

**INFORMATION FROM THE WRACK: Viability of Halophytic Vegetation within
Tidal Wetland Wrack Mats**

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ABSTRACT

Nova Scotia's coastal wetlands are under various anthropogenic pressures that can cause destruction or degradation to these ecosystems. Many of these valuable systems have not been protected in the past and have been lost. An important stage in the overall knowledge of coastal wetlands is figuring out how these systems can recolonize without planting. Wrack is understudied in the Minas Basin, Bay of Fundy and determining if there is viable halophytic plant material within the wrack in this area could be a clue to understanding how these systems function. In order to gain a better understanding of the role of wrack mats, 18 samples were analyzed from 6 study areas (3 sample locations per study area). A characterization of the wrack mat was completed and seed material was determined viable. Target species *Spartina patens* and *Spartina alterniflora* did not germinate at all, while target species *Plantago maritima* and *Juncus gerardii* did germinate from seed and rhizome material found within the wrack. This information complements ongoing studies within the Minas Basin, Bay of Fundy, and increases the overall knowledge of relationships between wrack and colonization within coastal wetlands.

May 2nd, 2013

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1. INTRODUCTION

1.1. Coastal Wetlands

Wetlands are known to be highly biologically productive habitat that contains plants and animals that are unique to this type of ecosystem. The National Wetlands Working Group developed a classification of wetlands in 1988 (NWWG 1997). The main wetland classes in Canada include bogs, fens, marshes, swamps, and shallow open waters. These are classified by several different factors including the plants that live there, the animals that live there, the soil type, the salinity of the water, and the height of the water table (Environment Canada 2012; Roman and Burdick 2012). Coastal wetlands are the transition zones between marine and terrestrial environments and have features representative of both ecosystems (EAC 2013; Cooke and Lefor 2004).

Coastal wetlands represent salt marshes, brackish marshes, and tidal freshwater marshes (Vernberg 1993). Salt marsh can be found along the coast, on the shielded side of barrier marshes, along tidal rivers, and located in estuaries (Adam 1993). Nova Scotia contains 154km² of salt marsh (Hanson and Calkins 1996). Within a salt marsh, there is the low marsh and the high marsh. The low marsh is usually smaller than the high marsh and floods daily, where as the high marsh only floods during the spring tide or during storm tides (Vernberg 1993). The frequency of flooding as well as salinity both greatly impact vegetation growth and this makes elevation an important factor in zonation (Pennings and Callaway 1992).

Since the arrival of European settlers along the Bay of Fundy, up to eighty-five percent of original salt marsh has been lost (MacDonald et al. 2010). Protecting these vulnerable

systems is essential in keeping these biologically diverse areas. Coastal wetlands are found in areas where they are shielded from direct wave action from the sea and are characterized by their distinct vegetation, which have adapted to the unique environmental conditions present in these areas (Batzner and Baldwin 2012). These unique environmental conditions include thriving despite the presence of salt. Vegetation that is capable of growing in relatively high saline concentrations is known as halophytic vegetation. Even though coastal wetlands provide many biological, economic, aesthetic, recreational, and health benefits, they continue to be under various anthropologically related pressures that threaten their existence.

1.1.1. Coastal Processes

There are many coastal processes that influence tidal wetlands. These processes may include wave action, ice, wind, tides, storm surge and sea level (Woodroffe 2002). Ice has the ability to destroy large areas of low-lying marsh (marsh found at low elevation (Pennings and Callaway 1992)), as well as relocate intact portions of marsh to new locations (Pennings and Bertness 2001). Wave action, tides, storm surge, and changes in sea level all impact the distribution of sediment throughout the system (Davidson-Arnott et al. 2002; Christiansen et al. 2000). Wave action, ice, tides, storm surge and sea level impact hydrochory, or the distribution of seeds or plants by water (Huiskes et al. 1995). Similarly, wind also assists in the dissemination of seed (Pennings and Bertness 2001).

Coastal wetlands perform a range of ecological functions and services. Wetlands can prevent coastal erosion through the absorption of the impact of water energy along the coast while simultaneously protecting the coast from flooding (Miller et al. 2001). Tidal

wetlands provide habitat and food to wildlife (Simpson et al. 1983; Lifjeld 1984) and work as a natural filter that increases the quality of water (Gilliam 1994; Whigham et al. 1988). Coastal wetlands also work as a carbon sink, sequestering carbon dioxide from the atmosphere and holding it in peat, depositing it in sediment or holding it in plant biomass (Bridgham et al. 2006). This carbon sequestration by coastal wetlands is a significant contributor in reducing atmospheric carbon dioxide, subsequently influencing climate change (Schimel 1998).

The role of soil, seed banks, hydrochory, ice and geomorphology within the Bay of Fundy has been examined in the past (Lemieux 2010; Deloughery 2010; Bijman 2012; Greene 2009). However, the potential role of wrack (also described as dead plant material (Leck 2003)) in primary, secondary, or successional colonization of halophytic vegetation on tidal wetlands in the Minas Basin, Bay of Fundy has yet to be explored. Wrack is found in wetland high marsh due to wave and tide action (Orr et al. 2005) and the transportation of this wrack from nearby coastal wetlands could play an important role in vegetation colonization.

1.1.2. Coastal Plants

Salt-tolerant grasses and sedges are the main component of vegetation in the North Atlantic tidal wetlands (Batzler and Baldwin 2012). Plants typically found in North Atlantic coastal wetlands may include *Spartina patens*, *Plantago maritima*, *Juncus gerardii* and *Spartina alterniflora* (Tiner 1987; Bertness 1991; van Proosdij et al. 2010; Bowron et al. 2011). There is a small amount of information known surrounding the mechanisms of salt marsh vegetation colonization within the Bay of Fundy, making it a

novel area of research. As restoration efforts have increased, research efforts have also increased on colonization mechanisms (Lemieux 2010; Deloughery 2010; Bijman 2012; Bowron et al. 2011, van Proosdij et al. 2010).

1.2. The Bay of Fundy and the Minas Basin

The Bay of Fundy is an extremely unique tidal system (Figure 1). Approximately 100 billion tons of water moves in and out of the bay twice a day. This makes the Bay of Fundy the location of the highest tides in the world, which range from 3.5 meters to 16 meters (ERDT 2012; Davidson-Arnott et al. 2002). The Minas Basin is an inlet on the Nova Scotia side of the Bay of Fundy. This is an ideal opportunity for wrack dispersal. The mass movement of this water greatly increases the potential transportation of wrack.

The climate in the Minas Basin varies from season to season. In the winter, temperatures fall below freezing around -15°C and in the summer, temperatures can surpass 25°C . Atlantic Canada in particular is prone to intense weather conditions, which can include hurricanes in the summer and blizzards in the winter. This causes increased amounts of precipitation and unusually high winds (Elsner and Kara 1999; Stewart et al. 1994) that impact sediment movement throughout the Bay of Fundy (Michener et al. 1997). The Minas Basin area can experience reasonably high precipitation of 100mm/month average (using climate data from 1971 until 2000 (Environment Canada 2012)).



Figure 1. Location of the Minas Basin within the Bay of Fundy, Canada.

1.3. Current State of Salt Marshes

Salt marshes can be degraded through hydrologic alterations, which impede the flow of tidal water from the Bay of Fundy. Hydrology is a fundamental factor in the function of wetlands and has been altered through ditching, channelization, drainage, impoundments, and tidal restrictions such as bridges, causeways, dykes, and tide gates (Bowron et al. 2011; Batzer and Baldwin 2012). The loss of these essential ecosystems impacts the biological integrity of the Bay of Fundy ecosystem in a harmful way. Wetland dependent species completely rely on these ecosystems (Gibbs 2000) and they are extremely beneficial to other species in the area (Hawksworth and Bull 2006). The main priority should be to protect these ecosystems; however, after the damage has been done,

restoring the flow of water to the site is one way to assist in the recovery of wetland habitat conditions.

The act of ecological restoration is defined as the “process of repairing damage caused by humans to the diversity and dynamics of indigenous ecosystems” (Jackson et al. 1995).

Within Nova Scotia, sixteen tidal restoration projects were completed, planned or underway as of 2012. Five of which are located along the Minas Basin (Bowron et al. 2012). Different approaches can be used to restore the tidal flow allowing the wetland to recover, and these depend on the nature of the original alteration. For example, at a 9.3ha area of salt marsh located near Walton River, Nova Scotia, a dike breach and creek excavation were completed successfully in 2005 in order to restore the tidal flow into the marsh (van Proosdij et al. 2010).

Passive restoration is one technique currently used in restoration in Atlantic Canada. This strategy involves no planting and allows for natural colonization from surrounding environments (Vaughn et al. 2010). Ecological monitoring following passive restoration in Nova Scotia has shown that after restoration the physical and biological components such as soil, elevation, vegetation, fish and wildlife do recover naturally (Bowron et al. 2011; Bowron et al 2009; van Proosdij et al. 2010). However, it has also been observed that on occasion wetlands have been slow to recover and differences in habitat conditions and vegetation community structure between reference or intact marshes of the wetland and the restored version of the wetland do persist. In this case, it may be useful to use an active restoration approach. Active restoration involves human action intended to accelerate the process of colonization (Vaughn et al. 2010). This may include restoration

professionals importing seeds or plants directly onto the site, but this can become time consuming and costly. Groups conducting coastal wetland restoration in Atlantic Canada tend to use passive restoration techniques, particularly in the Bay of Fundy. Restoration efforts are focused on restoring the physical features (for example, features impacting hydrology) that enable the biology to recover naturally. This is true unless natural colonization does not occur, or native target species that should be there are not and intervention is needed. The use of locally sourced wrack material could be considered a viable alternative to the re-introduction of native target species to a site. Placing wrack within a restoration site could speed up the natural rate of vegetation re-colonization and could reintroduce key species into the restoration site. It is important to explore the potential for wrack mats as a dispersal agent for seeds and rhizomes within the coastal environment. Understanding the role of wrack in the Minas Basin, Bay of Fundy is an important step in comprehending plant colonization in this area.

1.4. The Importance of Wrack Mats in Salt Marsh Ecosystems

An imperative step in the restoration process within an impacted area is the introduction of native plant species (Palmer et al. 2006). Understanding which viable plants the wrack material contains, if any, could determine if the use of wrack is a solution to the introduction of native plant species from other similar wetland ecosystems nearby. Scientific literature has concentrated on different aspects of the wrack's role within coastal marshes. This includes the dispersal of plants via wrack mats (Minchington 2006; Hulzen et al. 2006) and the disturbance of vegetation by wrack mats (Valiela and Riestma 1995; Allison 1995; Fischer et al. 2000), but has not yet focused on the viability of seed

and rhizome material found within the wrack in the unique tidal range of the Bay of Fundy.

Wrack mats consist of dead plant material, are found within coastal wetlands (typically washed up on or above high tide lines) and have been found to contain large amounts of various seeds and rhizomes (Leck 2003). Viable plants could potentially be derived from both seed and rhizome material found within the wrack material. Wrack material can have various influences on salt marsh function. In a positive light, wrack itself has been shown to administer nutrients to nutrient-poor soil, increase the diversity of vegetation as well as provide structure, which reduces erosion of the soil (Chapman and Roberts, 2004). Wrack also has the ability to cause vegetation disturbance by acting as a barrier for sunlight to reach vegetation (Valiela and Rietsma 1995; Fischer et al. 2000); however, recovery from such a small-scale disturbance can be quick (Hartman et al. 1983; Hartman 1988; Ellison 1987). Also, these small-scale disturbances give opportunity for new colonization (Leck 2003; Grubb 1977) and have been linked to creating and maintaining habitat for gap dependent species (Hulzen et al. 2006).

Wrack has been studied unintentionally through the examination of marine debris in salt marshes (Viehman et al. 2011). The potential for wrack to act as a dispersal agent for plant colonization has been studied in New England, USA (Minchington 2006).

Minchington's study (2006) suggested that wrack might be an important factor in the way plants disperse among coastal marshes. Ellison (1987) discovered that wrack has the ability to widely disperse seeds that would normally travel only short distances. Wrack

mats are generally an understudied topic. This is particularly true for function that wrack has within the Bay of Fundy, where the subject hasn't been studied at all.

1.5. Thesis Statement and Objectives

I hypothesize that there is viable halophytic plant material contained within the wrack mats found on tidal wetlands in the Minas Basin, Bay of Fundy.

The objectives of this study were to:

1. Characterize the wrack material present on tidal wetlands in the Minas Basin, Bay of Fundy.
2. Determine if seed and rhizomal material were present in wrack.
3. Determine if this seed and rhizomal material found in wrack were viable.
4. Examine whether the target halophyte species *Spartina alterniflora*, *Spartina patens*, *Juncus gerardii* and *Plantago maritima* were represented.

2. STUDY SITES

2.1. Site Descriptions

Sampling was conducted at three locations within each of six different study sites within the Minas Basin, for a total of eighteen samples. The location of the six study sites are shown in Figure 2. Of the six study sites, two were open face marsh and four were riverine marsh (Table 1). A marsh is delineated an open face marsh if it is directly on the coast and it is considered a riverine marsh if it is along a river (Tockner and Stanford 2002). Study sites were identified according to their geographic location within the Minas Basin. Southern samples consist of Kingsport and Avon, central samples consist of

Cogmagun and Lantz, and Northern samples consist of Walton and Noel. A combination of access, research activities, general interest, and restoration efforts at the study sites assisted in the selection process.

Sampling locations on the open face marshes were chosen in the middle of the site, as well as at either end along the high marsh. Sampling locations on the riverine marshes were conducted at the downstream, middle, and upper river areas of the marsh. This was done to get coverage of the entire system.



Figure 2. The six study sites shown within the Minas Basin, Bay of Fundy.

Table 1. Sites with corresponding site codes, corresponding global positioning system (GPS) data, as well as if the site is an open or linear salt marsh.

Site	Site Code	Type of Site	GPS: North (D M S)	GPS: West (D M S)
Avon	Av-01	Open	45 00 03.7	064 09 10.6
Avon	Av-02	Open	44 59 47.6	064 08 50.9
Avon	Av-03	Open	44 59 48.9	064 08 39.4
Cogmagun	Cog-01	Linear	44 05 04.2	064 07 06.9
Cogmagun	Cog-02	Linear	45 04 40.4	064 07 54.9
Cogmagun	Cog-03	Linear	45 04 24.8	064 08 11.3
Kingsport	Kp-01	Linear	45 08 49.9	064 24 39.9
Kingsport	Kp-02	Linear	45 08 30.8	064 23 54.8
Kingsport	Kp-03	Linear	45 08 32.4	064 23 26.3
Lance	Ltz-01	Linear	45 10 19.2	064 09 14.3
Lance	Ltz-02	Linear	45 10 23.6	064 09 28.0
Lance	Ltz-03	Linear	45 10 28.6	064 09 48.5
Noel	Nl-01	Open	45 18 07.3	063 44 58.4
Noel	Nl-02	Open	45 17 52.2	063 43 26.5
Noel	Nl-03	Open	45 17 57.4	063 43 46.3
Walton	Wal-01	Linear	45 13 11.3	063 59 12.2
Walton	Wal-02	Linear	45 13 16.9	063 59 47.2
Walton	Wal-03	Linear	45 23 39.1	064 00 08.0

2.1.1. Noel (NI)

Noel is an open system wetland approximately 200 ha (Figure 3). It is the furthest North and the furthest East of the six study sites in the Minas Basin. This area is a relatively rural, is bordered on the upland edge by Highway 215 and has agricultural lands to either side. All samples taken were far from the low marsh (NI-01 being the closest and NI-03 being the furthest), but all three were taken near a main tidal creek. *Spartina patens*, *Carex paleacea* and *Solidago sempervirens* dominated the three sample locations. Sample NI-01 was at the upland edge of the high marsh and was adjacent to a small terrestrial

island. The wrack in this area was located further from the creek. The wrack from sample NI-02 was located in the high marsh. NI-03 was off of Highway 215 and the wrack was pushed up against the bank of the road.

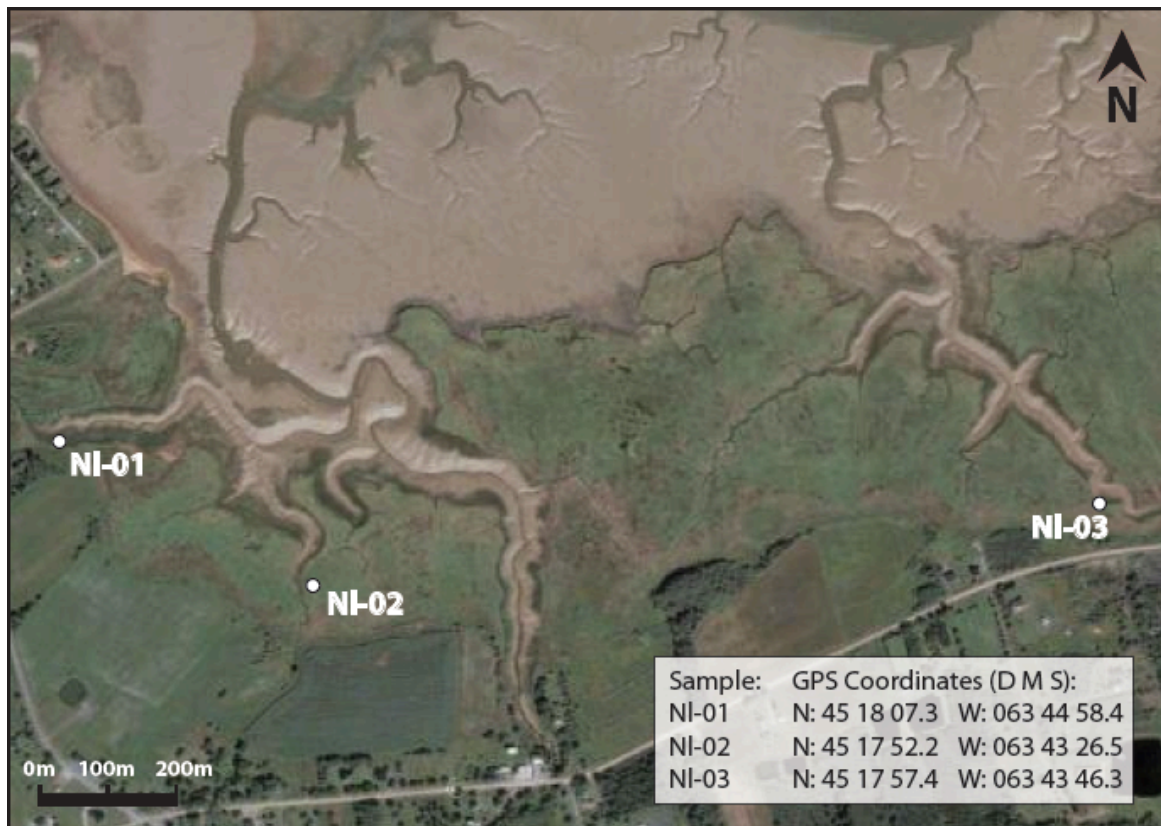


Figure 3. Study site Noel showing all three sample sites with corresponding GPS coordinates.

2.1.2. Walton River (Wal)

Walton River is a tidal river that has approximately 350ha of tidal wetland (Bowron et al. 2012). A dyke breach and creek excavation were completed in 2005 by the Nova Scotia Department of Transportation and Infrastructure Renewal (NSTIR) as a wetland compensation project and a monitoring program was implemented (Bowron et al. 2012). Wal-01 (Figure 4) was located on a small section of fringe marsh along the main river channel and was adjacent to the Walton Woods Rd. *Spartina alterniflora* and *Spartina patens* dominated the site. Sample Wal-02 was found directly on the slope of the high marsh and trees hung above the sample. *Spartina patens* and *Carex paleacea* were observed on the sample location. Wal-03 was also found up on the embankment of the high marsh near the mouth of the river and it was observed that a considerable amount of large woody debris was present in the wrack. This material was not collected as part of the sample.



Figure 4. The Walton River study site showing all three sample sites with corresponding GPS coordinates. The restoration site is outlined in yellow.

2.1.3. Lantz River (Ltz)

Lantz is a riverine marsh system within approximately 50 ha of tidal wetland (Figure 5).

Wrack sample Ltz-01 was located off of the side of Highway 215, which bordered the upstream end of the system. Sample Ltz-02 was also located off of the side of Sherman Lake Rd. in the high marsh, but was near a wooded area. Ltz-03 was taken at the end of Sherman Lake Rd. located near the mouth of the river. All three sample locations at Lantz were largely dominated by *Carex paleacea*.



Figure 5. Study site Lantz showing all three sample sites with corresponding GPS coordinates.

2.1.4. Cogmagun River (Cog)

Cogmagun is approximately 350 ha riverine salt marsh wetland (Figure 6) (Bowron et al. 2012). A dyke breach was completed in 2009 by NSTIR as a compensation project and a monitoring program was established (Bowron et al. 2012). Sample Cog-01 was located beside the road on high marshland. Samples Cog-02 and Cog-03 were both found behind farms high in the marsh. The dominant vegetation along Cogmagun River was *Spartina patens* and *Carex paleacea*. A mix of *Limonium nashii* and *Solidago sempervirens* were also observed on site.



Figure 6. The Cogmagun River study site showing all three sample sites with corresponding GPS coordinates. The restoration site is outlined in yellow.

2.1.5. Avon River (Av)

Avon is approximately a 60 ha open marsh at the Windsor causeway (Figure 7). This marsh formed after construction of Highway 101 in 1969, making it a relatively young marsh (van Proosdij et al. 2010). Sample Av-01 was located beside a sewage treatment plant, high on the marsh and very far from the river. Both Av-02 and Av-03 were located off of Highway 101 and found in the high marsh. A mix of *Spartina alterniflora* and *Carex paleacea* was the dominant vegetation along Avon River.

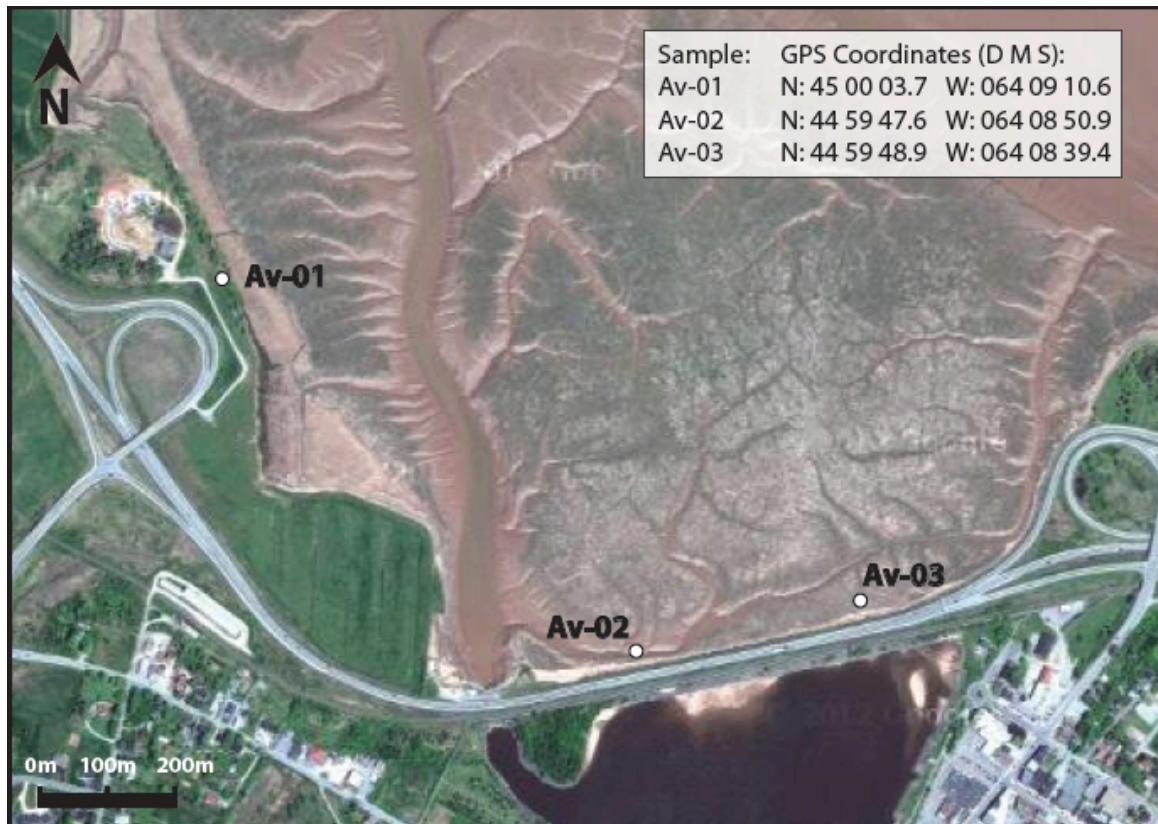


Figure 7. The Avon River study site showing all three sample sites with corresponding GPS coordinates.

2.1.6. Kingsport (Kp)

Kingsport is a tidal river that is approximately 200 ha (Figure 8). It is the most Western site of all six study sites. Sample Kp-01 was located off of the main road in the high marsh. Kp-02 was obtained off of a side street in the high marsh. Sample Kp-03 was found between the high and low marsh line. *Carex paleacea* and *Scirpus americanus* were the dominant species found along the Kingsport marsh.

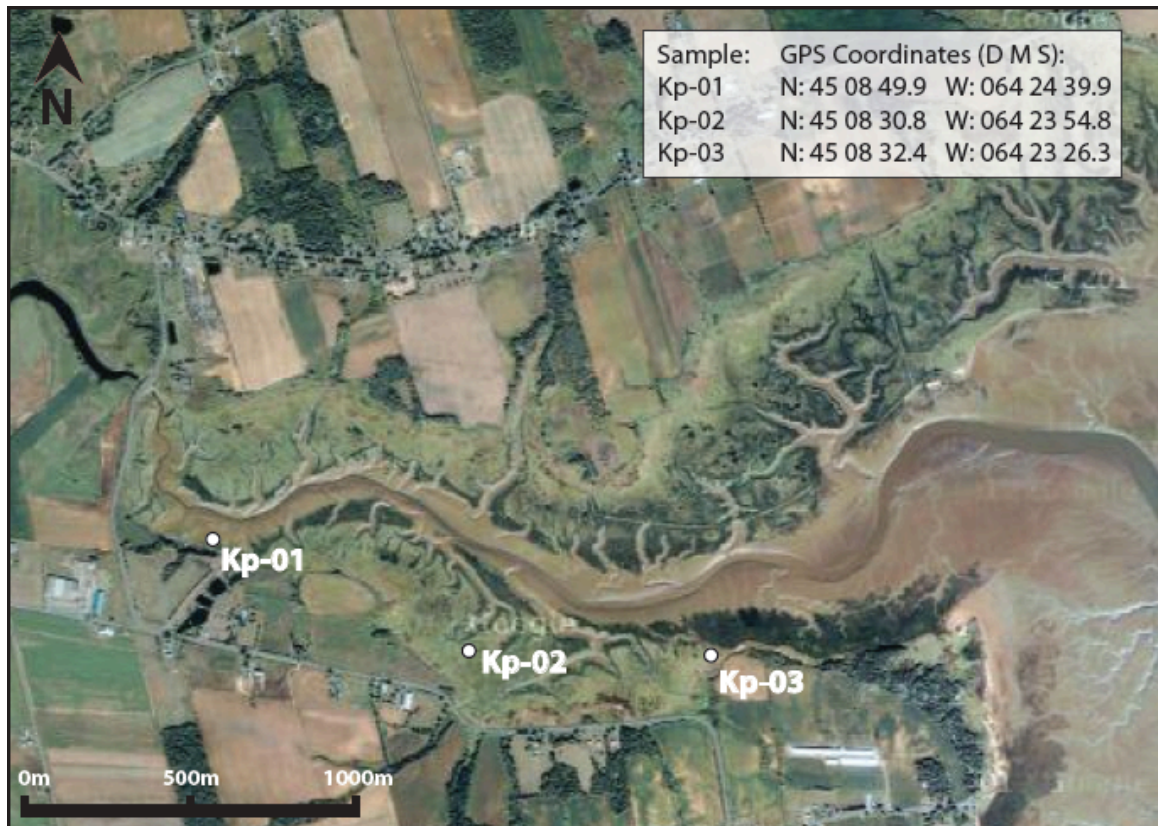


Figure 8. Study site Kingsport showing all three sample sites with corresponding GPS coordinates.

3. SAMPLE DESIGN AND METHODS

3.1. Field Collection of Data

Field sampling was conducted at NI, Cog, Wal and Ltz on June 1, 2012 and Av and Kp on June 5, 2012. Sampling was conducted using a 1m² quadrat in order to ensure uniformity throughout the study, and to ensure that an adequate sample was taken to ensure enough material was collected for research purposes.

It was necessary to include some flexibility for each sample location based on the presence and location of wrack mats on site. Once a large enough wrack mat was found (>10m long and >1m wide), a blind toss approach was used to locate the quadrat sample within the wrack mat. A quadrat standard sampling technique was applied (a 1m² quadrat was used). Photographs of the entire wrack mat (Figure 10), the quadrat sample before (Figure 11) and after wrack material was removed (Figure 12), and the surrounding marsh were taken. Parameters that were noted include:

- Depth (from the top of the wrack layer to the bottom of the wrack layer) (Figure 9):
 - Of the center of the sample
 - To the right end of the quadrat
 - To the left end of the quadrat
 - 5 meters to the right of the quadrat
 - 5 meters to the left of the quadrat
- Recent and current tide cycles
- Weather
- GPS coordinates
- Dominate vegetation type
- Proximity to marsh edge/creek

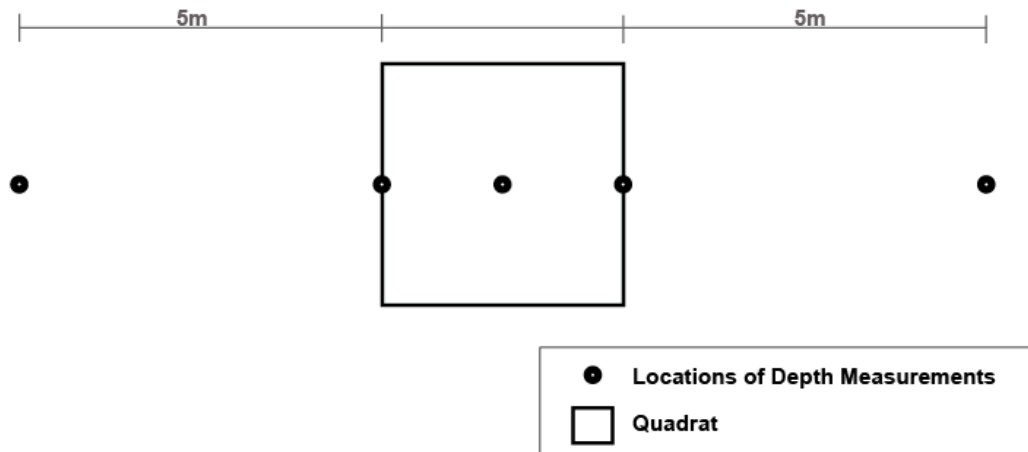


Figure 9. The location of depth measurements in relation to quadrat samples.

A site sketch was also completed showing the general layout of the area with the wrack mat in relation to the water source. Once all of this was accomplished, all organic material inside of the quadrat was gathered and placed in a clear garbage bag and tagged.



Figure 10. An extensive wrack mat along Avon River, June 5 2012.



Figure 11. Sample Kp-03 before wrack removal (June 5 2012).



Figure 12. Sample Kp-03 after wrack removal (June 5 2012).

3.2. Laboratory Techniques

3.2.1. Preliminary Stage

The wet weight of each 1m^2 sample was measured to the nearest hundredth using a scale. Each sample was then removed from their bag and laid on a tarp arranged inside of a 1m^2 quadrat. The sample was then divided into two halves (0.5m^2 each) (Figure 13). One 0.5m^2 half was selected for the indoor germination experiment (located in the Saint Mary's University greenhouse). The other 0.5m^2 half was further divided into two halves (0.25m^2 each). One of these 0.25m^2 halves was used for the outdoor germination experiment (Saint Mary's University green roof). The other 0.25m^2 was dried using a drying oven at 80°C for 48 hours, weighed, and then disposed of.

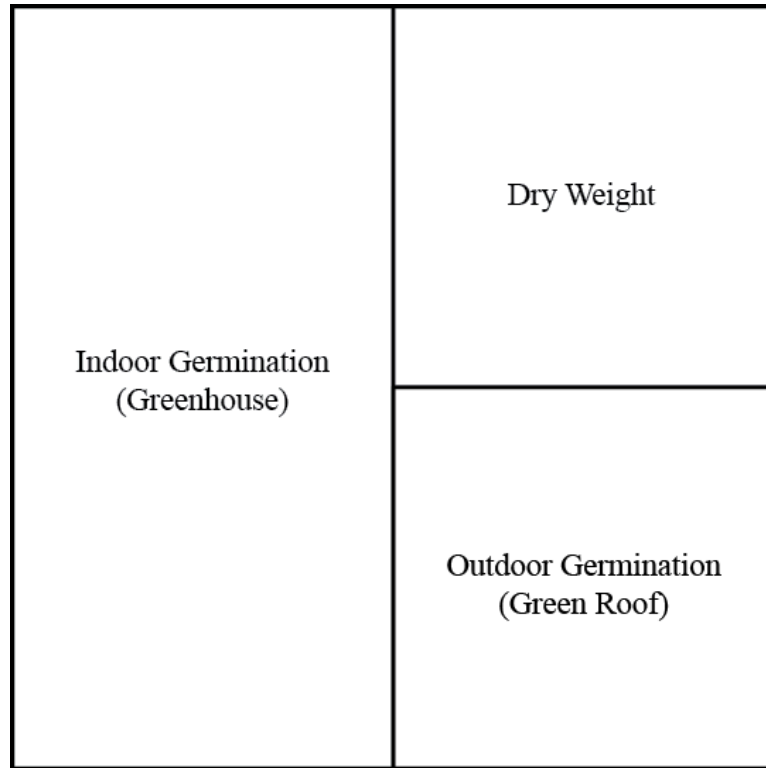


Figure 13. Illustration of how 1m² quadrats were divided for analysis purposes.

3.2.2. Indoor Germination (Greenhouse Experiment)

The eighteen 0.5m² indoor germination samples were individually sieved thoroughly for seeds using water and a 0.5mm sieve over a 0.2mm sieve (Figure 14). Seeds were planted in one plastic planting tray per 0.5m² sample (making eighteen trays) using sand as a growth medium on June 11th, 2012. The seed was spread on the surface of the sand and covered in approximately 2mm of sand. Seeds were watered once a day for a five-minute duration for fifteen weeks. This allowed all of the plants that successfully germinated to mature to the point where they could be identified accurately. Dr. Jeremy Lundholm (Saint Mary's University) identified each of the species. The plants were then counted and recorded. Plants that remained unidentifiable were allowed to mature to a stage where they could accurately be identified. They were transplanted into individual plots

containing loamy gardening soil and grown further until they could also be identified and recorded.



Figure 14. (A) The 0.5mm sieve over the 0.2mm sieve.



Figure 14. (B) Wrack sample being sieved throughly with water in order to separate seed and rhizomal material.



Figure 14. (C) The resulting debris after sieving the wrack.

3.2.3. Outdoor Germination (Green Roof Experiment)

Each 0.25m² sample intended for the outdoor germination on the green roof were spread equally over two planting trays (totaling thirty-six planting trays). Sand was used as a growth medium. These samples were left untouched, were exposed to the prevailing weather conditions and no supplementary watering or weeding occurred. Samples were observed on a weekly basis for six weeks.

3.2.4. Analysis

Statistical analysis was conducted using Minitab Statistical Software. Descriptive statistics were applied to the species data to assist in characterizing the wrack. Analysis of variance (ANOVA) tests were completed for the dry weight (lbs) versus site, the number of rhizomes found versus site, and for total seed (mL) versus site. Dry weight was multiplied by 2 so that it would be comparable with the sample intended for the

greenhouse, equal weight was assumed. It is also important to note that all seed material used in the calculation for total seed versus site was an estimate as other small debris smaller than 0.5mm could have been collected by the sieve and been recorded. Regression analysis tests were completed for wet weight versus the total number of species and germinated seeds versus average depth.

4. RESULTS

The average depth for all of the wrack was calculated to be 6.28 cm (Table 2). Seeds and rhizomes were present at all eighteen sites (Table 3).

In the one-way ANOVA analysis, between sites for the means of the weight (Figure 15) $P=0.664$, concluding that there was no significant difference between sites for mean wrack weight. The results were also not significant between sites for the means of seed amount (Figure 17) $P=0.064$. Between sites as determined by one-way ANOVA ($F(5,12)=6.67$, $p=0.003$) for the test regarding the number of rhizomes (Figure 16), analysis showed statistical significance.

In the regression analysis for wet weight (lbs) versus the number of germinated individuals (Figure 18) ($F(1,16) = 0.11$, $P = 0.742$, $R^2 = 0.7\%$), there was a positive relationship between the two; however, only 0.7% of the variation in the number of species can be attributed to the wet weight. The remaining 99.3% can be attributed to unknown variables. The regression analysis was determined not significant.

In the regression analysis for germinated seed versus the average depth of the sample (Figure 19) ($F(1,16) = 0.27$, $P = 0.613$, $R^2 = 1.6\%$), there was also a positive relationship between the two. The average depth according to the regression analysis can explain only 1.6% of the number of germinated seed. The remaining 98.4% can be attributed to other variables. This regression analysis was also determined not significant.

4.1. Characterization of the Wrack

The largest wrack mat was found at Av-02, while the most abundant wrack mat determined by depth was found at Av-03 (Table 2). The location with the heaviest total wet weight and dry weight sample was also Av-03 (Table 3). N1-03 yielded the most sieved material at 600mL and Kp-02 returned the most number of rhizomes at 82 (Table 3).

Table 2. Descriptive information on the wrack mats gathered for each site in the field.

Site Number	Dimensions of Wrack Mat WIDTH (m)	Dimensions of Wrack Mat LENGTH (m)	5m Left (Depth in cm)	Left End (Depth in cm)	Center (Depth in cm)	Right End (Depth in cm)	5m Right (Depth in cm)
Av-01	2	4	0	5	5	5	0
Av-02	25	>300	16	8	5	8	12
Av-03	20	>300	14	12	14	13	14
Cog-01	8	20	7	13	8	7	0
Cog-02	5	15	4	14	4	16	2
Cog-03	15	35	5	6	8	6	5
Kp-01	3	50	5	9	4	4	5
Kp-02	10	100	2	5	3	4	4
Kp-03	15	>300	5	7	11	5	8
Ltz-01	2	3	0	4	5	3	0
Ltz-02	30	>50	2	4	2	3	3
Ltz-03	2	15	3	6	4	5	9
Nl-01	5	4	6	6	5	4	3
Nl-02	7	100	4	8	7	15	1
Nl-03	6	75	2	15	13	12	13
Wal-01	10	35	1	4	3	5	1
Wal-03	4	30	7	5	7	2	0
Wal-03	2	20	3	3	6	4	1

Table 3. Information on the wrack samples gathered which were analyzed in the laboratory.

Site Number	Whole Sample			Sub-Sample		Sifted Sample		
	Wet Weight (lbs)	Condition	Depth (cm)	Dry Weight (lbs)	Depth (cm)	Number of Rhizomes	Seeds Present	Seeds (mL)
Av-01	8.76	Wet	7	0.49	4	8	Yes	50
Av-02	26.66	Wet	12	1.36	13	18	Yes	100
Av-03	39	Wet	15	2.16	12	4	Yes	50
Cog-01	1.61	Dry	4	0.38	3	8	Yes	100
Cog-02	5.46	Wet	11	1	6	27	Yes	225
Cog-03	5.48	Dry	13	1.14	9	8	Yes	250
Kp-01	9.83	Wet	4.5	0.6	3	23	Yes	50
Kp-02	11.16	Wet	5	0.52	2	82	Yes	500
Kp-03	11.48	Wet	7	0.88	3	46	Yes	350
Ltz-01	1.3	Dry	3	0.22	1	11	Yes	100
Ltz-02	1.29	Dry	2	0.25	1	8	Yes	50
Ltz-03	8.24	Damp	7.5	1.65	3	14	Yes	175
NI-01	2.83	Moist	6	0.4	3	64	Yes	300
NI-02	9.19	Moist	14	1.47	7	79	Yes	400
NI-03	10.73	Damp	15	1.6	8	61	Yes	600
Wal-01	5.8	Damp	7	1.1	4	2	Yes	25
Wal-03	3.02	Dry	8	0.6	5	43	Yes	350
Wal-03	3.78	Wet	4	0.46	2	21	Yes	100

4.2. Species Data

Overall, ten different plant species grew enough to maturity to be identified and there were 1410 individuals that made up the twelve different species (Table 4). It is important to note that the *Juncus* species that was not identified could also have been *Juncus gerardii*; however this conclusion couldn't be made since these plants didn't grow to maturity. It is also important to note that the majority of dead plant material that made up the wrack was *Spartina alterniflora* and *Juncus gerardi*.

Table 4. The number of plants that germinated from each site including corresponding identification names.

	Juncus Species A	Poa Compressa C	Sedge (Carex or Scirpus) E	Picea glauca F	Unknown Speices G Species G	Sonchus Species H Species H	Stelaria I Species I	Solidago sempervirens J Species J	Juncus gerardii K Species K	Plantago maritima L Species L	Unknown Speices M Species M	Cerastiu m fontanum N Species N	Total
Av-01													0
Av-02			1										1
Av-03		1											1
Cog-01	16		4				1			1			22
Cog-02	30		2							1			33
Cog-03	600		8					1					609
Kp-01								2					2
Kp-02	8		2										10
Kp-03	26		2										28
Ltz-01			1									1	2
Ltz-02			2					2		1			5
Ltz-03	23		1										24
NI-01	50		5					1					56
NI-02	50		10					2	19				81
NI-03	500			1	5	1	1	9					517
Wal-01			1										1
Wal-03			8	3						3	3		17
Wal-03			1										1
Total	1303	1	48	4	5	1	2	17	19	6	3	1	1410
Mean	217.167	0.167	8.000	0.667	0.833	0.167	0.333	2.833	3.167	1.000	0.500	0.167	
Standard Error of the Mean	41.3	0.0556	0.728	0.173	0.278	0.0556	0.0762	0.508	1.06	0.181	0.167	0.0556	

Table 5. Species identification table specifying each species as halophytic or non-halophytic as well as stating target species.

Species Identification	Location	Type	Target
<i>Juncus</i> (sp?)	Cog, Kp, Lz, Nl	Halophytic	Yes
<i>Poa Compressa</i>	Av	Halophytic	No
<i>Sedge (Carex or Scirpus)</i>	Av, Cog, Kp, Ltz, Nl, Wal	Halophytic (If Carex)	No
<i>Picea glauca</i>	Nl, Wal	Non-Halophytic	No
<i>Sonchus Species</i>	Nl	Non-Halophytic	No
<i>Stellaria</i> (sp?)	Nl	Non-Halophytic	No
<i>Soldago sempervirens</i>	Cog, Kp, Ltz, Nl	Halophytic	No
<i>Juncus gerardii</i>	Nl	Halophytic	Yes
<i>Plantago maritima</i>	Cog, Ltz, Wal	Halophytic	Yes
<i>Cerastium fontanum</i>	Ltz	Non-Halophytic	No
Unknown Speices G	Nl	Unknown	Unknown
Unknown Speices M	Wal	Unknown	Unknown

4.3. Analysis 1: One-Way ANOVA Test for Dry Weight (lbs) VS Site

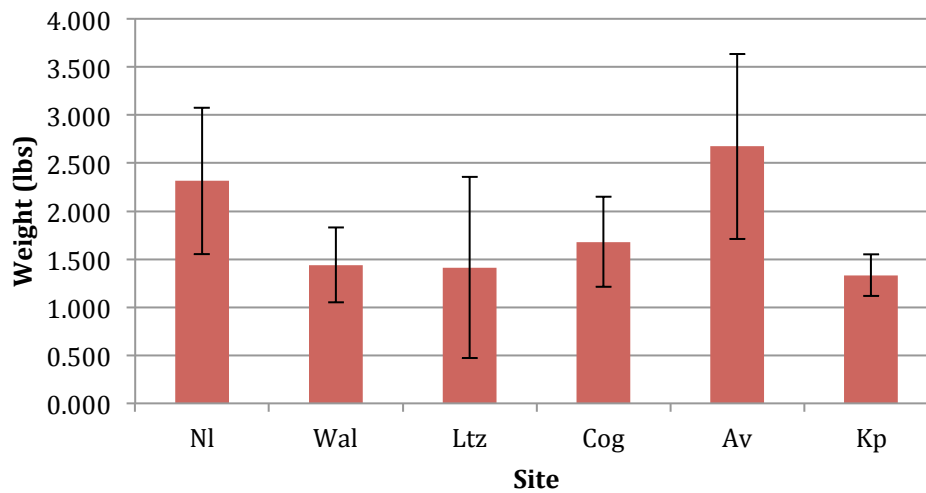


Figure 15. Mean wrack weight for each sample site.

4.4. Analysis 2: One-Way ANOVA Test for the Number of Rhizomes VS Site

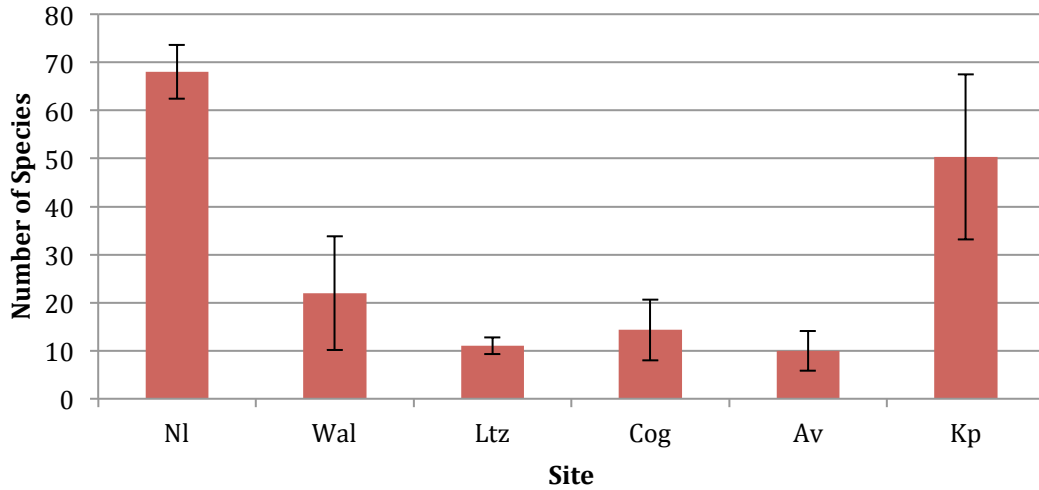


Figure 16. The mean number of rhizomes per study site.

4.5. Analysis 3: One-Way ANOVA Analysis for Seeds (mL) VS Site

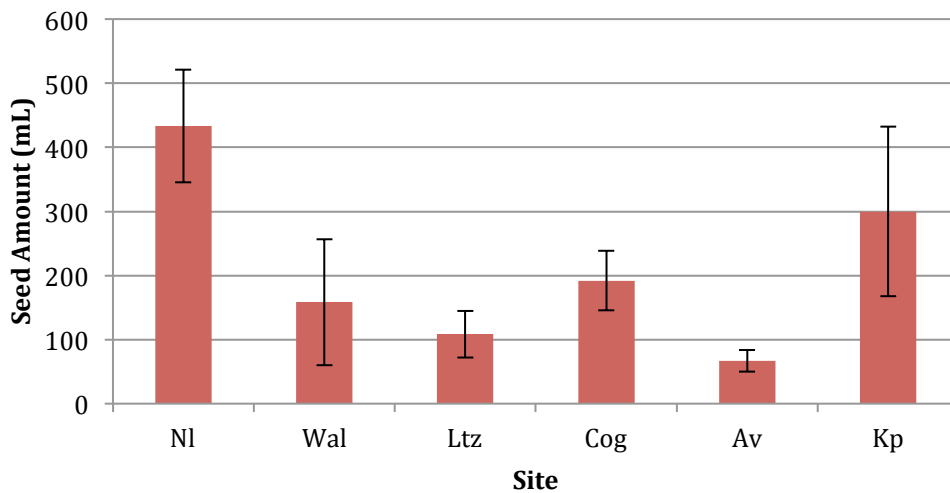


Figure 17. The mean seed amount sieved (mL) for each study site.

4.6. Analysis 4: Regression Analysis for Wet Weight (lbs) VS Number of Germinated Individuals

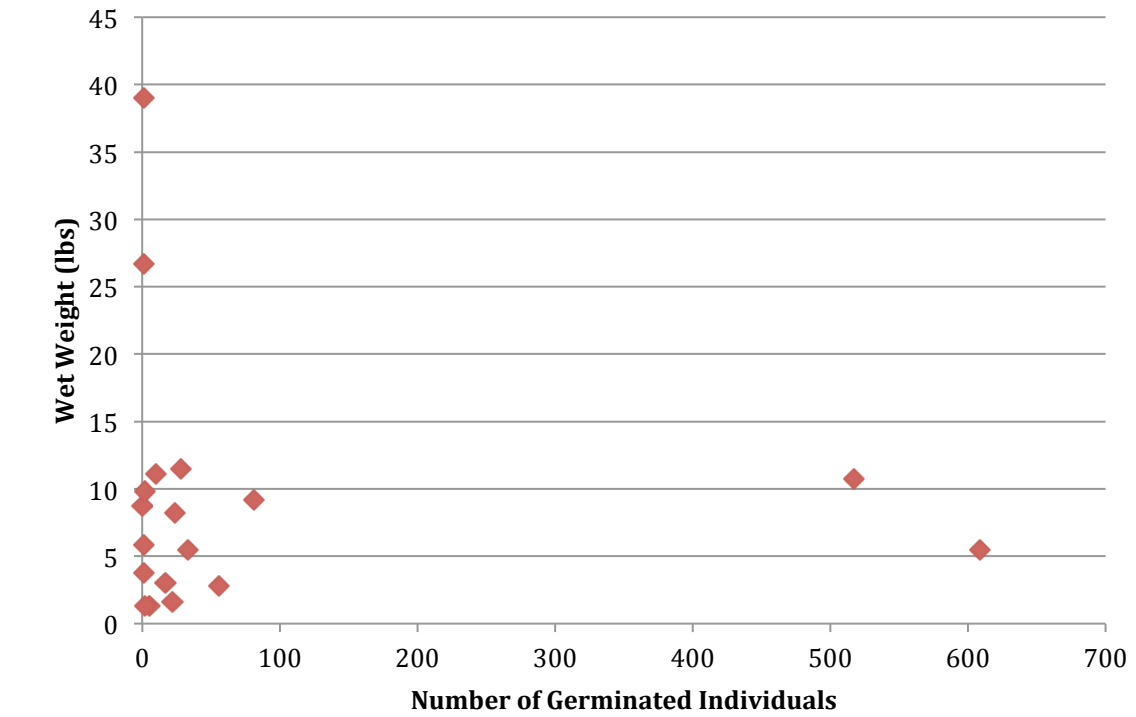


Figure 18. The number of germinated individuals VS wet weight (lbs).

4.7. Analysis 5: Regression Analysis for the Number of Germinated Seed VS Average Depth

Depth

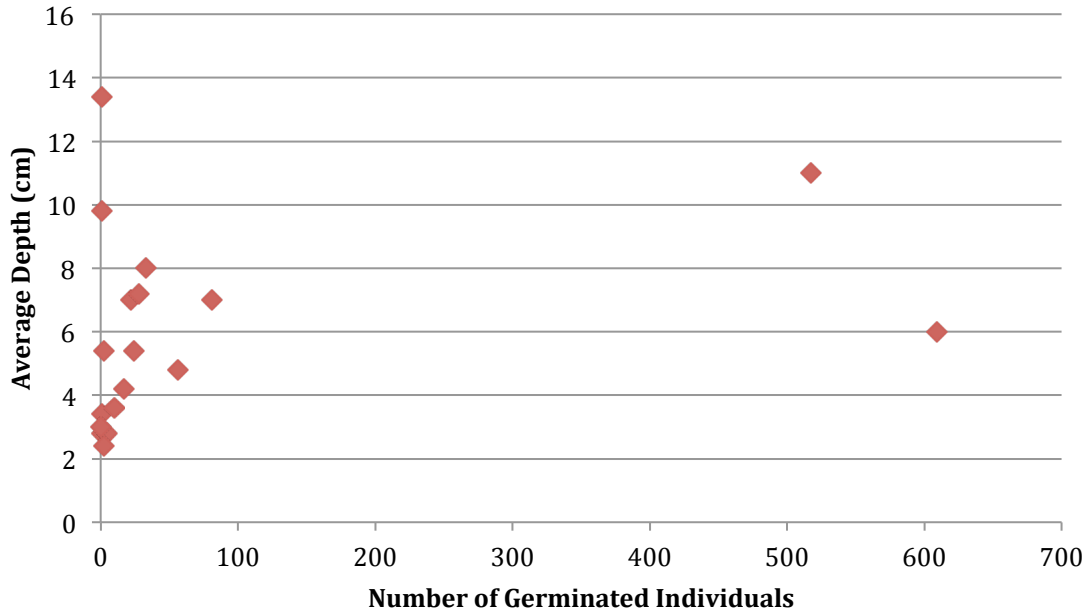


Figure 19. The number of germinated individuals VS the average depth of wrack for each sample.

4.8. Green Roof Experiment Results

The outdoor germination samples were observed weekly for six weeks (in comparison to the greenhouse samples, which germinated at two weeks). There were likely viable seeds within the samples, but germination conditions had prevented detection of this.

5. DISCUSSION

5.1. Characterization of the Wrack

Data from Table 1 shows raw data on the characterization of eighteen wrack mats from the Minas Basin, Bay of Fundy and how they varied from sample location to sample location.

Wrack material found on tidal wetlands in the Minas Basin, Bay of Fundy varied in size, depth, weight, seed amount and rhizome amount and many factors could attribute to this.

Total wet weight (lbs), the condition of the wrack, the depth, the dry weight, as well as seed and rhizome amount material can all be viewed in Table 3. As seen in the data in Table 3, seed and rhizome material were in fact present in the wrack and the wrack itself was not created equal (meaning that each wrack mat differed in size, weight, depth, etc.).

Environmental and geographical factors could be influencing this. For example, the differences in weather in the different site locations, the topography of the marsh, and the distance between the study site and neighboring marshes could all be potential factors in the differences in characteristics between wrack mats. If storm tides were larger in one area as opposed to another due to weather, it could favor or hinder the transportation of wrack. Also, some areas of the marsh may be more prone to wrack than others depending on topography. The distance between the study site and the neighboring marshes could also impact how the wrack forms, as well as how much wrack forms on the study site based on wrack availability.

5.2. Greenhouse Experiment

As can be seen in Table 3, there was certainly viable material within the wrack. *Poa compressa*, *Sonchus*, and *Cerastium fontanum* were all found, which is not surprising since

these species are generally found in wetlands in this area and have no trouble colonizing on their own (Lundholm 2013).

Also, it was observed that the native halophytes (*Juncus gerardii* and *Plantago maritima*) also have small seeds, which can provide as an advantage in colonization (Coomes and Grubb 2003). It is not possible to determine whether these seeds came from another site or from the site where the wrack was discovered, but since they were contained in the wrack, the species still had the potential to be transported to another area. Similarly, seeds of *Solidago sempervirens* and *Sonchus* have appendages (pappus), which give the seeds the ability to blow in the wind (Hood and Semple 2003; Reaume 2010). All of the species found, with the exception of white spruce (*Picea glauca*), are early colonizers (species that colonize early in the growing season) that make a lot of seed (Tiner 1987). They use seeds to establish themselves in new areas or increase existing populations.

There are not a lot of primary target species such as *Spartina patens*, *Plantago maritima*, and *Spartina alterniflora* discovered in the wrack, but some did germinate (Table 5) (Tiner 1987). This could potentially be linked to the time of the year that the wrack was gathered. Since the wrack was gathered in late May and early June, it is valid that many early colonizers show up in the species data. Also, the lack of primary target species could be related to the way that primary species in this area colonize. This is difficult to conclude since there is currently a gap in the literature regarding specifically how some halophytic plants colonize. For example, *Spartina alterniflora* is believed to produce a lot of seed, but most of this seed is generally not very viable. Instead it tends to colonize through vegetative reproduction (Lemieux 2010;

Deloughery 2010). The time of year that the wrack was collected may mean that there was little viable plant material and thus no germination occurred.

So many *Juncus* are seen germinated in the data likely because of the way the plant reproduces. *Juncus* tend spread everywhere and produce a lot of seed (Shipley and Parent, 1991). Rotting *Juncus* plants that had intact seed capsules were observed in the wrack (observed in samples Cog-03 and NI-03). This suggests the dispersal of large parts of dead plants, as opposed to individual seeds. Individual seeds could have also been in the wrack.

Although the age of the wrack is unknown, it is assumed to contain plant material from the previous growing seasons. This could play a factor in the rate of germination within the sample. The sample is also assumed to contain plant material from previous growing seasons. Weather that the wrack was subject to could potentially also inhibit the success of the sample. Both of these notions are dependent on the seed species function capabilities and how they respond to environmental factors.

As mentioned earlier, there were no statistically significant differences between sites for the means of the weight (Figure 15) and between sites for the means of seed amount (Figure 17). There was a statistically significant difference between sites for the test regarding the number of rhizomes (Figure 16), meaning that there is a valid relationship between the two variables.

Since 99.3% of the variation in the number of species can be attributed to unknown variables and not the wet weight (Figure 18), the wet weight is not significant in determining the number of species. Similarly, the average depth according to the regression analysis (Figure

19) can explain only 1.6% of the number of germinated seed, making the comparison also not significant.

5.3. Green Roof Experiment

Green roof samples did not germinate. Unsuitable growing conditions as opposed to an absence of viable plant material was likely the cause. There were unusually high temperatures and low precipitation throughout the growing period (Valladares and Percy 1997).

Temperatures and total precipitation for the study period can be seen in Table 6. For the months of June, July and August, precipitation amounts are well below the 100mm/month averages discussed earlier. These samples grown under different conditions would likely yield a different result.

Table 6. Weather data including average temperature (°C) and total precipitation (mm) from the Halifax Stanfield International Airport Weather Station during the growing period of May through September (Environment Canada, 2013).

	May	June	July	August	September
Average Temperature (°C)	11.8	14.6	20	20.7	16.9
Total Precipitation (mm)	101.8	75.1	58.5	54.1	148.9

6. CONCLUSIONS AND FUTURE RECOMMENDATIONS

In conclusion, it was determined that there is viable plant material contained within the wrack mats. The hypothesis that there is viable halophytic plant material contained within the wrack mats found on tidal wetlands in the Minas Basin, Bay of Fundy can be confirmed.

All four objectives of this study were completed. The wrack material present on tidal wetlands in the Minas Basin, Bay of Fundy was characterized. It was determined that seed and rhizomal material were in fact present in the wrack and this seed and rhizomal material was found viable. It was also examined that target halophyte species *Juncus gerardii* and *Plantago maritima* were present in the wrack, but it was found that they were not represented as the dominant species for every site in the germination experiments. Target halophyte species *Spartina alterniflora* and *Spartina patens* were not found in the germination data.

This data responds well to the possibility of using wrack as an intentional mode of seeding newly restored tidal wetlands that may be having trouble establishing new plants. However, it is difficult to predict what plants are contained within the wrack before the plants undergo germination, begin to grow to a substantial size and can be identified. The data does provide a better understanding of wrack mats in general, which is understudied particularly in the Minas Basin, Bay of Fundy.

Future studies would give a better understanding and improved prediction of what plants may be contained in the wrack. In the future, studies regarding the methods of plant colonization of halophytic vegetation should be considered to assist in a better comprehension of plant related processes in the Bay of Fundy. With more time and resources, it would be interesting to determine differences between wrack in different kinds of coastal marshes systems (open versus riverine) or consider collecting wrack at a different period of time (perhaps later in the season) to see how the success of species changes in comparison with this study. Also, the

study completed on the green roof could be recreated in more normal and encouraging weather conditions for plant success.

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