halophytes, and D) mean unvegetated cover.*

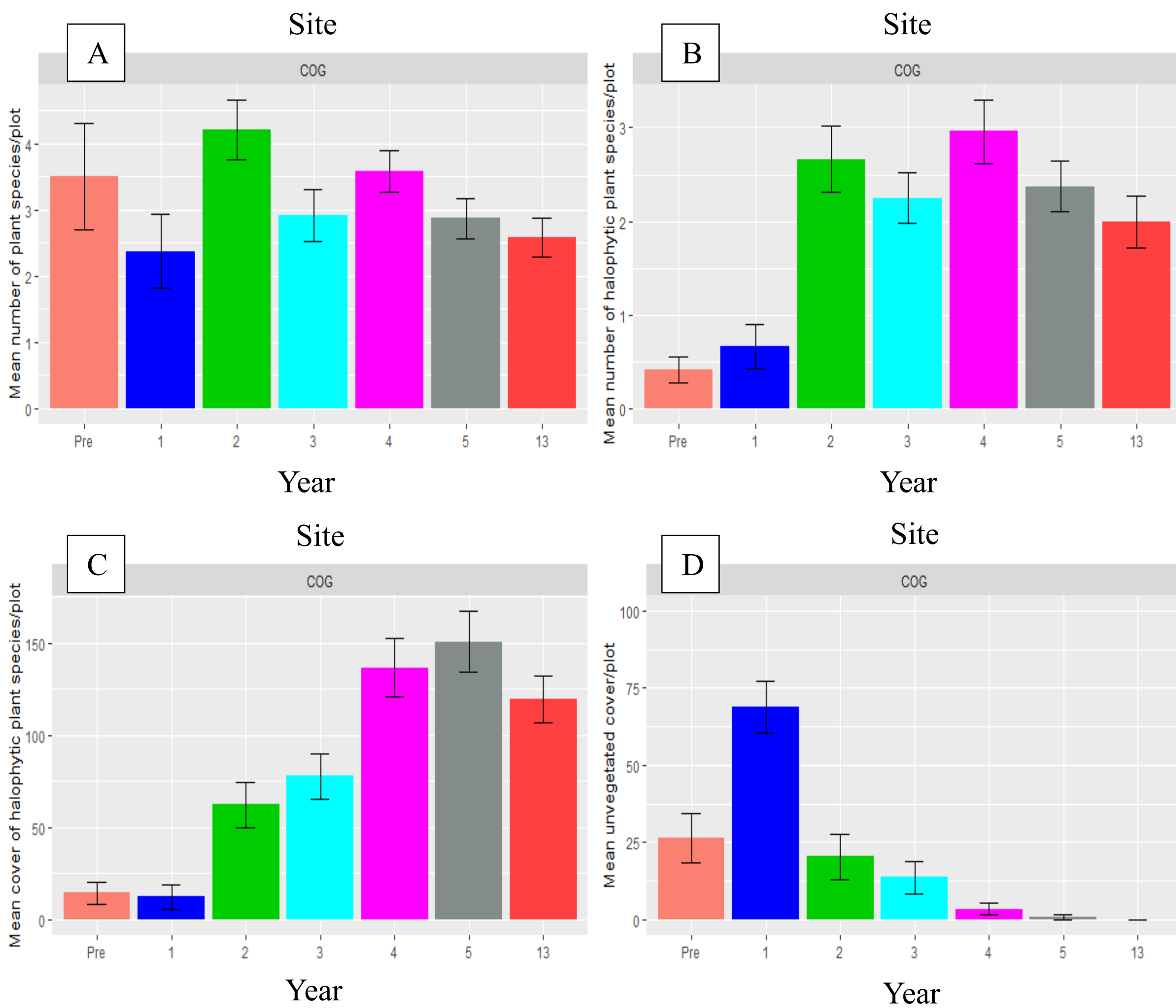


Figure C-6. *Vegetation plot data summary from COG from pre-restoration and years 1, 2, 3, 4, 5, and 13 post-restoration showing A) mean number of plant species, B) mean number of halophytic species, C) mean cover of halophytes, and D) mean unvegetated cover.*

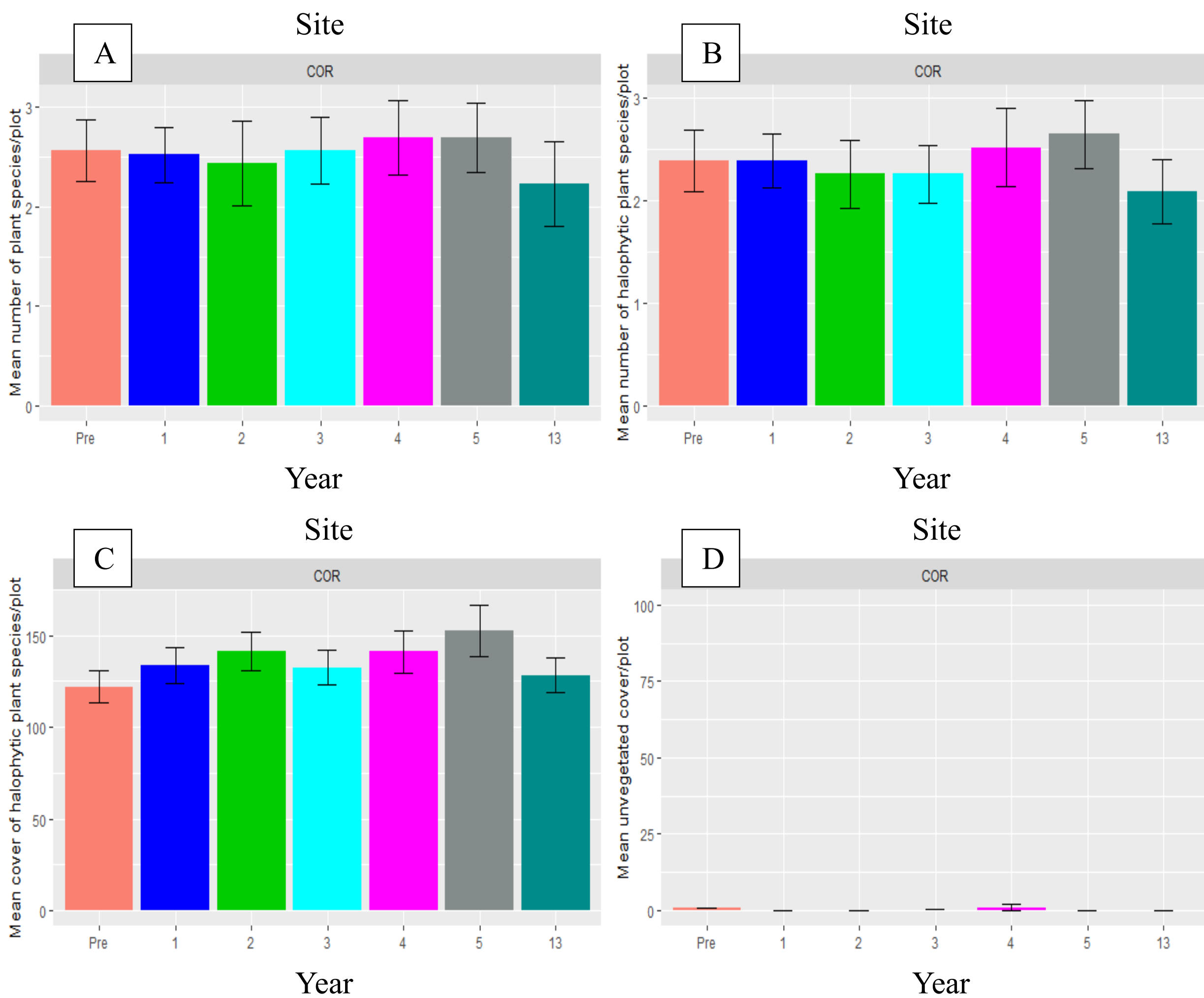


Figure C-7. *Vegetation plot data summary from COR from pre-restoration and years 1, 2, 3, 4, 5, and 13 post-restoration showing A) mean number of plant species, B) mean number of halophytic species, C) mean cover of halophytes, and D) mean unvegetated cover.*

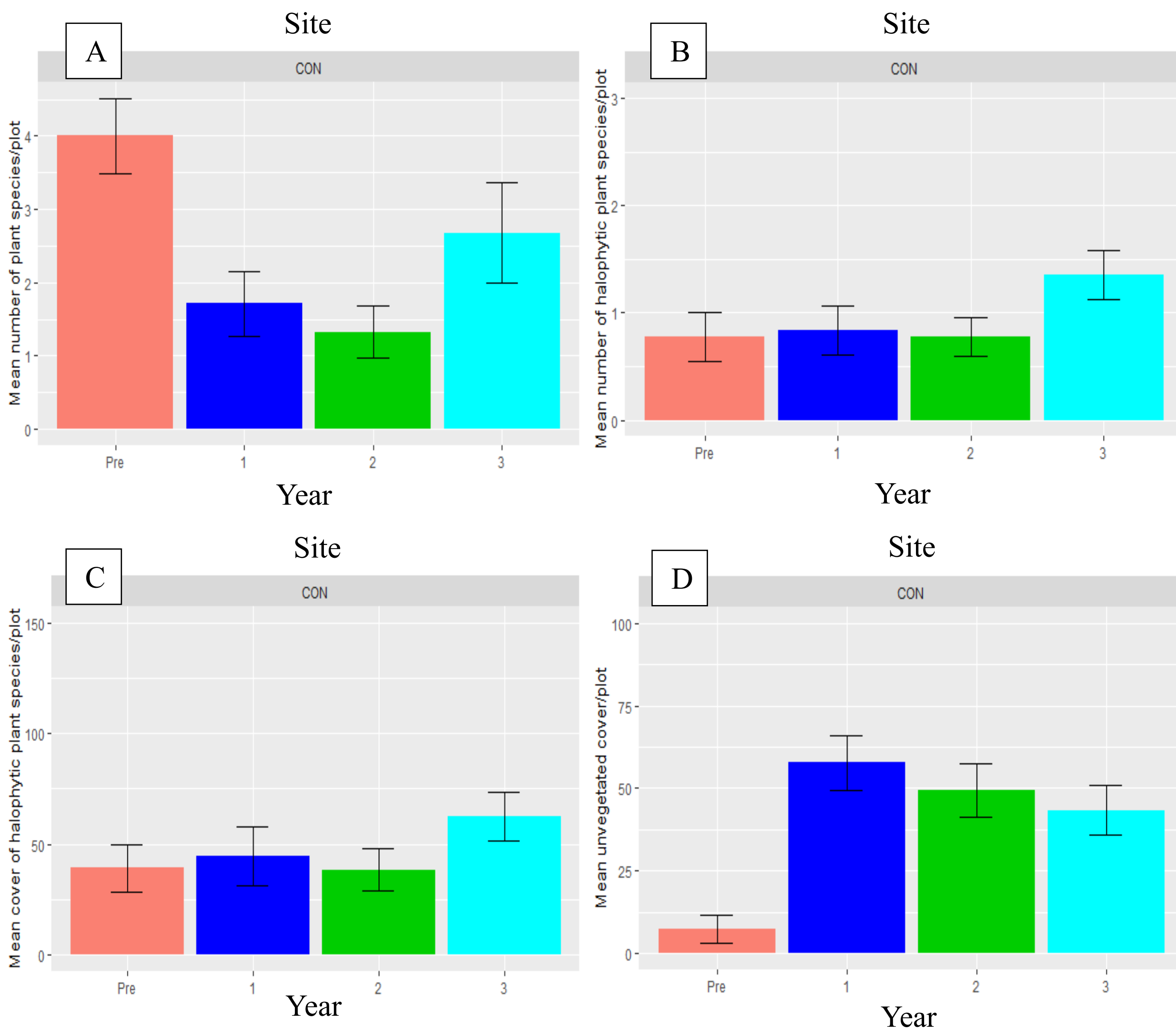


Figure C-8. *Vegetation plot data summary from CON from pre-restoration and years 1, 2 and 3 post-restoration showing A) mean number of plant species, B) mean number of halophytic species, C) mean cover of halophytes, and D) mean unvegetated cover.*

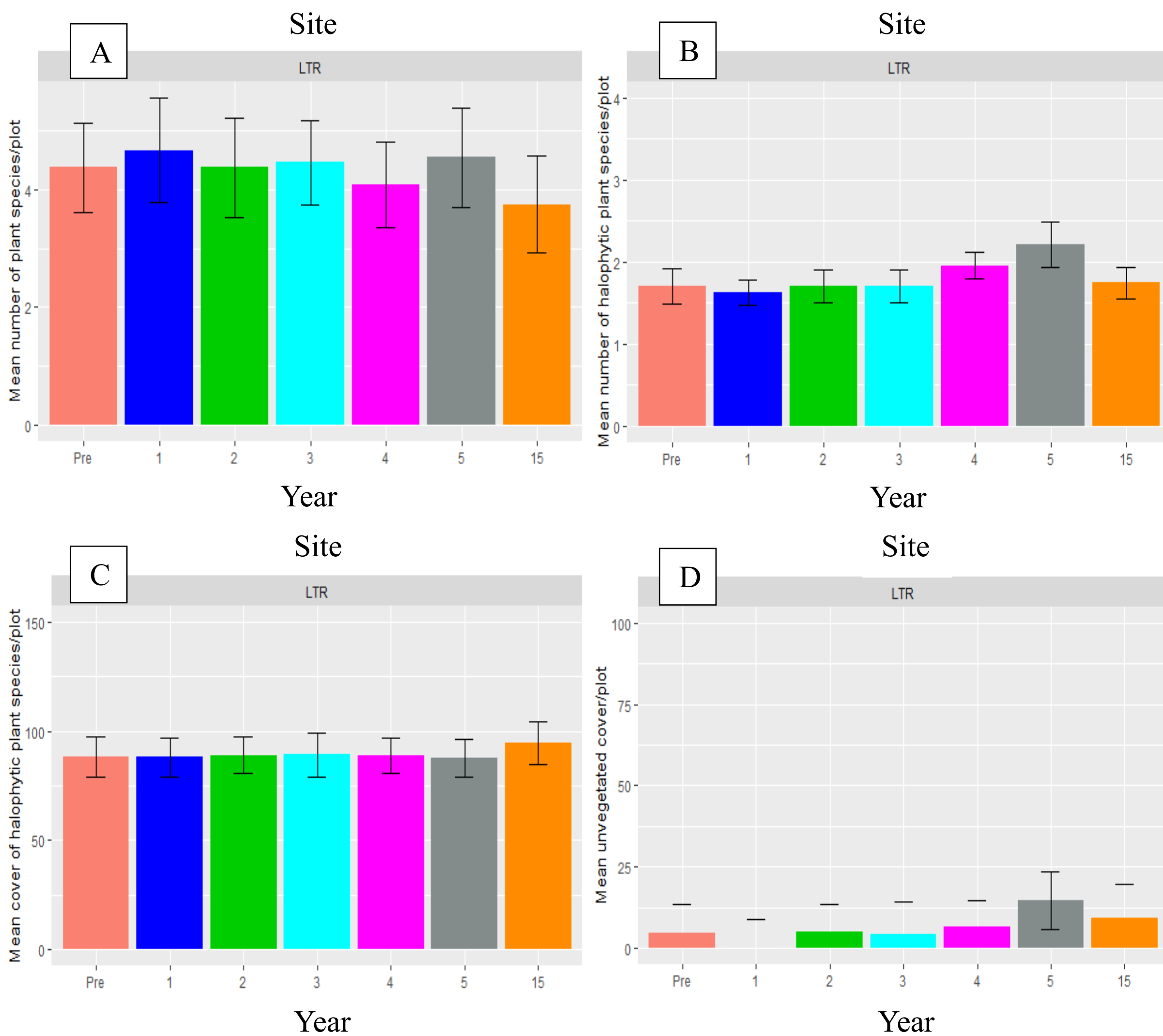


Figure C-9. *Vegetation plot data summary from LTR from pre-restoration and years 1, 2, 3, 4, 5, and 15 post-restoration showing A) mean number of plant species, B) mean number of halophytic species, C) mean cover of halophytes, and D) mean unvegetated cover.*

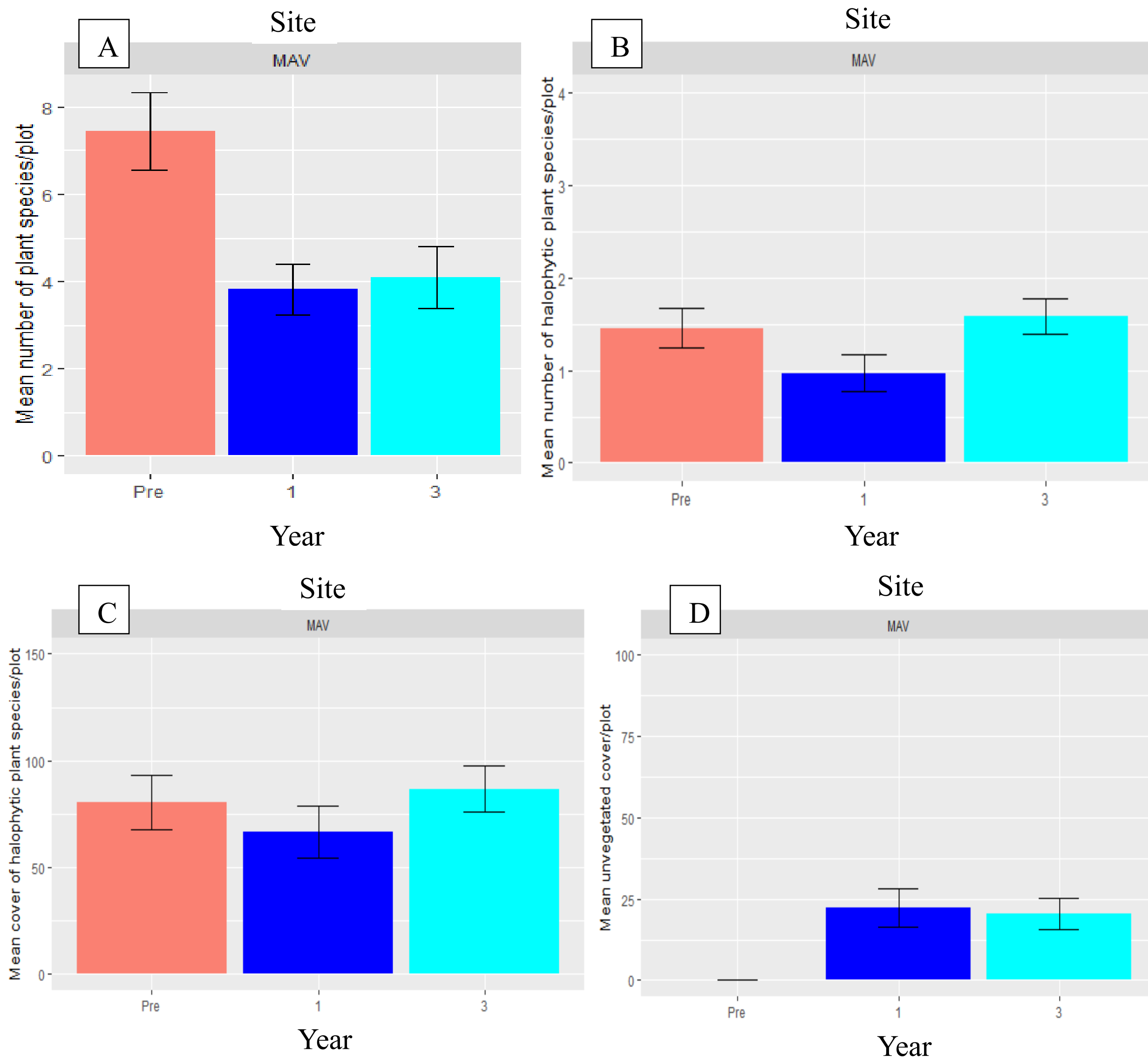


Figure C-10. *Vegetation plot data summary from MAV from pre-restoration and years 1 and 3 post-restoration showing A) mean number of plant species, B) mean number of halophytic species, C) mean cover of halophytes, and D) mean unvegetated cover.*

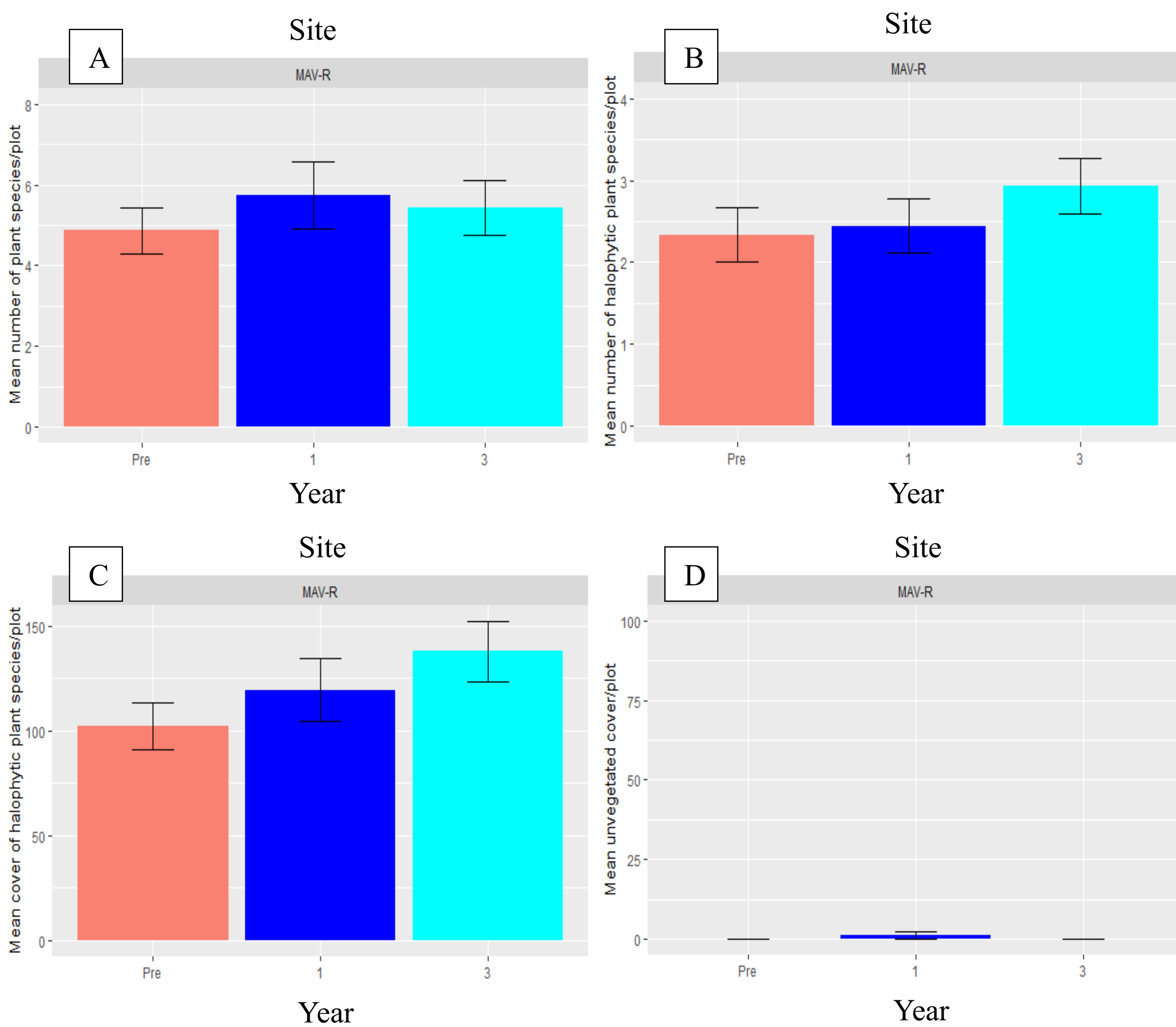


Figure C-11. *Vegetation plot data summary from MAV-R from pre-restoration and years 1 and 3 post-restoration showing A) mean number of plant species, B) mean number of halophytic species, C) mean cover of halophytes, and D) mean unvegetated cover.*

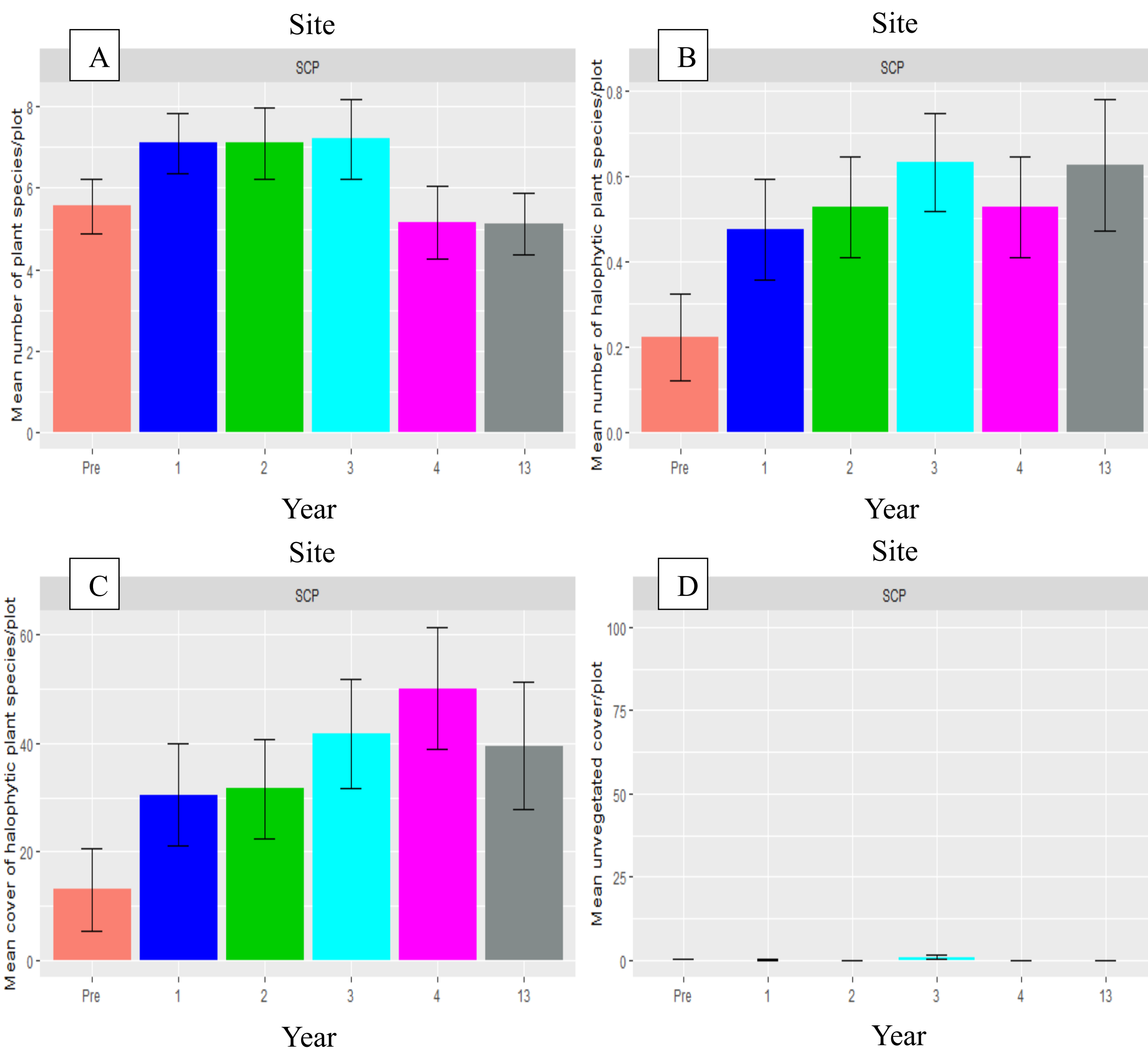


Figure C-12. *Vegetation plot data summary from SCP from pre-restoration and years 1, 2, 3, 4 and 13 post-restoration showing A) mean number of plant species, B) mean number of halophytic species, C) mean cover of halophytes, and D) mean unvegetated cover.*

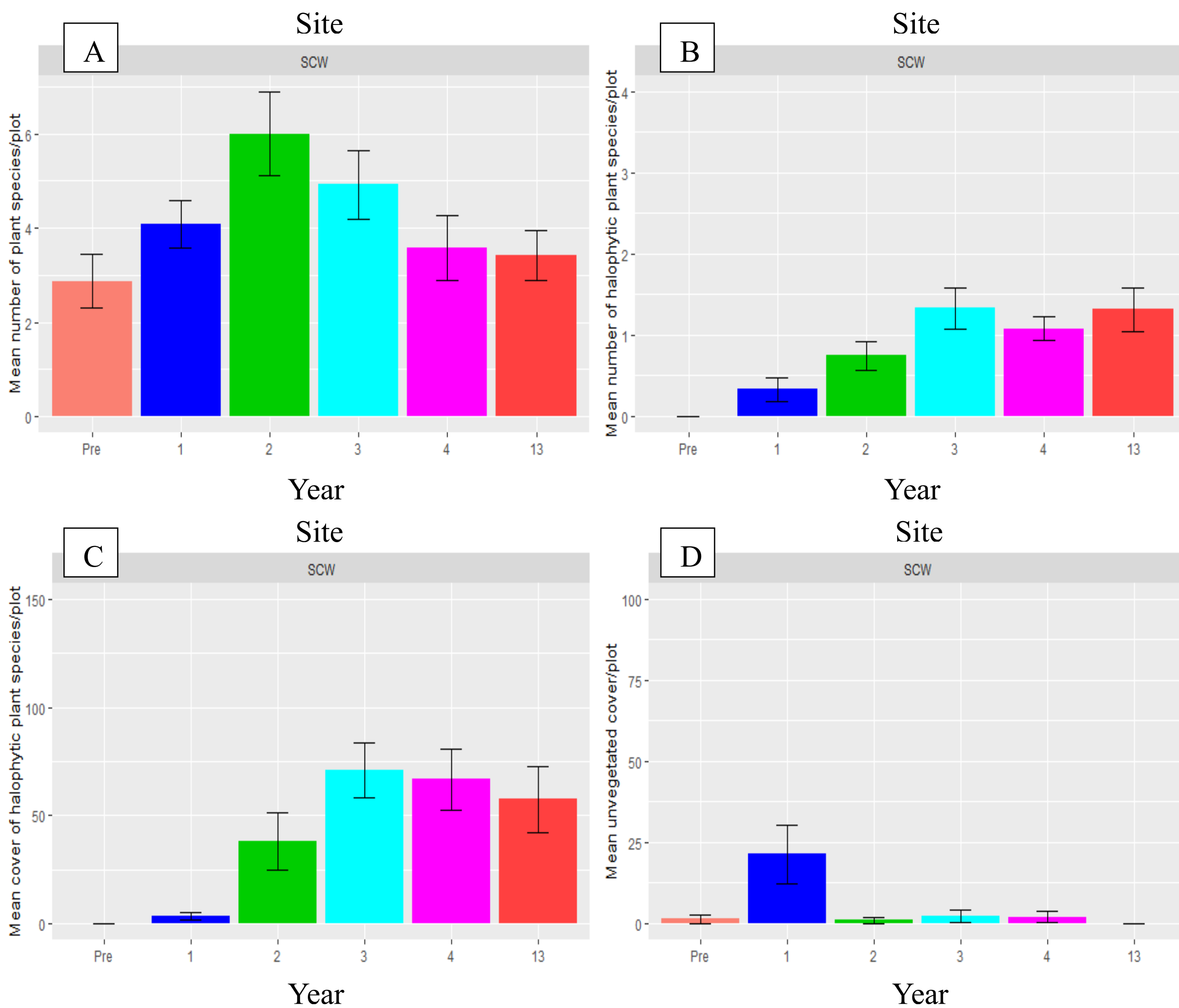


Figure C-13. *Vegetation plot data summary from SCW from pre-restoration and years 1, 2, 3, 4 and 13 post-restoration showing A) mean number of plant species, B) mean number of halophytic species, C) mean cover of halophytes, and D) mean unvegetated cover.*

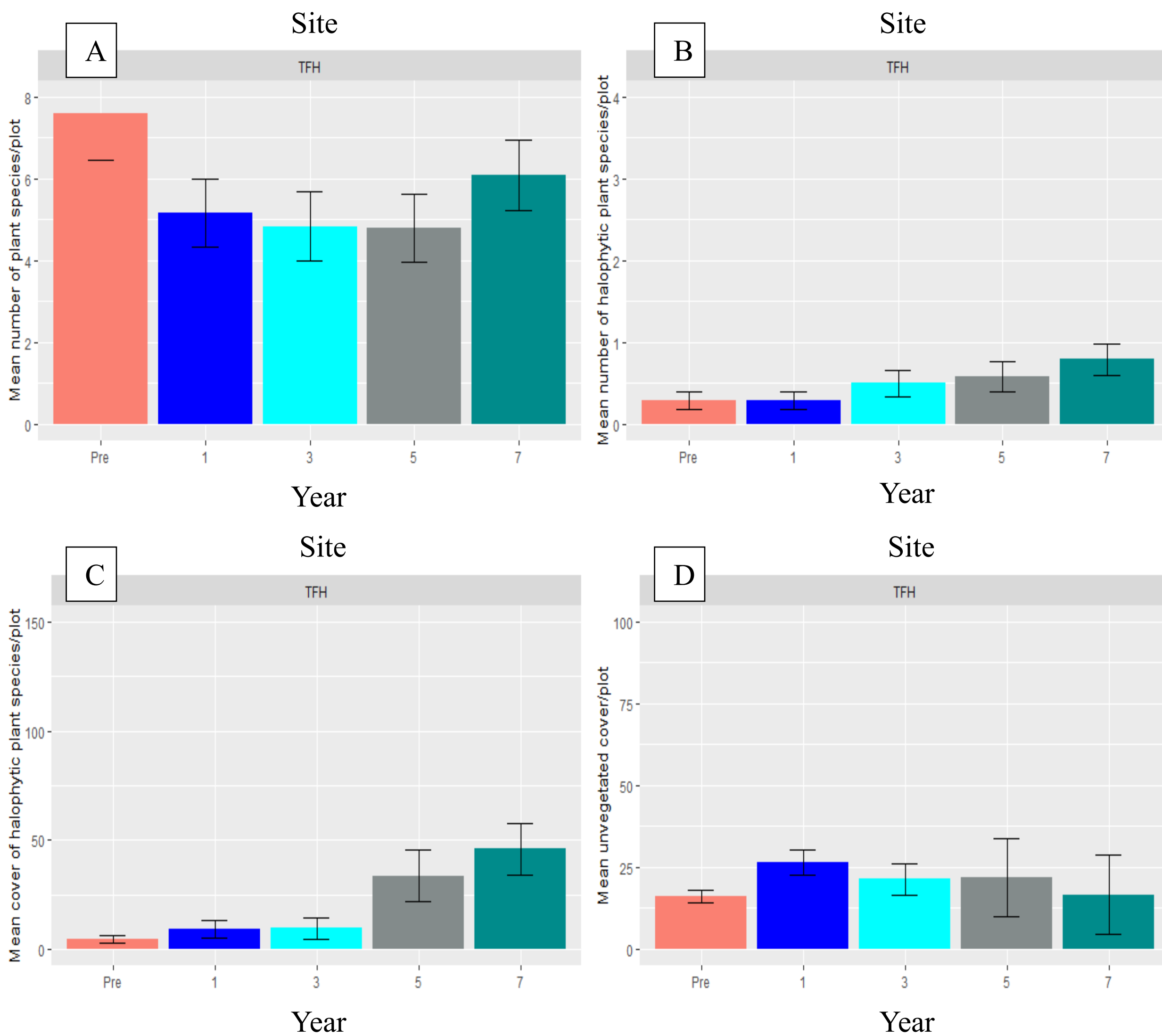


Figure C-14. *Vegetation plot data summary from TFH from pre-restoration and years 1, 2, 3, 4 and 13 post-restoration showing A) mean number of plant species, B) mean number of halophytic species, C) mean cover of halophytes, and D) mean unvegetated cover.*

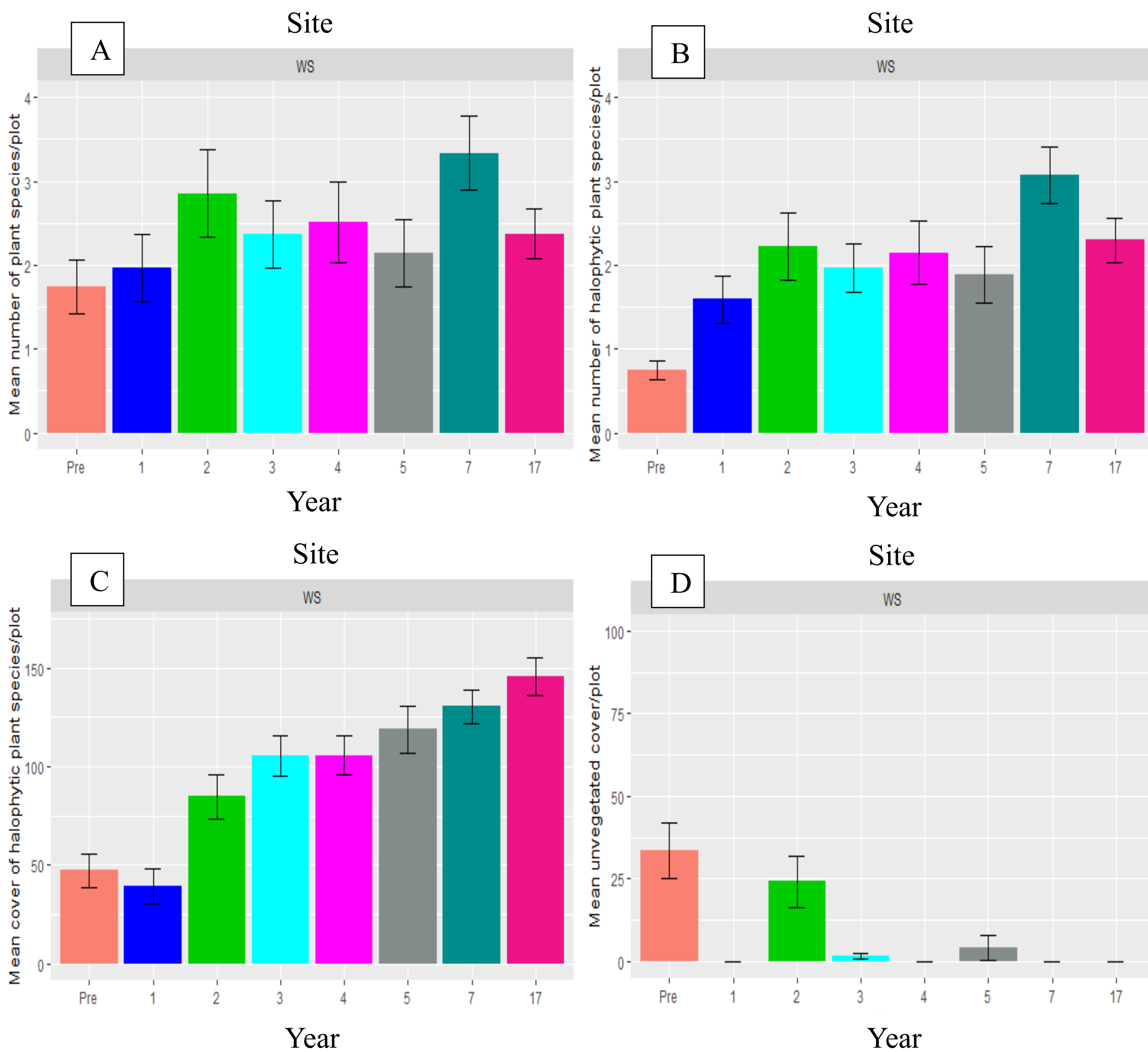


Figure C-15. *Vegetation plot data summary from WS from pre-restoration and years 1, 2, 3, 4 and 13 post-restoration showing A) mean number of plant species, B) mean number of halophytic species, C) mean cover of halophytes, and D) mean unvegetated cover.*

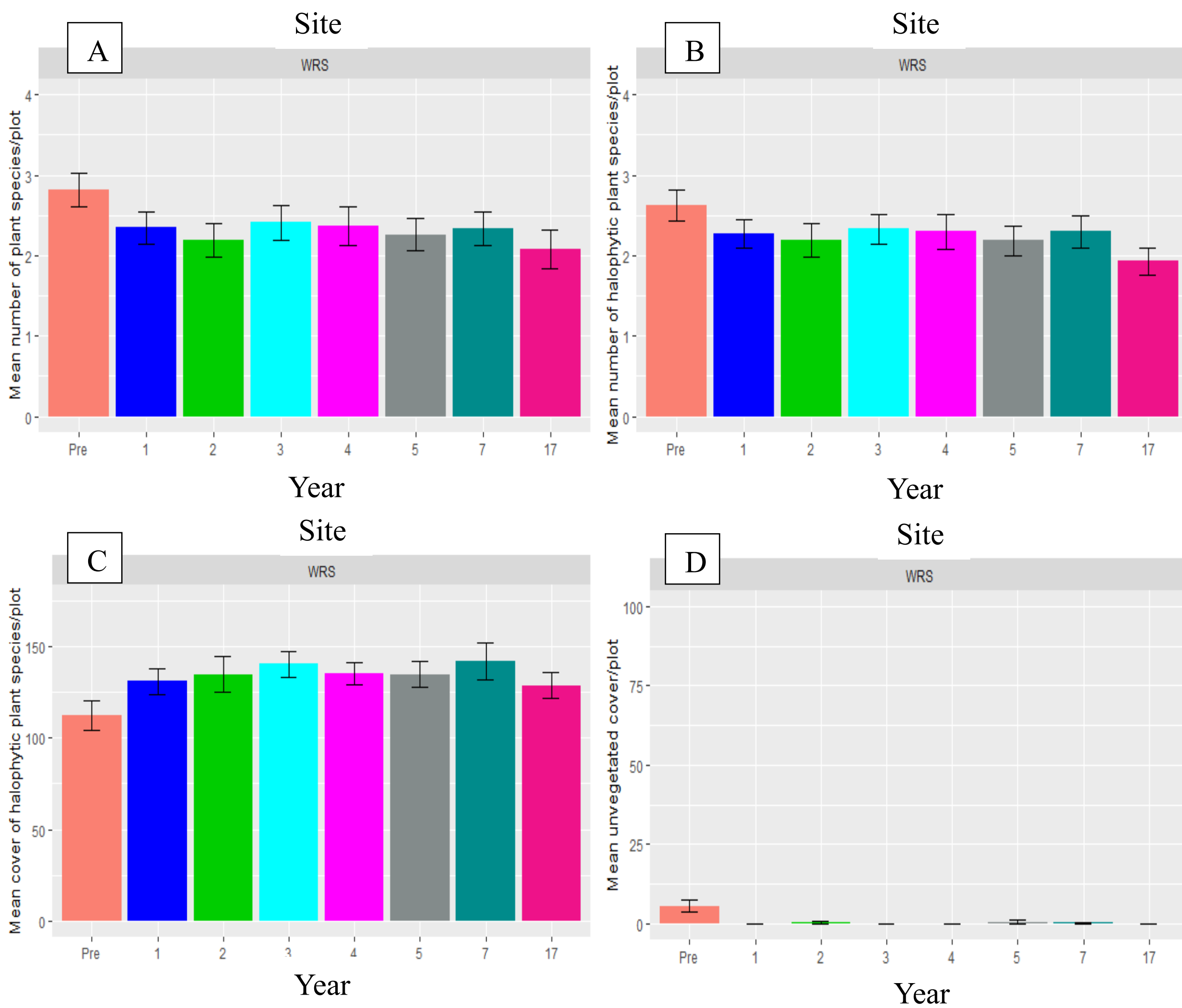


Figure C-16. *Vegetation plot data summary from WRS from pre-restoration and years 1, 2, 3, 4 and 13 post-restoration showing A) mean number of plant species, B) mean number of halophytic species, C) mean cover of halophytes, and D) mean unvegetated cover.*

Appendix D– Soil and Sediment Tables

Table D-1. Sediment characteristics from cores taken at the Abrams River restoration site pre and years 1 and 3 post-restoration. Elevations are in meters above geodetic datum CGVD2013 measured during the 2021 field season by CBWES Inc.

Station	Elev	Water Content (%)			Organic Matter (%)			Bulk Density (g cm^{-3})		
a) ABR	(m)	pre	Yr 1	Yr 3	pre	Yr 1	Yr 3	pre	Yr 1	Yr 3
ABR T1S1	0.71	78.0	81.0	82.0	45.0	74.0	73.0	0.12	0.20	0.35
ABR T1S3	0.50	80.0	86.0	84.0	25.0	66.0	33.0	0.35	0.12	0.13
ABR T2S2/1	0.63	87.0	NA	87.0	60.0	NA	39.0	0.06	0.13	0.11
ABR T3S1	0.68	94.0	91.0	89.0	76.0	63.0	61.0	0.05	0.15	0.09
ABR T3S3	0.38	89.0	86.0	NA	53.0	61.0	NA	0.13	0.15	0.09
ABR T4S2	0.57	68.0	63.0	69.0	18.0	16.0	19.0	0.24	0.27	0.09
ABR T5S1	0.59	94.0	73.0	NA	73.0	34.0	NA	0.07	0.26	NA
ABR T5S2	0.49	85.0	80.0	80.0	50.0	34.0	33.0	0.15	0.14	0.22
ABR T5S3	0.51	91.0	89.0	85.0	62.0	50.0	31.0	0.12	0.11	0.14
ABR T6S2	0.37	85.0	74.0	73.0	53.0	26.0	21.0	0.13	0.17	0.19
ABR T7S2	0.08	85.0	82.0	78.0	47.0	42.0	35.0	0.15	0.17	0.17
ABR T7S4	0.61	94.0	87.0	91.0	77.0	50.0	62.0	0.09	0.18	0.11

Table D-2. Sediment characteristics from cores taken at the Abrams River reference site pre and years 1 and 3 post-restoration. Elevations are in meters above geodetic datum CGVD2013 measured during the 2021 field season by CBWES Inc.

Station	Elev	Water Content (%)			Organic Matter (%)			Bulk Density (g cm^{-3})		
a) ABR-R	(m)	pre	Yr 1	Yr 3	pre	Yr 1	Yr 3	pre	Yr 1	Yr 3
ABR-R T1S2	1.22	84.0	79.0	77.0	41.0	27.0	29.0	0.07	0.16	0.22
ABR-R T2S1	1.42	90.0	84.0	86.0	74.0	42.0	83.0	0.04	0.12	0.10
ABR-R T2S4	1.17	74.0	71.0	66.0	25.0	23.0	20.0	0.18	0.30	0.31
ABR-R T4S2	1.30	83.0	84.0	83.0	38.0	37.0	42.0	0.07	0.16	0.22
ABR-R T5S3	1.16	78.0	78.0	76.0	35.0	39.0	27.0	0.08	0.22	0.16
ABR-R T5S4	1.05	62.0	62.0	92.0	17.0	19.0	20.0	0.16	0.37	0.36

Table D-3. Sediment characteristics from cores taken at the Bass Creek reference site 1, 3, 5, 7 and 17 years post-restoration. Elevations are in meters above geodetic datum CGVD2013 measured during the 2022 field season.

Station	Elev	Water Content (%)					Organic Matter (%)					Bulk Density (g cm^{-3})				
a) BAS	(m)	Yr 1	Yr 3	Yr 5	Yr 7	Yr 17	Yr 1	Yr 3	Yr 5	Yr 7	Yr 17	Yr 1	Yr 3	Yr 5	Yr 7	Yr 17
BAS L1S1	6.15	51.1	59.3	52.0	58.0	43.4	13.4	17.7	15.1	17.4	9.0	0.55	0.47	0.56	0.37	0.52
BAS L1S2	5.67	37.6	47.5	42.3	39.6	34.4	7.7	10.3	10.4	7.6	4.8	0.92	NA	0.77	0.58	0.90
BAS L1S3	4.44	29.4	36.9	37.4	43.6	45.4	4.9	6.0	5.5	8.1	7.3	1.35	0.72	0.88	0.62	0.56
BAS L2S1	6.31	39.3	71.9	69.2	38.9	67.6	9.5	27.9	33.8	9.8	21.9	0.87	0.28	0.34	0.58	0.25
BAS L2S3	5.83	34.4	66.2	56.1	52.3	38.5	5.7	19.4	17.9	12.4	5.8	0.95	0.39	0.51	0.35	0.59
BAS L3S1	6.31	53.6	70.3	63.7	15.0	71.2	17.2	24.0	17.5	70.3	29.3	0.61	0.34	0.47	0.28	0.36
BAS L3S2	5.97	52.7	62.1	55.9	57.5	56.2	15.2	14.7	14.2	13.6	10.2	0.75	NA	0.41	0.39	0.39
BAS L3S3	4.72	49.3	46.6	44.5	45.6	42.5	10.2	9.0	7.2	8.3	8.1	0.62	0.55	0.86	0.70	0.95
BAS L4S1	6.48	27.6	52.8	52.7	57.4	59.5	7.2	28.0	18.1	21.4	21.4	1.38	0.72	0.83	0.87	0.49
BAS L4S2	4.08	41.4	46.7	46.3	44.1	41.0	9.2	7.1	7.1	7.5	6.2	0.73	NA	0.80	0.61	0.64
BAS L5S2	5.98	53.1	68.7	61.1	58.2	64.0	13.6	19.1	16.3	16.6	12.9	0.57	NA	0.54	0.38	0.50
BAS L5S3	5.98	48.9	58.2	57.1	50.7	36.0	12.5	14.3	17.2	10.9	5.7	0.59	0.45	0.46	0.36	0.87
BAS L5S4	5.00	38.6	40.6	42.2	46.5	54.8	7.6	7.7	8.3	9.0	12.9	0.77	0.67	0.89	0.57	0.52
BAS L6S1	6.14	56.2	60.8	60.7	58.7	61.2	118.8	23.2	21.8	24.2	16.2	0.48	0.37	0.49	0.40	0.43
BAS L6S2	5.96	65.7	67.3	61.8	50.8	66.1	20.8	17.1	20.0	8.7	13.5	0.36	0.28	0.42	0.34	0.39
BAS L6S3	5.31	44.6	48.0	44.7	41.7	41.2	8.0	9.9	9.0	8.4	6.9	0.65	0.62	0.78	0.66	0.82
BAS L7S2	5.96	57.1	32.1	58.7	59.2	61.5	13.0	4.3	13.9	15.2	12.2	0.50	0.36	0.48	2.05	0.32
BAS L7S3	5.25	42.0	47.0	48.0	39.7	38.5	7.7	8.9	15.4	8.1	6.3	0.70	0.50	0.83	4.71	0.83
BAS L8S2	5.87	61.8	59.7	61.2	54.7	61.7	21.2	13.9	27.6	17.1	12.0	0.56	0.41	0.46	NA	0.54
BAS L8S3	5.36	43.4	51.0	NA	44.5	44.7	8.2	10.1	NA	10.0	9.2	0.70	0.48	NA	0.56	0.69

Table D-4. Sediment characteristics from cores taken at the Belcher Street restoration site pre and years 1, 2, 3 and 4 post-restoration. Elevations are in meters above geodetic datum CGVD2013 measured during the 2021 field season by CBWES Inc.

Station	Elev	Water Content (%)					Organic Matter (%)					Bulk Density (g cm $^{-3}$)				
a) BEL	(m)	pre	Yr 1	Yr 2	Yr 3	Yr 4	pre	Yr 1	Yr 2	Yr 3	Yr 4	pre	Yr 1	Yr 2	Yr 3	Yr 4
BEL T1S2	6.38	91.0	48.0	52.0	60.0	53.0	75.0	5.0	5.0	8.0	5.0	0.07	0.54	0.51	0.49	0.42
BEL T2S1	6.41	88.0	59.0	61.0	61.0	53.0	61.0	6.0	6.0	7.0	5.0	0.14	0.53	0.54	0.61	0.58
BEL T2S4	6.43	74.0	56.0	56.0	49.0	51.0	24.0	6.0	5.0	7.0	5.0	0.44	0.66	0.63	0.60	0.70
BEL T2S5	6.43	76.0	52.0	50.0	52.0	59.0	24.0	6.0	6.0	7.0	6.0	0.64	0.60	0.95	0.59	0.62
BEL T2S6	6.43	79.0	29.0	41.0	56.0	57.0	26.0	1.0	6.0	8.0	6.0	0.73	0.68	0.82	0.46	0.73
BEL T3S2	7.02	83.0	90.0	33.0	19.0	18.0	37.0	45.0	3.0	1.0	1.0	0.23	0.14	0.65	1.24	1.59
BEL T3S4	6.30	44.0	44.0	63.0	33.0	38.0	14.0	4.0	13.0	4.0	3.0	0.74	1.08	1.08	1.29	0.51
BEL T4S3	6.57	48.0	40.0	36.0	38.0	43.0	15.0	6.0	9.0	6.0	7.0	0.95	1.04	0.23	1.09	0.13

Table D-5. Sediment characteristics from cores taken at the Cheverie Creek restoration site pre and years 1, 3, 5, 7 and 17 post-restoration. Elevations are in meters above geodetic datum CGVD2013 measured during the 2022 field season.

Station	Elev	Water Content (%)						Organic Matter (%)						Bulk Density (g cm $^{-3}$)					
a) CHV	(m)	pre	Yr 1	Yr 3	Yr 5	Yr 7	Yr 17	pre	Yr 1	Yr 3	Yr 5	Yr 7	Yr 17	pre	Yr 1	Yr 3	Yr 5	Yr 7	Yr 17
CHV L1S4	5.79	19.7	41.2	56.2	48.4	48.5	57.2	26.0	11.6	21.0	16.9	9.7	14.6	0.54	0.73	0.48	0.57	0.80	0.55
CHV L1S6	5.14	47.1	52.2	52.4	50.8	45.0	61.8	10.3	9.2	8.4	10.8	6.3	7.9	0.62	0.40	0.50	0.57	0.48	0.52
CHV L1S8	2.81	38.4	36.1	43.7	38.7	41.8	33.1	5.5	4.3	5.4	5.3	7.3	4.7	0.68	0.91	0.68	0.92	1.18	1.10
CHV L2S3	5.39	63.3	62.5	58.0	61.1	50.6	54.6	20.1	12.3	9.0	8.9	11.5	5.9	0.47	0.42	0.38	0.47	0.23	0.59
CHV L2S7	5.02	41.9	44.4	41.7	48.1	43.0	34.9	13.1	6.1	5.0	4.0	6.8	5.3	0.67	0.74	0.48	0.84	1.09	1.16
CHV L3S1	5.69	68.4	68.4	70.0	56.2	59.8	58.4	43.0	30.4	30.0	14.6	13.2	12.7	0.39	0.32	0.26	0.41	0.36	0.34
CHV L3S3	5.68	66.9	75.0	58.0	53.0	46.1	45.8	44.4	42.0	11.7	8.9	6.9	7.7	0.33	0.26	0.17	0.42	0.72	0.64
CHV L4S3	5.60	75.2	75.3	62.2	62.7	58.9	49.6	39.2	34.3	13.4	13.0	9.9	7.4	0.19	0.22	0.31	0.39	0.53	0.48

CHV L4S7	5.78	36.5	49.9	54.2	36.2	35.1	39.7	26.1	19.2	17.5	7.0	5.8	6.5	0.52	0.54	0.67	0.86	0.79	0.66
CHV L5S4	5.65	73.4	78.4	76.1	52.1	55.7	45.7	47.1	34.7	24.4	8.3	8.0	7.1	0.26	0.18	0.13	0.43	0.49	0.34
CHV L5S6	2.76	38.7	40.0	50.0	36.0	81.1	34.7	6.0	4.6	7.1	4.6	1.2	4.5	1.04	0.81	0.60	0.85	1.10	0.98
CHV L6S2	5.73	79.7	83.0	66.2	63.1	54.7	64.6	74.3	48.2	20.6	17.1	29.6	13.2	0.19	0.15	0.30	0.40	0.22	0.37
CHV L6S4	5.55	79.8	80.4	69.1	60.3	49.4	58.7	63.3	41.3	18.6	12.8	7.1	10.8	0.25	0.20	0.20	0.63	0.52	0.25
CHV L6S6	5.55	60.8	65.2	67.6	53.0	44.5	49.9	24.9	15.4	16.1	8.0	6.7	7.2	0.43	0.35	0.27	0.45	0.59	0.82
CHV L6S8	5.68	53.9	46.6	44.5	37.1	36.5	37.6	26.9	12.2	8.9	7.2	5.5	5.6	0.54	0.66	0.48	0.82	0.85	0.83
CHV L7S10	5.72	63.3	58.8	47.0	40.2	40.1	44.6	38.6	23.4	9.4	7.4	6.9	5.8	0.34	0.35	0.45	0.66	0.69	0.85
CHV L7S12	5.76	56.9	49.5	56.9	45.1	43.2	44.8	34.3	15.6	14.7	8.7	7.5	7.2	0.43	0.67	0.65	0.61	0.55	0.74
CHV L7S14	3.77	41.1	47.5	43.5	40.3	40.9	40.8	7.8	7.1	6.5	5.5	6.7	5.1	0.84	0.62	0.84	0.92	0.91	0.81
CHV L8S7	5.53	77.4	83.2	68.4	60.2	72.5	44.8	52.1	48.1	18.7	12.2	18.7	10.7	0.23	0.16	0.20	0.44	0.24	0.37
CHV L8S11	5.51	41.4	71.2	49.9	39.2	39.7	37.0	13.2	20.3	10.7	7.5	6.8	6.0	0.65	0.28	0.54	0.93	0.96	0.89
CHV L8S13	5.62	60.8	60.9	55.0	38.6	45.4	52.2	32.5	22.8	14.1	10.4	6.1	8.8	0.36	0.39	0.44	0.6	0.90	0.70

Table D-6. Sediment characteristics from cores taken at the Cogmagun restoration site pre and years 1, 3, 5 and 13 post-restoration. Elevations are in meters above geodetic datum CGVD2013 measured during the 2022 field season.

Station	Elev	Water Content (%)					Organic Matter (%)					Bulk Density (g cm^{-3})				
a) COG	(m)	pre	Yr 1	Yr 3	Yr 5	Yr 13	pre	Yr 1	Yr 3	Yr 5	Yr 13	pre	Yr 1	Yr 3	Yr 5	Yr 13
COG L1S1	6.95	63.1	73.2	76.4	69.1	77.3	-4.2	36.4	43.7	29.1	35.1	0.22	0.34	0.31	0.30	0.20
COG L1S4	6.06	81.7	31.8	29.4	39.2	42.1	38.9	7.3	5.0	6.2	6.3	0.33	0.97	0.46	0.85	0.84
COG L2S2	6.23	76.3	50.0	49.2	45.9	43.4	87.8	9.7	7.7	7.1	6.2	0.15	0.55	0.46	0.74	0.82
COG L3S2	6.21	85.2	63.0	39.7	39.4	52.4	45.6	13.3	6.4	4.5	7.4	0.25	0.41	0.58	0.69	0.48
COG L3S4	6.19	86.6	39.5	37.2	45.8	54.0	49.2	13.4	5.7	8.1	9.4	0.23	0.66	0.53	0.48	0.70
COG L4S4	6.28	66.6	38.3	38.7	50.1	44.8	36.9	9.5	6.0	9.9	6.8	0.67	0.81	0.54	0.62	1.02
COG L5S2	6.21	93.0	76.8	41.0	77.5	55.6	122.3	30.7	7.2	26.9	8.2	0.04	0.22	0.59	0.52	0.55
COG L5S4	6.23	83.0	52.1	38.8	47.9	48.3	60.3	12.1	7.1	8.8	7.6	0.31	0.51	0.51	0.47	0.78

Table D-7. Sediment characteristics from cores taken at the Cogmagun reference site pre and years 1, 3, 5 and 13 post-restoration. Elevations are in meters above geodetic datum CGVD2013 measured during the 2022 field season.

Station	Elev	Water Content (%)					Organic Matter (%)					Bulk Density (g cm $^{-3}$)				
a) COR	(m)	pre	Yr 1	Yr 3	Yr 5	Yr 13	pre	Yr 1	Yr 3	Yr 5	Yr 13	pre	Yr 1	Yr 3	Yr 5	Yr 13
COR L1S4	6.62	43.8	32.8	24.5	36.6	40.7	12.8	8.9	5.5	8.7	7.9	0.78	1.02	0.77	0.76	0.96
COR L2S1	6.62	72.0	71.0	60.4	60.0	67.0	35.4	32.8	15.4	16.6	15.2	0.41	0.22	0.23	0.38	0.31
COR L2S3	6.52	55.4	54.4	52.6	58.0	54.3	13.5	11.3	9.2	11.4	8.1	0.61	0.71	0.42	0.39	0.55
COR L3S2	6.56	30.9	32.6	NA	32.7	63.1	9.8	2.1	NA	7.2	11.0	0.91	1.14	NA	0.86	0.40
COR L3S4	6.60	15.9	58.7	59.4	62.0	49.1	NA	16.4	9.9	13.4	8.2	0.33	0.49	0.31	0.32	0.80
COR L4S1	6.61	70.0	56.8	56.5	64.9	64.5	25.2	16.2	11.6	17.9	13.3	0.31	0.34	0.24	0.31	0.37
COR L4S3	6.65	45.9	46.5	NA	53.0	42.3	14.1	115.0	NA	10.9	6.4	0.65	0.85	NA	0.57	0.64
COR L5S2	5.99	5.6	49.8	50.2	56.1	50.2	98.9	11.3	9.2	11.2	9.4	0.61	0.69	0.47	0.46	0.74

Table D-8. Sediment characteristics from cores taken at the Converse restoration site pre and years 1, 2 and 3 post-restoration. Elevations are in meters above geodetic datum CGVD2013 measured during the 2021 field season by CBWES Inc.

Station	Elev	Water Content (%)				Organic Matter (%)				Bulk Density (g cm $^{-3}$)			
a) CON	(m)	pre	Yr 1	Yr 2	Yr 3	pre	Yr 1	Yr 2	Yr 3	pre	Yr 1	Yr 2	Yr 3
CON T1S2	5.57	80.0	66.0	36.0	44.0	77.0	18.0	7.0	6.0	0.41	0.40	0.83	0.63
CON T1S4	5.80	71.0	39.0	30.0	33.0	87.0	6.0	5.0	5.0	0.49	1.03	1.04	1.21
CON T1S6	5.64	82.0	45.0	31.0	39.0	85.0	6.0	6.0	6.0	0.43	0.67	1.16	0.88
CON T2S1	5.51	39.0	42.0	32.0	36.0	16.0	12.0	6.0	6.0	0.64	0.77	1.04	1.22
CON T2S4	5.91	55.0	38.0	25.0	31.0	31.0	8.0	6.0	5.0	0.84	0.66	0.82	1.39
CON T2S6	6.26	59.0	44.0	16.0	30.0	45.0	20.0	5.0	7.0	0.68	0.65	0.89	0.81
CON T2S7	6.06	51.0	36.0	19.0	25.0	18.0	12.0	4.0	4.0	0.69	0.96	1.10	0.98
CON T3S1	NA	69.0	NA	2.0	16.0	41.0	NA	3.0	3.0	0.37	NA	1.19	1.33
CON T3S4	5.21	77.0	37.0	19.0	42.0	82.0	4.0	3.0	5.0	0.28	1.13	0.98	0.75

Table D-9. Sediment characteristics from cores taken at the Lawrencetown reference site pre and years 1, 3, 5 and 13 post-restoration. Elevations are in meters above geodetic datum CGVD2013 measured during the 2022 field season.

Station	Elev	Water Content (%)					Organic Matter (%)					Bulk Density (g cm $^{-3}$)				
a) LTR	(m)	pre	Yr 1	Yr 3	Yr 5	Yr 15	pre	Yr 1	Yr 3	Yr 5	Yr 15	pre	Yr 1	Yr 3	Yr 5	Yr 15
LTR L1S1	0.11	85.2	86.5	76.1	81.4	NA	65.2	58.5	36.2	49.7	NA	0.10	0.11	0.11	0.23	NA
LTR L1S3	-0.04	80.9	60.2	86.6	91.1	79.5	51.5	92.4	58.6	35.9	40.7	0.15	0.08	0.10	0.10	0.19
LTR L1S4	0.18	65.9	74.9	74.5	82.4	67.3	19.8	64.9	40.5	62.3	23.5	0.39	0.08	0.11	0.08	0.34
LTR L3S1	0.19	83.0	73.2	87.3	83.1	90.5	62.8	83.1	61.4	54.4	57.6	0.16	0.10	0.10	0.11	0.12
LTR L3S3	0.03	86.7	77.5	85.8	90.0	86.1	59.1	78.3	56.9	43.8	51.3	0.13	0.08	0.10	0.11	0.15
LTR L3S6	0.06	70.2	59.1	70.0	72.6	57.8	20.7	42.2	35.7	32.0	11.1	0.28	0.24	0.20	0.25	0.44

Table D-10. Sediment characteristics from cores taken at the Mavillette restoration (a) and reference (b) sites in the third year post-restoration. Elevations are in meters above geodetic datum CGVD2013 measured during the 2021 field season by CBWES Inc. There is no earlier data.

Station a) MAV	Elev (m)	Water Content (%)	Organic Matter (%)	Bulk Density (g cm $^{-3}$)
MAV 07	1.53	17.0	1.6	0.11
MAV 12	1.42	24.0	2.9	0.11
MAV 24	1.72	20.0	3.1	0.12
MAV 25	1.48	20.0	2.3	0.14
MAV 27	1.41	15.0	1.7	0.15
MAV 28	1.44	23.0	2.7	0.20
MAV 35	1.40	17.0	1.5	0.16
MAV 1253	1.49	10.0	0.8	0.17

Station b) MAV-R	Elev (m)	Water Content (%)	Organic Matter (%)	Bulk Density (g cm $^{-3}$)
MAV-R 203	1.34	16.0	1.0	0.19
MAV-R 223	1.63	27.0	3.1	0.20
MAV-R 229	1.78	18.0	1.6	0.23
MAV-R 1156	1.67	16.0	1.8	0.18

Table D-11. Sediment characteristics from cores taken at the St. Croix South-East restoration site pre and years 1, 3, 5 and 13 post-restoration. Elevations are in meters above geodetic datum CGVD2013 measured during the 2022 field season.

Station	Elev	Water Content (%)					Organic Matter (%)					Bulk Density (g cm $^{-3}$)				
a) SCP	(m)	pre	Yr 1	Yr 3	Yr 5	Yr 13	pre	Yr 1	Yr 3	Yr 5	Yr 13	pre	Yr 1	Yr 3	Yr 5	Yr 13
SCP L1S2	6.68	30.4	40.2	29.9	40.2	37.2	5.2	6.4	5.0	7.3	5.4	NA	0.9	1.0	0.8	0.9
SCP L1S4	6.75	38.6	40.9	34.7	44.4	32.0	7.5	3.5	4.8	5.3	3.5	NA	0.8	0.9	0.8	0.8
SCP L1S6	6.70	65.3	38.5	28.2	37.0	42.2	21.0	4.4	3.8	5.1	7.5	NA	0.6	0.9	0.8	0.9
SCP L3S2	6.75	37.3	38.6	30.9	34.5	34.3	8.6	5.1	4.3	5.2	5.7	NA	0.9	0.9	0.9	1.1
SCP L3S3	6.93	24.8	29.8	26.1	32.4	29.1	4.9	3.8	4.1	5.4	4.2	NA	1.0	0.8	1.0	1.0
SCP L3S5	6.57	44.0	53.4	39.9	42.6	37.7	9.7	12.7	10.6	8.1	5.9	NA	1.0	0.6	0.7	1.0

Table D-12. Sediment characteristics from cores taken at the St. Croix West restoration site pre and years 1, 3, 5 and 13 post-restoration. Elevations are in meters above geodetic datum CGVD2013 measured during the 2022 field season.

Station	Elev	Water Content (%)					Organic Matter (%)					Bulk Density (g cm $^{-3}$)				
a) SCW	(m)	pre	Yr 1	Yr 3	Yr 5	Yr 13	pre	Yr 1	Yr 3	Yr 5	Yr 13	pre	Yr 1	Yr 3	Yr 5	Yr 13
SCW L1S1	7.01	29.9	47.9	30.9	37.7	30.5	23.0	4.9	4.4	4.5	3.7	0.80	1.23	0.74	0.82	1.19
SCW L1S2	NA	43.0	63.6	37.0	47.1	41.7	33.0	6.3	6.7	6.8	7.6	0.65	1.26	1.01	0.62	NA
SCW L2S1	6.85	26.0	53.5	42.0	43.8	30.3	16.9	5.8	6.3	5.6	4.6	0.93	1.23	0.83	0.78	1.09
SCW L2S2	6.96	36.8	44.0	29.9	40.4	35.7	23.6	5.1	5.9	7.0	6.8	0.75	1.25	1.06	0.85	1.07
SCW L2S3	6.71	42.4	52.6	42.0	50.7	38.0	25.0	6.9	5.6	6.2	6.5	0.79	0.55	0.66	0.65	0.84
SCW L4S1	6.49	29.0	44.7	39.8	43.8	26.7	26.8	5.2	4.1	5.4	2.9	0.85	0.98	0.61	0.66	1.11
SCW L4S2	6.73	31.4	31.0	40.5	37.9	33.1	18.3	4.2	7.7	5.3	5.6	0.81	1.00	0.83	0.88	1.03
SCW L4S4	5.83	37.6	40.1	38.0	46.1	34.8	27.0	4.7	5.0	5.2	3.3	0.69	1.04	0.88	0.68	1.18
SCW L4S6	6.62	42.8	33.2	33.6	44.2	53.3	25.0	3.1	4.7	5.8	8.4	0.68	0.87	0.77	0.68	0.52
SCW L5S1	6.30	53.4	44.8	43.0	34.4	26.8	22.1	4.5	6.8	3.6	3.0	0.55	0.72	0.78	0.85	1.09
SCW L5S4	6.74	28.9	50.8	38.9	NA	32.5	12.8	5.3	5.6	NA	4.3	0.92	1.27	0.76	NA	1.08
SCW L5S8	6.84	43.8	48.7	33.0	NA	35.3	38.9	5.3	4.7	NA	6.7	0.59	1.09	0.85	NA	0.92

Table D-13. Sediment characteristics from cores taken at the Three Fathom Harbour restoration site pre and years 1, 3, 5, and 6 post-restoration. Elevations are in meters above geodetic datum CGVD2013 measured during the 2022 field season and sediment cores were taken in 2021 by CBWES Inc.

Station	Elev	Water Content (%)					Organic Matter (%)					Bulk Density (g cm^{-3})				
a) TFH	(m)	pre	Yr 1	Yr 3	Yr 5	Yr 6	pre	Yr 1	Yr 3	Yr 5	Yr 6	pre	Yr 1	Yr 3	Yr 5	Yr 6
TFH T1S2	0.47	NA	NA	72.8	90.9	87.2	NA	NA	37.3	83.9	63.6	NA	NA	0.17	0.06	0.13
TFH T2S2	NA	90.9	93.4	75.6	NA	81.0	79.9	87.5	34.3	NA	29.5	0.05	0.08	0.21	NA	0.19
TFH T2S5	NA	84.6	64.8	50.4	NA	79.8	45.1	26.4	14.1	NA	39.1	0.14	0.34	0.53	NA	0.66
TFH T3S2	0.53	88.1	88.4	70.5	NA	85.8	71.5	60.7	33.8	NA	43.7	0.16	0.08	0.20	NA	0.19
TFH T3S3	NA	88.9	79.3	82.1	NA	72.2	64.6	51.9	35.4	NA	27.5	0.11	0.16	0.25	NA	0.26
TFH T3S4	NA	89.8	83.0	81.1	NA	77.7	61.2	48.3	41.6	NA	30.1	0.13	0.09	0.22	NA	0.23
TFH T3S5	0.64	85.7	86.2	74.9	78.9	75.2	81.3	83.0	51.1	42.6	69.4	0.16	0.12	0.17	0.24	0.19
TFH T5S2	0.61	94.9	93.7	92.1	94.8	NA	85.3	97.5	76.2	86.4	NA	0.05	0.09	0.04	0.09	NA
TFH T5S3	0.58	93.8	92.6	93.2	90.2	92.0	86.1	85.7	78.6	86.6	73.9	0.07	0.10	0.04	0.07	0.09

Table D-14. Sediment characteristics from cores taken at the Walton River restoration site pre and years 2, 3, 5, 7 and 17 post-restoration. Elevations are in meters above geodetic datum CGVD2013 measured during the 2022 field season.

Station	Elev	Water Content (%)					Organic Matter (%)						Bulk Density (g cm^{-3})				
a) WS	(m)	Yr 2	Yr 3	Yr 5	Yr 7	Yr 17	pre	Yr 2	Yr 3	Yr 5	Yr 7	Yr 17	Yr 2	Yr 3	Yr 5	Yr 7	Yr 17
WS L1S2	5.54	51.2	58.4	60.0	51.7	57.8	9.5	8.2	10.8	13.3	10.7	10.0	0.66	0.42	0.63	0.60	0.54
WS L1S3	5.67	46.6	51.5	43.9	52.0	51.1	9.6	7.2	10.6	10.3	9.8	9.2	0.75	0.61	0.81	0.51	0.35
WS L1S4	5.61	62.6	60.2	47.6	61.6	53.7	10.5	10.1	11.3	7.3	10.0	7.7	0.48	0.26	0.70	0.51	0.60
WS L5S2	5.36	65.1	57.0	52.0	53.8	62.3	7.8	10.5	10.4	7.2	8.5	8.3	0.45	0.36	0.72	0.41	0.35
WS L5S3	5.59	50.1	55.1	50.7	57.7	60.0	9.9	8.0	9.5	9.9	11.4	8.7	0.67	0.47	0.79	0.36	0.48
WS L5S5	5.55	54.1	51.0	47.1	61.0	64.4	25.8	8.7	10.2	9.2	10.6	9.3	0.58	0.55	0.75	0.30	0.27

Table D-15. Sediment characteristics from cores taken at the Walton River reference site pre and years 2, 3, 5, 7 and 17 post-restoration. Elevations are in meters above geodetic datum CGVD2013 measured during the 2022 field season.

Station	Elev	Water Content (%)					Organic Matter (%)						Bulk Density (g cm $^{-3}$)				
a) WRS	(m)	Yr 2	Yr 3	Yr 5	Yr 7	Yr 17	pre	Yr 2	Yr 3	Yr 5	Yr 7	Yr 17	Yr 2	Yr 3	Yr 5	Yr 7	Yr 17
WRS L1S1	5.99	64.0	62.7	63.1	58.6	63.7	NA	15.3	15.5	21.7	17.1	5.1	0.48	0.30	0.44	0.32	0.81
WRS L1S2	5.58	56.1	62.3	57.9	64.8	60.3	9.1	8.0	12.0	9.5	15.0	14.7	0.65	0.27	0.51	0.44	0.31
WRS L1S3	5.70	47.4	61.9	54.2	57.7	58.6	NA	6.5	10.0	11.9	9.1	9.0	0.72	0.28	0.69	0.37	0.51
WRS L3S2	6.07	69.9	69.6	57.5	55.9	68.0	12.1	19.3	21.4	12.2	12.5	6.6	0.38	0.22	0.38	0.43	0.58
WRS L3S5	5.81	59.4	56.6	55.7	57.2	49.7	9.4	11.3	10.9	9.6	17.8	16.6	0.58	0.39	0.59	0.35	0.41
WRS L3S8	5.58	55.0	49.0	41.5	53.5	37.8	6.7	9.9	7.0	7.3	14.9	9.4	0.57	0.37	0.84	0.58	0.51

Appendix E – Sediment Core Photos

BAS L5S2
split photo
not available

Bass Creek sediment core and split core sections for samples collected in spring 2022.


K.Williams, MSc
CHV L257
April 19 / 2022
Sed. core split
K.Williams, MSc
CHV L257
April 19 / 2022
Sed. core split
Kayla Williams MSc
CHV L331
April 19, 2022
Sed. Core
Kayla Williams MSc
CHV L331
April 19, 2022
Sed. core
Kayla Williams, MSc.
CHV L353
April 19 / 2022
Sed. core
Kayla Williams, MSc.
CHV L353
April 19 / 2022
Sed. core
Kayla Williams, MSc
CHV L453
April 19 / 2022
Sed. core
Kayla Williams, MSc
CHV L453
April 19 / 2022
Sed. core
Kayla Williams, MSc
CHV L457
April 19 / 2022
Sed core
Kayla Williams, MSc
CHV L457
April 19 / 2022
Sed core
Kayla Williams, MSc
CHV L534
April 19 / 2022
Sed. core
Kayla Williams, MSc
CHV L534
April 19 / 2022
Sed. core
Kayla Williams, MSc
CHV L536
April 19 / 2022
Sed. core
Kayla Williams, MSc
CHV L536
April 19 / 2022
Sed. core
Kayla Williams, MSc
CHV L652
April 19 / 2022
Sed. core
Kayla Williams, MSc
CHV L652
April 19 / 2022
Sed. core


Kayla Williams, MSC
CHV L654
April 19/2022
Sed. core
Kayla Williams, MSC
CHV L654
April 19/2022
Sed. core
Kayla Williams, MSC
CHV L650
April 19/2022
Sed. core
Kayla Williams, MSC
CHV L650
April 19/2022
Sed. core
K. Williams, MSC
CHV L638
April 18/2022
Sed. core
K. Williams, MSC
CHV L638
April 18/2022
Sed. core
K. Williams, MSC
CHV LT510
April 18/2022
Sed. core
K. Williams, MSC
CHV LT510
April 18/2022
Sed. core
K. Williams, MSC
CHV LT512
April 18/2022
Sed. core
K. Williams, MSC
CHV LT512
April 18/2022
Sed. core
K. Williams, MSC
CHV LT514
April 18/2022
Sed. core
K. Williams, MSC
CHV LT514
April 18/2022
Sed. core
K. Williams, MSC
CHV LB57
April 18/2022
Sed. core
K. Williams, MSC
CHV LB57
April 18/2022
Sed. core
K. Williams, MSC
CHV LB510
April 18/2022
Sed. core split
K. Williams, MSC
CHV LB510
April 18/2022
Sed. core split

Cheverie Creek sediment core and split core sections for samples collected in spring 2022.

COG L1S1
split photo
not available

Cogmagun Restoration sediment core and split core sections for samples collected in spring 2022.

Cogmagun Reference sediment core and split core sections for samples collected in spring 2022.

LTR L1S2 core lost	LTR L1S2 split photo not available

Lawrencetown Reference sediment core and split core sections for samples collected in spring 2022.

St. Croix South-East Restoration sediment core and split core sections for samples collected in spring 2022.

SCW L2S2
split photo
not available

SCW L2S3
split photo
not available

St. Croix West Restoration sediment core and split core sections for samples collected in spring 2022.

Walton River Restoration sediment core and split core sections for samples collected in spring 2022.

Walton River Reference sediment core and split core sections for samples collected in spring 2022.

Appendix F - Random Effects, ANOVA and Post-hoc Test Outputs

Table F-1. Outputs of the statistical analyses performed on the elevation data at the restoration sites: A) The random effects, B) Analysis of Variance Table, and C) A post-hoc comparison test exploring elevation pre-restoration and in Years 1, 3, 5, and 10+ post-restoration. Means with shared group numbers are not considered significantly different (alpha = 0.05).

A) Random Effects

Groups	Name	Variance	St. Dev.
plot:site	Intercept	0.14183	0.3766
site	Intercept	0.25152	0.5015
Residual		0.08302	0.2881

1063 observations; groups: plot:site = 269; site = 10

B) Analysis of Variance Table

Type	Response		npar	Sum Sq	Mean Sq	F value
		sms	1	17.9689	17.9689	216.434
Restoration	Elevation	year	4	7.9872	1.9968	24.052
		sms:year	3	5.5715	1.8572	22.369

C) Post-hoc Comparison Test

Type	Response	sms	year	lsmean	SE	df	lower CL	upper CL	group
		org	Pre	0.78	0.33	12.6	0.06	1.49	a
		org	1	0.87	0.33	12.5	0.16	1.59	a
		org	3	0.89	0.33	12.5	0.18	1.60	a
		org	5	1.55	0.34	13.9	0.83	2.27	b
Restoration	Elevation	min	3	5.98	0.22	12.7	5.51	6.45	c
		min	1	5.99	0.22	12.7	5.52	6.46	c
		min	Pre	6.03	0.22	12.7	5.56	6.50	c
		min	5	6.08	0.22	12.8	5.61	6.55	c
		min	10+	6.24	0.22	12.8	5.77	6.71	d

Table F-2. Outputs of the statistical analyses performed on the organic matter content data at the restoration sites: A) The random effects, B) Analysis of Variance Table, and C) A post-hoc comparison test exploring organic matter content pre-restoration and in Years 1, 3, 5, and 10+ post-restoration. Means with shared group numbers are not considered significantly different (alpha = 0.05).

A) Random Effects

Groups	Name	Variance	St. Dev.
plot:site	Intercept	42.01	6.482
site	Intercept	116.72	10.804
Residual		152.25	12.339

388 observations; groups: plot:site = 108; site = 10

B) Analysis of Variance Table

Type	Response		npar	Sum Sq	Mean Sq	F value
Restoration	Organic Matter	sms	1	1417.20	1417.20	9.31
		year	4	30204.30	7551.10	49.60
		sms:year	3	2864.60	954.40	6.27

C) Post-hoc Comparison Test

Type	Response	sms	year	lsmean	SE	df	lower CL	upper CL	group
Restoration	Organic Matter	min	10+	7.51	5.08	17.0	-3.21	18.2	a
		min	3	8.47	4.98	15.5	-2.12	19.1	a
		min	5	8.57	5.10	17.2	-2.17	19.3	a
		min	1	12.54	4.99	15.5	1.94	23.1	a b
		org	3	29.94	7.63	15.3	13.70	46.2	a c
		min	Pre	32.17	4.99	15.5	21.57	42.8	c d
		org	1	45.50	8.00	18.8	28.75	62.3	b d
		org	Pre	50.55	7.97	18.5	33.83	67.3	d
		org	5	53.35	10.14	53.9	33.02	73.7	c d

Table F-3. Outputs of the statistical analyses performed on the bulk density data at the restoration sites: A) The random effects, B) Analysis of Variance Table, and C) A post-hoc comparison test exploring bulk density pre-restoration and in Years 1, 3, 5, and 10+ post-restoration. Means with shared group numbers are not considered significantly different (alpha = 0.05).

A) Random Effects

Groups	Name	Variance	St. Dev.
plot:site	Intercept	0.000362	0.01903
site	Intercept	0.0006563	0.02562
Residual		0.0018827	0.04339

378 observations; groups: plot:site = 108; site = 10

B) Analysis of Variance Table

Type	Response		npar	Sum Sq	Mean Sq	F value
Restoration	Bulk Density	sms	1	0.05	0.05	24.04
		year	4	0.13	0.03	17.21
		sms:year	3	0.24	0.08	43.36

C) Post-hoc Comparison Test

Type	Response	sms	year	lsmean	SE	df	lower CL	upper CL	group
Restoration	Bulk Density	org	5	-1.25	0.0300	98.7	-1.31	-1.188	a
		org	Pre	-1.17	0.0207	22.2	-1.22	-1.130	a b
		org	3	-1.15	0.0190	16.5	-1.19	-1.113	b
		min	Pre	-1.06	0.0128	18.9	-1.09	-1.034	c
		min	3	-1.04	0.0125	16.8	-1.07	-1.013	c d
		min	1	-1.04	0.0125	16.9	-1.06	-1.012	c d
		min	5	-1.03	0.0130	20.4	-1.05	-0.998	d
		min	10+	-1.02	0.0130	20.0	-1.05	-0.996	d
		org	1	-1.02	0.0207	22.2	-1.06	-0.978	c d

Table F-4. Outputs of the statistical analyses performed on the *S. alterniflorus* abundance data at the restoration sites: A) The random effects, B) Analysis of Variance Table, and C) A post-hoc comparison test exploring abundances of *S. alterniflorus* pre-restoration and in Years 1, 3, 5, and 10+ post-restoration. Means with shared group numbers are not considered significantly different (alpha = 0.05).

A) Random Effects

Groups	Name	Variance	St. Dev.
plot:site	Intercept	31.24	5.59
site	Intercept	14.3	3.782
Residual		38.52	6.207

1094 observations; groups: plot:site = 270; site = 10

B) Analysis of Variance Table

Type	Response		npar	Sum Sq	Mean Sq	F value
Restoration	*S.alterniflorus*	sms	1	22.10	22.09	0.57
		year	4	5648.40	1412.10	36.66
		sms: year	3	330.60	110.21	2.86

C) Post-hoc Comparison Test

Type	Response	sms	year	lsmean	SE	df	lower CL	upper CL	group
Restoration	*S.alterniflorus*	min	Pre	0.69	1.75	14.5	-3.05	4.43	a b
		min	1	2.05	1.75	14.3	-1.69	5.78	a b
		org	Pre	4.02	2.63	13.7	-1.63	9.67	a c d
		min	10+	5.38	1.78	15.6	1.60	9.15	c e
		org	1	5.72	2.63	13.6	0.07	11.36	a b c d e f
		min	3	5.83	1.75	14.3	2.10	9.57	c d e f

		org	5	6.80	2.90	21.8	0.78	12.81	a b c d e f
		min	5	7.88	1.77	15.4	4.11	11.65	d f
		org	3	8.12	2.63	13.6	2.47	13.77	b e f

Table F-5. Outputs of the statistical analyses performed on the *S. pumilus* abundance data at the restoration sites: A) The random effects, B) Analysis of Variance Table, and C) A post-hoc comparison test exploring abundances of *S. pumilus* pre-restoration and in Years 1, 3, 5, and 10+ post-restoration. Means with shared group numbers are not considered significantly different (alpha = 0.05).

A) Random Effects

Groups	Name	Variance	St. Dev.
plot:site	Intercept	30.34	5.508
site	Intercept	14.85	3.854
Residual		34.91	5.909

1094 observations; groups: plot:site = 270; site = 10

B) Analysis of Variance Table

Type	Response		npar	Sum Sq	Mean Sq	F value
		sms	1	3.30	3.30	0.09
Restoration	*S.pumilus*	year	4	4441.20	1110.29	31.80
		sms:year	3	529.70	176.57	5.06

C) Post-hoc Comparison Test

Type	Response	sms	year	lsmean	SE	df	lower CL	upper CL	group
		min	Pre	1.34	1.76	14.0	-2.44	5.12	a
		min	1	2.07	1.76	13.8	-1.70	5.85	a
		min	3	2.74	1.76	13.8	-1.04	6.51	a b
		org	3	3.19	2.65	13.2	-2.52	8.90	a b c
Restoration	*S.pumilus*	org	1	3.84	2.65	13.2	-1.87	9.55	a b c
		org	5	4.09	2.89	20.1	-1.94	10.13	a b c
		min	5	4.42	1.78	14.8	0.62	8.23	b
		org	Pre	5.62	2.65	13.3	-0.10	11.33	a b c
		min	10+	8.75	1.79	14.9	4.94	12.55	c

Table F-6. Outputs of the statistical analyses performed on the *S. michauxianus* abundance data at the restoration sites: A) The random effects, B) Analysis of Variance Table, and C) A post-hoc comparison test exploring abundances of *S. michauxianus* pre-restoration and in Years 1, 3, 5, and 10+ post-restoration. Means with shared group numbers are not considered significantly different (alpha = 0.05).

A) Random Effects

Groups	Name	Variance	St. Dev.
plot:site	Intercept	10.732	3.276
site	Intercept	4.505	2.123
Residual		16.635	4.079

1094 observations; groups: plot:site = 270; site = 10

B) Analysis of Variance Table

Type	Response		npar	Sum Sq	Mean Sq	F value
Restoration	*S.michauxianus*	sms	1	3.55	3.55	0.21
		year	4	707.47	176.87	10.63
		sms:year	3	579.96	193.32	11.62

C) Post-hoc Comparison Test

Type	Response	sms	year	lsmean	SE	df	lower CL	upper CL	group
Restoration	*S.michauxianus*	org	3	0.739	1.50	14.2	-2.48	3.95	a b c
		min	Pre	1.196	1.00	15.3	-0.94	3.33	a d
		org	1	1.660	1.50	14.2	-1.55	4.87	a b c
		min	1	1.818	1.00	15.1	-0.31	3.95	a b d e
		org	Pre	2.072	1.50	14.4	-1.15	5.29	a b c
		min	10+	2.842	1.02	16.9	0.68	5.00	b c e f
		min	3	3.686	1.00	15.1	1.56	5.82	c f
		min	5	3.839	1.02	16.6	1.68	5.99	c f
		org	5	5.885	1.70	25.9	2.38	9.39	d e f

Table F-7. Outputs of the statistical analyses performed on the elevation data at the reference sites: A) The random effects, B) Analysis of Variance Table, and C) A post-hoc comparison test exploring elevation pre-restoration and in Years 1, 3, 5, and 10+ post-restoration. Means with shared group numbers are not considered significantly different (alpha = 0.05).

A) Random Effects

Groups	Name	Variance	St. Dev.
plot:site	Intercept	10.732	3.276
site	Intercept	4.505	2.123
Residual		16.635	4.079

651 observations; groups: plot:site = 155; site = 6

B) Analysis of Variance Table

Type	Response		npar	Sum Sq	Mean Sq	F value
Reference	Elevation	sms	1	3.06	3.06	75.10
		year	4	3.37	0.84	20.71
		sms:year	4	0.77	0.19	4.71

C) Post-hoc Comparison Test

Type	Response	sms	year	lsmean	SE	df	lower CL	upper CL	group
Reference	Elevation	org	5	1.02	0.456	9.23	-0.008	2.05	a
		org	Pre	1.07	0.454	9.03	0.041	2.09	a
		org	1	1.13	0.454	9.03	0.101	2.15	a
		org	3	1.13	0.454	9.03	0.106	2.16	a
		org	10+	1.16	0.456	9.27	0.132	2.19	a
		min	1	5.57	0.454	9.04	4.547	6.60	b
		min	Pre	5.59	0.454	9.05	4.566	6.62	b
		min	3	5.59	0.454	9.04	4.567	6.62	b
		min	5	5.63	0.454	9.04	4.602	6.66	b
		min	10+	5.84	0.454	9.04	4.817	6.87	c

Table F-8. Outputs of the statistical analyses performed on the organic matter content data at the reference sites: A) The random effects, B) Analysis of Variance Table, and C) A post-hoc comparison test exploring organic matter content pre-restoration and in Years 1, 3, 5, and 10+ post-restoration. Means with shared group numbers are not considered significantly different (alpha = 0.05).

A) Random Effects

Groups	Name	Variance	St. Dev.
plot:site	Intercept	0.1148	0.3388
site	Intercept	1.0063	1.0032
Residual		0.1196	0.3459

195 observations; groups: plot:site = 52; site = 6

B) Analysis of Variance Table

Type	Response		npar	Sum Sq	Mean Sq	F value
Reference	Organic Matter	sms	1	0.01	0.01	0.06
		year	4	2.28	0.57	4.77
		sms:year	3	1.48	0.37	3.10

C) Post-hoc Comparison Test

Type	Response	sms	year	lsmean	SE	df	lower CL	upper CL	group
Reference	Organic Matter	min	10+	2.24	0.724	9.4	0.613	3.87	a
		org	10+	2.27	0.749	11.0	0.628	3.92	a b
		min	1	2.34	0.724	9.4	0.715	3.97	a
		min	3	2.43	0.725	9.4	0.799	405	a b
		min	5	2.52	0.724	9.4	0.891	4.15	a b

		org	5	2.57	0.744	10.6	0.929	4.22	a b
		org	Pre	2.62	0.734	9.9	0.983	4.26	a b
		org	3	2.63	0.729	9.5	0.990	4.26	a b
		org	1	2.79	0.734	9.9	1.155	4.43	a b
		min	Pre	2.81	0.730	9.8	1.177	4.44	b

Table F-9. Outputs of the statistical analyses performed on the bulk density data at the reference sites: A) The random effects, B) Analysis of Variance Table, and C) A post-hoc comparison test exploring bulk density pre-restoration and in Years 1, 3, 5, and 10+ post-restoration. Means with shared group numbers are not considered significantly different (alpha = 0.05).

A) Random Effects

Groups	Name	Variance	St. Dev.
plot:site	Intercept	0.01805	0.1343
site	Intercept	0	0
Residual		0.01609	0.1269

188 observations; groups: plot:site = 52; site = 6

B) Analysis of Variance Table

Type	Response		npar	Sum Sq	Mean Sq	F value
Reference	Bulk Density	sms	1	1.24	1.24	76.93
		year	4	0.64	0.16	9.89

C) Post-hoc Comparison Test

Type	Response	sms	year	lsmean	SE	df	lower CL	upper CL	group
Reference	Bulk Density	org	3	0.111	0.0423	12.1	0.0186	0.203	a
		org	Pre	0.186	0.0478	16.7	0.0845	0.287	a b
		org	5	0.206	0.0458	14.8	0.1085	0.304	b
		org	10+	0.208	0.0459	14.9	0.1105	0.306	b
		org	1	0.282	0.0438	12.6	0.1872	0.377	b c
		min	3	0.489	0.0376	3.1	0.3716	0.606	c d
		min	Pre	0.564	0.0439	9.0	0.4644	0.663	d e
		min	5	0.584	0.0373	2.9	0.4638	0.705	e
		min	10+	0.587	0.0372	2.9	0.4653	0.708	e
		min	1	0.660	0.0367	2.7	0.5345	0.786	e

Table F-10. Outputs of the statistical analyses performed on the *S. alterniflorus* abundance data at the reference sites: A) The random effects, B) Analysis of Variance Table, and C) A post-hoc comparison test exploring abundances of *S. alterniflorus* pre-restoration and in Years 1, 3, 5, and 10+ post-restoration. Means with shared group numbers are not considered significantly different (alpha = 0.05).

A) Random Effects

Groups	Name	Variance	St. Dev.
plot:site	Intercept	69.29	8.324
site	Intercept	0	0
Residual		25	5

657 observations; groups: plot:site = 155; site = 6

B) Analysis of Variance Table

Type	Response		npar	Sum Sq	Mean Sq	F value
Reference	*S.alterniflorus*	sms	1	4.57	4.57	0.18
		year	4	113.18	28.29	1.13

C) Post-hoc Comparison Test

Type	Response	sms	year	lsmean	SE	df	lower CL	upper CL	group
Reference	*S.alterniflorus*	org	10+	5.75	1.13	6.7	3.04	8.46	a
		org	5	5.94	1.13	6.6	3.23	8.65	a
		org	Pre	6.31	1.06	4.9	3.58	9.04	a
		org	3	6.49	1.05	4.9	3.76	9.22	a
		min	10+	6.56	1.1	6.0	3.87	9.25	a
		min	5	6.75	1.09	5.9	4.06	9.44	a
		org	1	7.03	1.05	4.9	4.30	9.76	a
		min	Pre	7.12	1.07	5.4	4.43	9.81	a
		min	3	7.30	1.07	5.3	4.61	10.0	a
		min	1	7.84	1.07	5.4	5.14	10.5	a

Table F-11. Outputs of the statistical analyses performed on the *S. pumilus* abundance data at the reference sites: A) The random effects, B) Analysis of Variance Table, and C) A post-hoc comparison test exploring abundances of *S. pumilus* pre-restoration and in Years 1, 3, 5, and 10+ post-restoration. Means with shared group numbers are not considered significantly different (alpha = 0.05).

A) Random Effects

Groups	Name	Variance	St. Dev.
plot:site	Intercept	76.79	8.763
site	Intercept	14.95	3.867
Residual		36.97	6.08

657 observations; groups: plot:site = 155; site = 6

B) Analysis of Variance Table

Type	Response		npar	Sum Sq	Mean Sq	F value
Reference	*S.pumilus*	sms	1	0.12	0.12	0.00

		year	4	571.80	142.95	3.87

C) Post-hoc Comparison Test

Type	Response	sms	year	lsmean	SE	df	lower CL	upper CL	group
Reference	*S.pumilus*	min	Pre	9.02	3.07	9.7	2.17	15.9	a
		min	1	9.16	3.07	9.7	2.3	16.0	a
		org	Pre	9.49	3.06	9.6	2.63	16.3	a
		org	1	9.62	3.06	9.6	2.76	16.5	a
		min	10+	10.61	3.08	10.0	3.74	17.5	a
		min	5	10.91	3.08	9.9	4.04	17.8	a
		org	10+	11.07	3.10	10.4	4.19	17.9	a
		min	3	11.21	3.06	9.7	4.350	18.1	a
		org	5	11.37	3.10	10.3	4.49	18.2	a
		org	3	11.67	3.06	9.6	4.82	18.5	a

Table F-12. Outputs of the statistical analyses performed on the *S. michauxianus* abundance data at the reference sites: A) The random effects, B) Analysis of Variance Table, and C) A post-hoc comparison test exploring abundances of *S. michauxianus* pre-restoration and in Years 1, 3, 5, and 10+ post-restoration. Means with shared group numbers are not considered significantly different (alpha = 0.05).

A) Random Effects

Groups	Name	Variance	St. Dev.
plot:site	Intercept	23.2118	4.8179
site	Intercept	0.6009	0.7752
Residual		10.9864	3.3146

657 observations; groups: plot:site = 155; site = 6

B) Analysis of Variance Table

Type	Response		npar	Sum Sq	Mean Sq	F value
Reference	*S.michauxianus*	sms	1	0.96	0.96	0.09
		year	4	75.40	18.85	1.72

C) Post-hoc Comparison Test

Type	Response	sms	year	lsmean	SE	df	lower CL	upper CL	group
Reference	*S.michauxianus*	min	Pre	1.23	0.928	11.0	-0.81	3.28	a
		min	1	1.46	0.928	11.0	-0.58	3.50	a
		org	Pre	1.63	0.922	10.5	-0.41	3.68	a
		org	1	1.86	0.921	10.5	-0.18	3.90	a
		min	10+	1.89	0.942	12.0	-0.16	3.95	a
		min	5	1.98	0.941	11.8	-0.08	4.03	a

	min	3	2.10	0.927	10.9	0.06	4.14	a
	org	10+	2.29	0.963	13.4	0.22	4.37	a
	org	5	2.38	0.961	13.3	0.30	4.45	a
	org	3	2.50	0.921	10.4	0.46	4.54	a

Appendix G– MWL & HHWLT Compared to Marsh Platform Elevations

Table G-1. Average elevations of the marsh platform for each site from 2021-2022 compared to the mean water level (MWL) and higher high water large tide (HHWLT) values reported by the Canadian Hydrographic Service (CHS) stations closest to each site. Elevations were determined by taking the average of the surveyed stations for each site.

Site	ELV (m)	CHS Station	MWL (m)	HHWLT (m)
ABR	0.49	Abrams River (00380)	1.85	3.82
ABR-R	1.23	Abrams River (00380)	1.85	3.82
BEL	6.54	Hantsport (00282)	7.49	14.99
BAS	5.69	Burntcoat Head (00270)	7.53	15.48
CHV	5.28	Burntcoat Head (00270)	7.53	15.48
COG	6.27	Burntcoat Head (00270)	7.53	15.48
COR	6.28	Burntcoat Head (00270)	7.53	15.48
CON	6.02	Pecks Point (00190)	6.73	13.6
LTR	0.05	Little Harbour (00497)	1.11	2.11
MAV	1.61	Meteghan (00355)	3.01	5.94
MAV-R	2.14	Meteghan (00355)	3.01	5.94
SCP	6.82	Hantsport (00282)	7.49	14.99
SCW	6.64	Hantsport (00282)	7.49	14.99
TFH	0.69	Little Harbour (00497)	1.11	2.11
WS	5.64	Burntcoat Head (00270)	7.53	15.48
WRS	5.64	Burntcoat Head (00270)	7.53	15.48