CB Wetlands &
Environmental Specialists

A Report for:
Nova Scotia Department of
Transportation and Infrastructure Renewal

Post-Restoration Monitoring (Year 4) of the St. Croix River High Salt Marsh & Tidal Wetland Restoration Project

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Executive Summary

Efforts by Nova Scotia Department of Transportation and Infrastructure Renewal (NSTIR) to restore tidal flow and wetland habitat conditions to the four quadrants of dykeland at the intersection of Highway 101 and the St. Croix River began in 2007 with the completion of a restoration feasibility study. It was determined that breaching the agricultural dykes would result in the periodic flooding of the sites leading to the re-establishment of wetland habitat conditions. Baseline ecological monitoring and restoration design took place between 2007 and 2009 leading to the actual restoration (earthworks) in 2009. It was determined that restoration activities would re-establish the four study sites to wetland habitat as part of the Thumbhill Creek and St. Croix River coastal floodplain ecosystem and result in the:

- Re-establishment of a more natural connection between each of the sites and the larger St. Croix tidal river system;
- Re-development of a more diverse range of habitat conditions (from tidal brackish, to tidal fresh, to freshwater wetlands grading into coastal floodplain and riparian habitat);
- Improved fish passage to the sites and access to the marsh surfaces;
- Creation and enhancement of bird and waterfowl habitat;
- Improved productivity and transport of materials (nutrients); and
- Allowance of each of the sites to re-establish a natural process of habitat succession.

Restoration activities were carried out in three phases during the summer of 2009 and consisted of breaching the dykes on each of the four sites in one or more locations; the excavation of tidal channels in order to reconnect original drainage basins and creek networks to the river; and the creation of shallow water ponds on the largest site (SCW: Chapter 2).

A pre-and post-restoration monitoring program was developed for the project based on the experience with similar projects in the region (Chapter 3). In addition to the baseline monitoring activities, which were conducted in 2007 and 2008 (Bowron et al. 2008b; Bowron et al. 2009), a minimum of five years of post-restoration monitoring will be completed at the St. Croix study sites (SCW, SCE, SCS and SCP) and the reference site (SCR) in order to quantify environmental change in response to restoration, to facilitate adaptive management actions if required, and to verify project success. The fourth year of post-restoration monitoring commenced in July of 2013, the results of which are provided in the following report (Chapter 4), and a summary is provided below.

Geospatial Attributes

The total area of the SC restoration sites was delineated to approximately 18.13 ha with the addition of more accurate elevation and hydrological data collected in 2012. Low-altitude orthorectified aerial imagery of SCW was obtained in 2010 and 2012. The SCP, SCE and SCS study sites were photographed October of 2012, which enabled improved delineation of these sites over previous years. The habitat maps and the SC DEM will be further updated in Year 5 (2014) with data collected during that monitoring season.

Hydrology

Hydroperiod and Tidal Signal:

The highest tide level recorded for the sampling period 24 September to 07 November 2012 for SCW, SCP and the St. Croix River was 7.86 m, 8.01 m and 7.07 m respectively. The maximum recorded high tide in 2012 (7.90 m: CGVD28) covered 17.40 ha of the SC restoration sites. The plots at SCP were flooded on 0 – 20% of the high tides, compared to SCW which had a greater number of plots flooded at more than 30% of the high tides. The plot inundation frequency at SCR was similar to that of SCP. The tidal signal will be measured again in Year 5 (2014) of the monitoring program.

Water Quality:

For the 2013 sampling events that occurred within the site at SCW (aboiteau channel) during nekton sampling, the salinity ranged from 2.5 ppt in September to 0.8 ppt in October. The salinity of the river water during high tide ranged from 0.0 ppt (surface) to 5.8 ppt (at depth; 2.5 m). The other parameters measured were within the expected range for estuarine habitat.

Soils and Sediments

Pore Water Salinity:

Salinity readings at SCW and SCP have increased from pre-restoration readings of 0.0 ppt to a mean of 1.58 ppt and 0.70 ppt respectively (includes all shallow and deep readings). The mean salinity reading at SCR was 0.97 ppt. No Significant differences were detected between shallow and deep readings at any site. Significant differences were, however, detected between sites for deep readings and shallow readings. For deep readings no significant differences were found between years at SCR or SCP, while shallow readings showed significant differences. SCW showed the opposite pattern, with deep readings showing significant differences and shallow readings showing no differences.

Sediment Accretion and Elevation:

At SCW, RSET-01 and RSET-04 saw an increase in the rate of surface elevation more than double that of the previous year. Conversely, RSET-02 and RSET-03 were close to half of the values reported in 2012. Over time the sediment accretion rates have decreased at all RSET locations, although there is still a net accretion over the four years of post-restoration monitoring. SCP was similar to SCW as higher rates of sediment accretion were also recorded for 2013. All RSETs at SCW and SCP recorded surface elevation changes much greater than SCR, with the exception of SCP_RSET-02, which has displayed the closest values to SCR (< 1 cm) in all years except 2013 (1.77 cm). Sub surface processes such as decomposition, compaction or de-watering of the deposited soils were recorded at all RSETs in 2012 and at SCP_RSET-01 in 2013.

Soil Chemistry (Redox Potential):

At SCR the values indicated that aerobic respiration was occurring at all sampling locations. At SCW, values indicated that aerobic respiration was only experienced at two locations. Conversely, at SCP values indicated aerobic respiration at all but three locations. SCP had the closest values to SCR compared to the other restoration sites. Overall, the values indicated moderate anaerobic stress on vegetation with the potential for moderate decomposition rates to occur within the soil under these anaerobic conditions. There is potential for sulfide, a known phytotoxin, to accumulate within the soil. However, sulfate reduction was not the dominant redox reaction being measured at any of the SC restoration sites; therefore, high levels of sulfide are not expected to accumulate. An additional year of data collection should provide some insight into whether the SC restoration sites are trending towards conditions at SCR or if a greater anaerobic stress is expected in the future.

Vegetation

Species richness increased between pre- and post- sampling at most sites. Halophytic richness increased significantly at SCP, SCW and SCP-fringe between pre- and post-restoration sampling, especially at SCW, but has been relatively constant since 2011 at these sites. Halophytic abundance was greatest at SCS-fringe, which contains just two plots that have relatively high abundances of *S. pectinata*. Halophytic species abundances increased significantly at SCW and SCP over the study period; SCE showed an increase in 2011 followed by decline to previous levels by 2012, and an increase again in 2013 (due to fluctuations in *S. pectinata* plot frequency). The largest increase was between 2010 and 2011 for SCW, with 2012 and 2013 levels staying high but not increasing. Most of these increases are accounted for by *Spartina pectinata*, which increased at SCW and SCP sites in both coverage and frequency. The other sites (reference, SCS and the fringe sites) did not show consistent changes over the same time period. The amount of unvegetated area was highly variable from year to year, with notable increases at SCW between pre-restoration and 2010, and then a decline between 2010 and 2013.

Nekton

Over the first three years of post-restoration monitoring, six different species were caught in the minnow traps and fyke net at SCW. In 2013, the numerically dominant species caught in the fyke net were *Anguilla rostrata*, and *Microgadus tomcod*. *Fundulus heteroclitus* were the only species captured in the minnow traps in 2013. Over the four years post-restoration, the presence of a large number of juvenile striped bass, tomcod and (*Anguilla rostrata*), as well as a large number of *Fundulus heteroclitus* utilizing the ponds and the harbour porpoise and sturgeon remains discovered on SCW in 2009 and 2013 respectively, are all evidence of the importance of tidal wetlands, and SCW in particular, as fish habitat.

Benthic and Other Aquatic Invertebrates

Benthic Invertebrates:

It was found that, similar to 2012, the samples collected at SCW, Sweet's Corner and SCR four years post-restoration were not statistically different. The species found in the samples at the highest numbers were species of the sub-class Oligochaetes. In 2012, *Corophium volutator* was found in the Sweet's Corner samples, but not at SCW or SCR and this year (2013), *Corophium volutator* was found at each sampling location.

Aquatic Invertebrates:

There were over 60 species found at the three sampling locations (SCW, SCP_Pond and SCP_Channel) during the post-restoration monitoring program data collection. Of note was the presence of juvenile American eel (*Anguilla rostrata*; elvers) in the IAT samples from both ponds at SCW. It was found in 2013 (Year 4) that SCW was statistically different from SCP_Channel and from SCP_Pond. In 2012 the results showed that SCW and SCP_Channel were not statistically different. Similar to 2012, it was found in 2013 that SCP_Channel was not statistically different from SCP_Pond. For species richness, the SCW samples were found to be statistically different from SCP_Channel, opposite to 2012 findings, and SCW was statistically different from SCP_Pond. At SCP, the samples from SCP_Channnel and SCP_Pond were found to be statistically different. Overall, the abundance numbers were found to be low across all samples.

Summary

The results of the fourth year of post-restoration (2013) monitoring of the St. Croix River High Salt Marsh & Tidal Wetland Restoration project were presented in this report. The goal of the monitoring program was to provide a scientific record of habitat conditions at both the restoration and reference sites, to document the change in physical and biological conditions in response to manipulation and to facilitate adaptive management if warranted.

Prior to restoration, the SC restoration sites were fallow agricultural lands, with only one of the four sites (SCW) used intermittently as marginal grazing land for a small number of cattle. The restoration of these sites, which included dyke breaching and channel excavation, re-established tidal flooding of the former dykelands upon completion of restoration activities. The result was a more natural hydrological regime; a rapid influx of sediment (increase in marsh surface elevation); a shift in vegetation community assemblage (decrease in pasture weeds and increase in fresh, brackish and halophyte species); an increase in soil water content and salinity levels; creation of new habitat for birds and waterfowl; restored fish access and an increase in fish habitat.

The vegetation at SCW has not yet reached equilibrium at year four, with individual plots still changing vegetation type year to year. In addition, with the continued sediment deposition, there is continued disturbance potential at the site, which can allow for vegetation colonization of differing species at certain areas. With the initial high sediment deposition at SCW there was concern that the agricultural layer would decay, creating an anoxic layer with a subsequent vegetation die-back. Soil chemistry readings taken in year four revealed that this was not occurring at the present time. The values indicated anaerobic respiration was present, but sulfate reduction was not the dominant redox reaction; therefore, sulfide, a known phytotoxin, was not accumulating in the soils. SCW differs from the other restoration sites as it receives flooding on a greater number of tides than the other three sites. SCW appears to be located at the turbidity maximum (upstream limit of the tidal salt wedge) and has the potential for sediment to be sequestered on the incoming tide at SCW thereby lower sediment accretion rates at SCP. SCP differs from SCW in most parameters and is the most similar to the reference site four year post-restoration than the other SC restoration sites. There have been little to no changes at the reference site over the duration of the monitoring program.

In year five (2014) data will be collected for all parameters including geospatial attributes, hydrology, soils and sediment, nekton and vegetation, giving a more complete picture of the changes that have and are occurring at the SC restoration sites. Thus far the St. Croix River High Salt Marsh & Tidal Wetland Restoration project has been successful in restoring tidal wetland physical and biological conditions from fallow agricultural sites, without the need for additional manipulations beyond the original restoration activities.

Acknowledgments

This project would not have possible without the tireless efforts of Dr. Bob Pett (Environmental Services – NS Department of Internal Services) and Ken Carroll (former employee: Land Protection Services - Nova Scotia Department of Agriculture [NSDA]). Their efforts to obtain project approval, secure the land, and to assist with project design and construction were what made this project happen. Thank you as well to the staff at Nova Scotia Department of Environment, Department of Natural Resources (DNR) and Fisheries and Oceans Canada for their contributions to the design and support of the project.

Financial and in-kind supporters of this project include: NSTIR, NSDA, Natural Sciences and Engineering Research Council of Canada (NSERC), Employment and Social Development Canada, Community-Based Environmental Monitoring Program (Saint Mary's University (SMU)), Maritime Provinces Spatial Analysis Research Centre (MP_SpARC: SMU), the Intertidal Coastal Sediment Transport Research Unit (In_CoaST: SMU) and the Ecology of Plants In Communities Research Lab (EPIC: SMU).

1.0 Introduction

When it was determined that on-going efforts to twin Highway 101 would result in unavoidable alteration to several wetlands, including the Ben Jackson Wetland (NSE Approval No. 2006-054136) and Meadow Pond (NSE Approval No. 2008-063206 and DFO HADD Authorization No. 08-HMAR-MA7-00067), CBWES Inc. was commissioned by NSTIR to develop a wetland and fish habitat compensation (restoration) proposal (Bowron and Neatt 2007). The proposal detailed the restoration of four fallow dykeland sites along the St. Croix River (West Hants County, NS). The four sites bordering the Highway 101/St. Croix River crossing were suggested to NSTIR by NSDA as potential wetland restoration sites.

In 2007, in order to complete the compensation proposal, a feasibility study was conducted which included an elevation survey of three of the four sites, development of a digital elevation model (DEM) and flood model, consultation with NSDA staff, and the development of a restoration design proposal and monitoring program (Bowron and Neatt 2007). Baseline data was collected on these three sites as well as a reference site during the 2007 monitoring season (Bowron et al. 2008). In 2008, baseline monitoring for the fourth site was completed as well as the restoration design (Bowron et al. 2009; Graham et al. 2008).

Based on the feasibility studies, it was determined that if the agricultural dykes were to be partially (or completely) removed, the periodic flooding of the sites by tidal waters would have the potential to create a very dynamic and productive wetland habitat. Dyke removal and the re-activation of tidal creek networks within the sites to re-connect the wetlands to the adjacent watercourse, along with the re-direction of surface runoff and the creation of one or more ponds, would re-create a tidally influenced brackish (high salt marsh) and floodplain wetland complex that was present prior to the sites being dyked. It was determined that restoration activities would re-establish the four study sites as part of the Thumbhill Creek and St. Croix River coastal floodplain ecosystem and result in the:

- Re-establishment of a more natural connection between each of the sites and the larger St. Croix tidal river system;
- Re-development of a more diverse range of habitat conditions (from tidal brackish, to tidal fresh, to freshwater wetlands grading into coastal floodplain and riparian habitat);
- Improved fish passage to the sites and access to the marsh surfaces;
- Creation and enhancement of bird and waterfowl habitat;
- Improved productivity and transport of materials (nutrients); and
- Re-establishment of a natural process of habitat succession at each of the four sites (Bowron and Neatt 2007).

Restoration activities (construction) were carried out in three phases during the summer of 2009 (see Chapter 2), according to the design proposal (Graham et al. 2008), after one year of baseline (pre-restoration) monitoring was completed (Bowron and Neatt 2007). Long-term, post-restoration monitoring (minimum five years) of the St. Croix Restoration site began in 2010 in order to quantify environmental changes and verify project benefits and success.

All aspects of this project were conducted and supervised by CBWES staff and project partners, under contract to NSTIR. Field and laboratory work was carried out by: Tony M. Bowron, Nancy C. Neatt, Jennie M. Graham, Christa Skinner and Carly Wrathall with CBWES; Dr. Jeremy Lundholm, Dr. Danika van Proosdij, Greg Baker (Mp_SpARC) with Saint Mary's University (SMU); and Patrick Stewart and Heather Levy (Envirosphere Consultants Limited).

1.1 Tidal Wetlands

There are three major types of tidal wetlands according to salinity: salt marshes, brackish wetland and freshwater tidal wetland (Coultas and Hsieh 1997; Tiner 2005). The freshwater tidal wetland represents the upstream end of the gradient of the three habitats and tends to be found just upstream of the salt front (MDFW 1999). Tidal freshwater wetlands are important to a mixture of fish species including freshwater, anadromous, estuarine and marine (Odum 1988). They are also important feeding, nesting and breeding habitat for birds such as waterfowl (mallards, American black duck), red-winged blackbird, kingfisher, osprey and great blue heron (MDFW 1999; NSDNR 1998). Brackish wetlands, found upstream in tidal rivers, have reduced salinity (half that of sea water to almost fresh) with vegetation diversity greater than that of salt marshes (Tiner 2005), as the salinity of salt marshes only allows for halophytes to survive. Salt marshes are highly productive and provide habitat to many species of wildlife including fish, mammals and birds (waterfowl and shorebirds). It is anticipated that elements of all three wetland types will be present at the St. Croix Restoration sites, but that overall the sites will be pre-dominantly brackish and tidal fresh in nature. Wetland habitat recovery will be analyzed by the post-restoration monitoring program (Chapter 3).

1.2 CBWES Inc.

Since 2005, CBWES has been involved in the restoration and monitoring of ten tidal wetland restoration projects within NS in collaboration with NSTIR[1]. These projects, in particular, the design and monitoring activities, have been presented by CBWES staff in poster and oral presentation formats at a number of regional, national and international scientific conferences[2]. Please contact CBWES for more information on these presentations. CBWES is committed to continuing to participate in important events such as these.

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[1] Cheverie Creek, Walton River, Lawrencetown Lake, Smith Gut, St. Croix River, Cogmagun River, Antigonish Landing (in collaboration with CBCL Ltd.), Three Fathom Harbour, Tennycape and Morris Island (Bowron et al. 2011a,b,c; Bowron et al. 2012b,c; Bowron et al. 2013a,b,c,d; Bowron et al. 2014a,b; CBCL 2011; Neatt et al. 2013; van Proosdij et al. 2010).
CBWES reports available for download at www.gov.ns.ca/tran/enviroservices/enviroSaltMarsh.asp)

[2] 6th Annual Atlantic Reclamation Conference (ARC 2013); Coastal and Estuarine Research Federation 22nd International Conference (CERF 2013); 2013 Mid-Atlantic Living Shorelines Summit (RAE 2013); Atlantic Canada Coastal and Estuarine Science Society 2012 (ACCESS 2012); BoFEP's 9th Bay of Fundy Science Workshop (BoFEP 2011); Coastal and Estuarine Research Federation's 21st International Conference (CERF 2011); Restore America's Estuaries 5th National Conference on Coastal and Estuarine Habitat Restoration (RAE 2010); Atlantic Reclamation Conference (ARC 2008; 2009, 2010); Coastal and Estuarine Research Federation's 2009 International Conference (CERF 2009); BoFEP's 8th Bay of Fundy Science Workshop (BoFEP 2009); Canadian Water Resources Association - Maritime Water Resources Symposium (CWRA 2008); Atlantic Canada Coastal and Estuarine Science Societies' 2008 conference (ACCESS 2008); Estuarine Research Federations' 2007 International Conference (ERF 2007); Canadian Land Reclamation Associations National Conference (CLRA 2007); Ecology Action Centre's "Six Years in the Mud – Restoring Maritime Salt Marshes: Lessons Learned and Moving Forward" workshop (EAC 2007).

CBWES has a strong research partnership with SMU. Through this partnership, a number of undergraduate and graduate level research projects involving the restoration project sites have been supported. As a recognized Industrial Partner with the Natural Sciences and Engineering Research Council of Canada (NSERC), CBWES Inc. received NSERC grants for six of these projects (four undergraduate and two graduate). The resulting theses are available from the SMU library. Summaries of these salt marsh restoration research projects, as well as the non-NSERC funded current and completed projects are provided in Appendix A.

To date, two peer-reviewed papers have been published focusing on separate restoration projects. One was published in *Restoration Ecology* on the Cheverie Creek Restoration Project titled "*Macro-Tidal Salt Marsh Ecosystem Response to Culvert Expansion*" (Bowron et al. 2011a) and the second appeared in the journal *Ecological Engineering* on the Walton River Restoration Project titled *Ecological Re-engineering of a Freshwater Impoundment for Salt Marsh Restoration in a Hypertidal System* (van Proosdij et al. 2010). A third paper, "*Classification and environmental correlates of tidal wetland vegetation: implications for ecological restoration and monitoring"* is being peer-reviewed for publication in the journal *Estuaries and Coasts* (Porter et al. submitted). A book chapter has also recently been published titled "Chapter 13 – Salt Marsh Tidal Restoration in Canada's Maritime Provinces" in *Tidal Marsh Restoration: A Synthesis of Science and Management* (Roman et al. 2012). Abstracts for each of these publications appear in Appendix A.

1.3 Purpose and Rational for 2013 Study

The purpose of this project was to conduct the fourth of the required five years of post-restoration monitoring of the St. Croix River High Salt Marsh and Tidal Wetland Restoration Project. The intent of this program was to document and determine the nature of the changes at the restoration site (SCW, SCE, SCS, SCP) in response to the restoration activities and the return of tidal wetland features and functions (natural connection between the sites and the St. Croix River; fish access to the marsh surface and pannes/ponds; improved productivity and transport of materials) and the re-establishment of a self-sustaining system over time.

In order to document the restoration trajectory and determine project success (restored marsh exhibits similar physical, chemical and biological characteristics as the reference site), a suite of ecological indicators representative of the structure, function and composition of natural salt marshes were monitored. The suite of indicators were drawn primarily from a tidal wetland restoration monitoring protocol for the assessment of tidal restoration on salt marshes in the Gulf of Maine and Bay of Fundy, and included hydrology, soils and sediments, vegetation, fish, and invertebrates (Neckles and Dionne 2000; Neckles et al. 2002; Weldon et al. 2005). The changes in physical, chemical and biological indicators over time (following construction) are being tracked against the conditions exhibited by the site prior to construction and those of an intact reference site in order to determine restoration success.

1.4 Report Organization

The focus of this report was to describe the fourth year (2013) of post-restoration monitoring activities and to continue the process of comparing the post-restoration habitat conditions to the conditions that were present prior to dyke breaching and to those exhibited by the reference site.

Information on the study and reference sites is provided in Chapter 2. An overview of the monitoring program and the parameter specific sampling techniques are given for each indicator category in Chapter 3. The results of the fourth year of post-restoration data collection and analysis, along with a discussion of these results are presented in Chapter 4. Chapter 5 is a summary and integration of the results and the implications of these findings for project progression. Chapter 6 contains recommendations for the fifth year of post-restoration monitoring. Appendices in the 2013 report provide: (A) CBWES supported student research project descriptions; (B) NMDS Ordination diagrams, (C) Vegetation Analysis Species Composition Tables; and (D) Photographic documentation of 2013/14 winter conditions.

2.0 Description of Restoration and Reference Sites

2.1 St. Croix River

Much of what was once tidal wetland habitat along the St. Croix River (West Hants County; Figure 1) has been historically dyked and converted to agricultural uses. Many of the dykes, and the former wetland habitats behind them, have been in agricultural production for over 200 years. In recent years, due to economic pressures and changing agricultural and land-use practices, a number of these dykeland areas along the river have been left fallow, significantly underutilized, or have become economically unviable. Four such fallow dykeland sites border the Highway 101 where it crosses the St. Croix River (Figure 1). As part of the Highway 101 expansion project, an additional two lanes of 100-Series Highway (arterial highway) and an overpass spanning the St. Croix River channel were constructed.

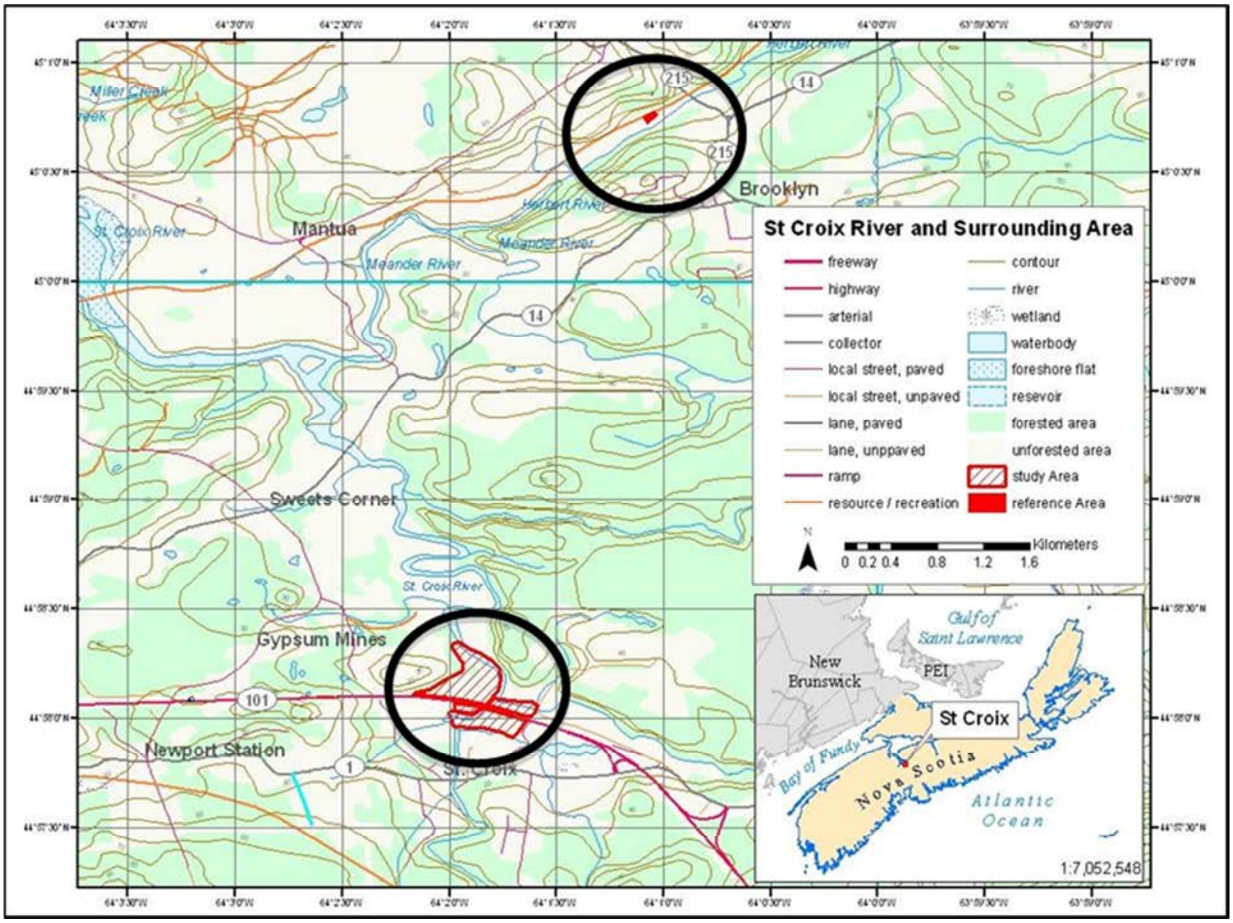

Figure 1 Location of the St. Croix Study and Reference Sites (within black circles).

2.2 Restoration Sites (SCW, SCE, SCS, SCP)

The restoration site consists of four separate areas divided by the Highway 101 and the St. Croix River: St. Croix West (SCW); St. Croix East (SCE); St. Croix South (SCS); and Southeast Parcel

(SCP) (Figure 2). SCW is the largest of the four sites at approximately 10.03 ha[3] (100,300 m^2) and was mainly pastureland (cattle) dominated by a variety of grasses, *Rosa virginiana,* and *Juncus effusus* (wet areas) prior to restoration. SCW contains a network of agricultural drainage ditches leading to one main aboiteau (Figure 2 to Figure 5). Two areas of higher elevation (islands) are present within the site, which have a mixture of pasture grasses, shrubs and trees. Cattle had access to the site up to the time of construction in 2009. There was evidence of their presence immediately post-construction, but this has been resolved and the cattle have since been restricted from the site. Notable changes post-restoration at SCW included colonization by *Alopecurus* sp., *Typha angustifolia*, *Spartina alterniflora, S. pectinata, Atriplex sp., Elymus repens* (not native but common in the upper edges of salt marshes)*, Polygonum hydropiper, and Scirpus validus. Carex paleacea*, a high-marsh/brackish species was observed for the first time three years post-restoration. A wide range of bird species have been observed on the site since restoration including Great Blue Heron (*Ardea herodias*), Canada Geese (*Branta canadensis*), and Northern Harrier (formally Marsh Hawk; *Circus cyaneus*). In 2011 red-winged blackbirds (*Agelaius phoeniceus*) were sighted at SCW (August) for the first time. As well as birds, several other notable species have been observed on site, including a dead harbour porpoise (*Phocoena phocoena*; 8 October 2009) on the marsh surface in the middle of site, a live snapping turtle (*Chelydra serpentina*) in one of the created channels (22 June 2010) and the remains of a Sturgeon species (Acipenseridae sp.) near the aboiteau channel in 2013.

SCE is 1.46 ha (14,600 m^2), and had been seasonally mowed by NSDA as part of the dykeland maintenance program prior to restoration (Figure 3b and Figure 5b). Post-restoration, this site has been colonized by a few freshwater wetland species such as *Polygonum hydropiper*, *P. persicaria*, *Rorippa palustris* and *Scirpus acutus*, and there has been a loss or decline of some pasture weeds such as *Filipendula ulmaria* and *Taraxacum officinale*.

SCS, the smallest of the three sites, is located on the southern side of the Highway and is a 0.75 ha (7,500 m^2) catchment area for runoff water from the ditch which borders the southwest side of the Highway (Figure 3a and Figure 5d). This site had some areas dominated by brackish species (*Agrostis stolonifera, Spartina pectinata*) and others a mix of pasture weeds or freshwater wetland vegetation.

SCP was comprised of a section of fallow agricultural dykeland bordering the main river channel, a treed area along the south-eastern edge of the site, three freshwater ponds and a cattail (*Typha latifolia*) swamp (Figure 3d,e and Figure 5c). This 5.89 ha (58,900 m^2) site, a former field and gravel pit (cattail and pond area), has experienced large increases of the vegetation species *Alopecurus pratensis*, *A. geniculatus* and *Spartina pectinata*. Notable decreases in the number of plots containing *Solidago* sp. were also seen (2011), suggesting a change from a more terrestrial environment to a brackish wetland environment.

Restoration Overview

Restoration (earthworks) took place in three phases between May – August 2009. A total of eleven breaches were made in the dykes during the second and third phases of construction. All breaches and channels were excavated to the dimensions indicated in the original restoration design (Graham et al. 2008). Channels were constructed with an approximately 2 m wide

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[3] The areas for all sites were re-calculated with the data collected during the 2012 field season, including aerial photography.

bottom, a zero degree slope for 80% of the distance from the river edge grading up to meet the marsh surface over the remaining 20%. Channel sides had a 3:1 slope (Bowron et al. 2009).

The first phase, involved the excavation of two ponds on SCW. Ponds were constructed to a depth of approximately 0.5 m and with an irregular shape. The second phase involved two breaches in the dyke surrounding SCP and a channel in the location of the aboiteau, which was removed, as well as a single breach made in the SCS dyke. The third phase involved six breaches in the dyke on SCW and two breaches at SCE; excavation of multiple tidal channels; burying two aboiteaux (on the recommendation of NSDA) and constructing a new protective dyke along the eastern end of SCE in order to protect Rocks Road and Highway 101 infrastructure.

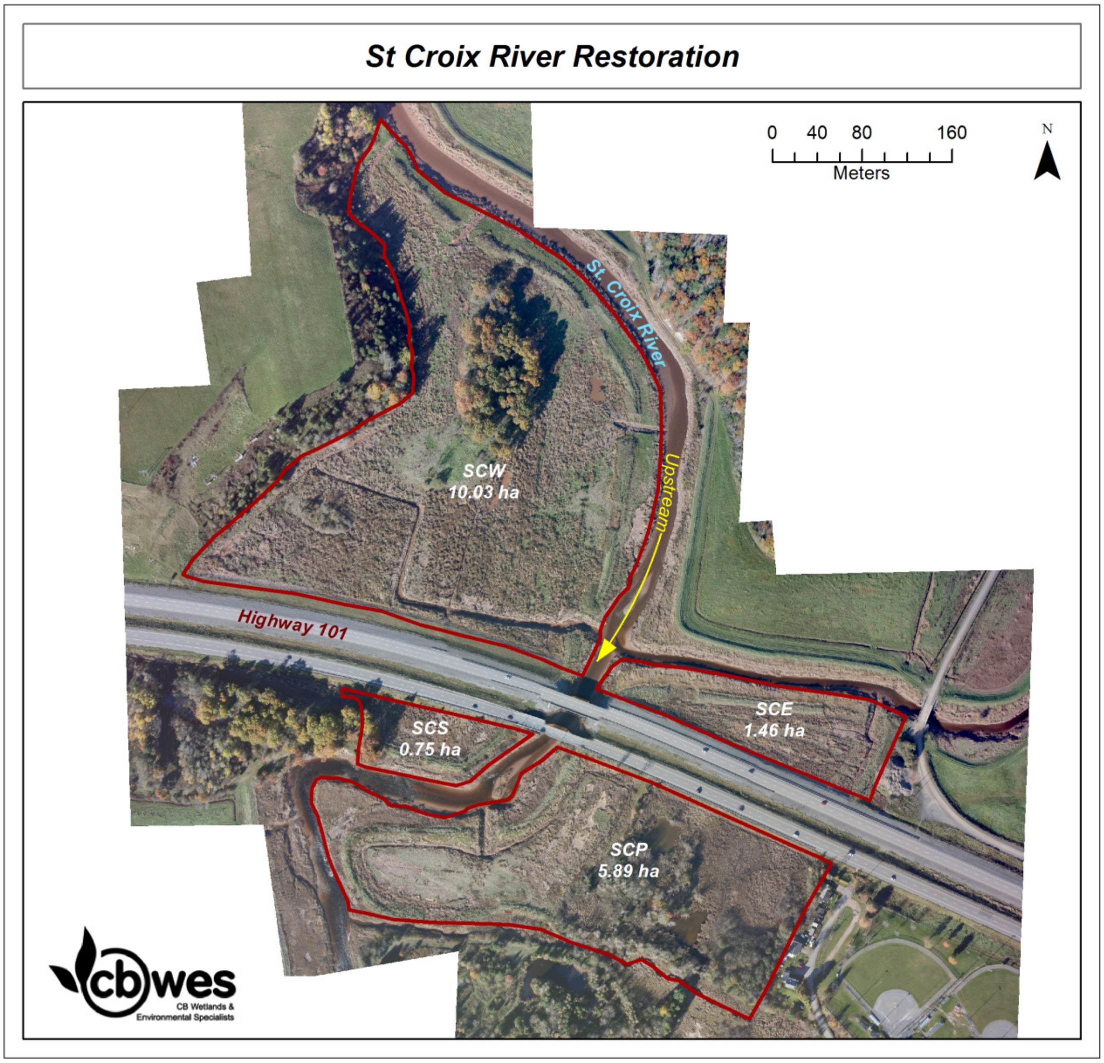

Figure 2 The four St. Croix River restoration project sites (SCW, SCE, SCS, and SCP). 2012 mosaic created with Gaiamatics Solutions Inc. aerial imagery.

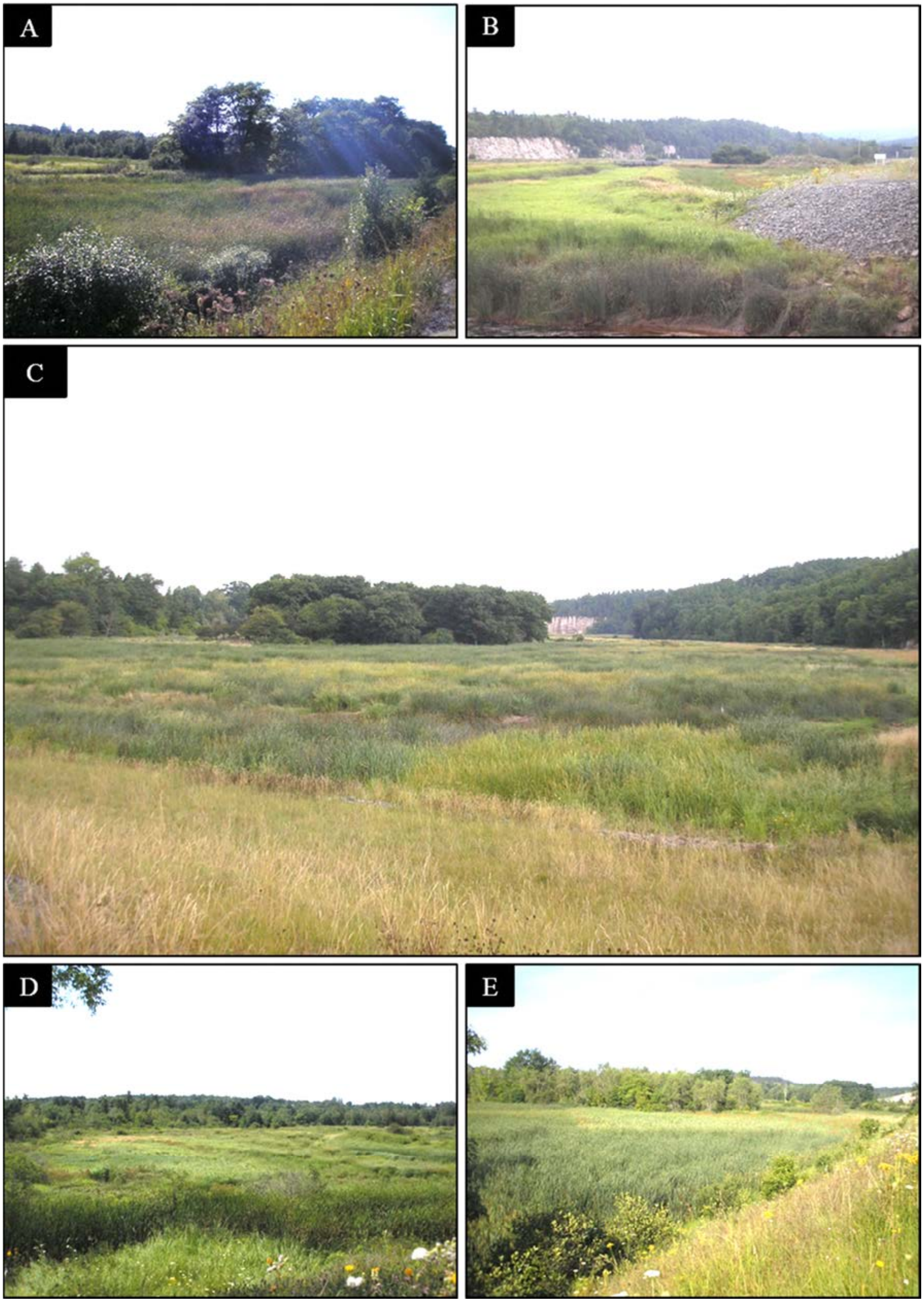

Figure 3 St. Croix Restoration sites: A) SCS; B) SCE; C) SCW; D) SCP front portion; and E) SCP back portion taken from eastern corner. Photographs taken by CBWES Inc., August 2012.

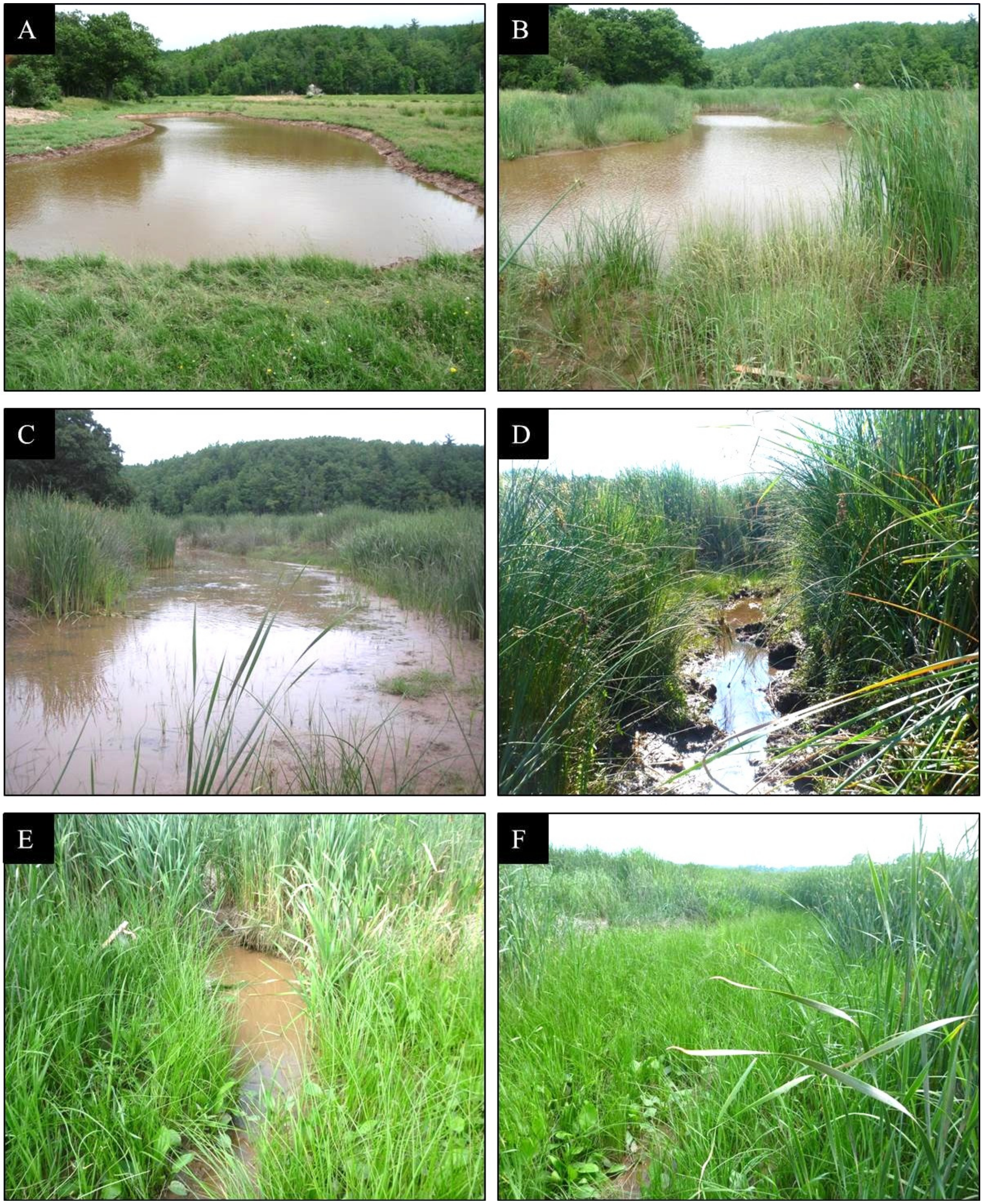

Figure 4 Sediment deposition and vegetation infilling of SCW constructed pond (south) a) immediate post-construction (July 2009); b) one year post (July 2010); c) two years post (August 2011); d) three years post (July 2012); and e/f) four years post (July 2013). Photographs taken by CBWES Inc.

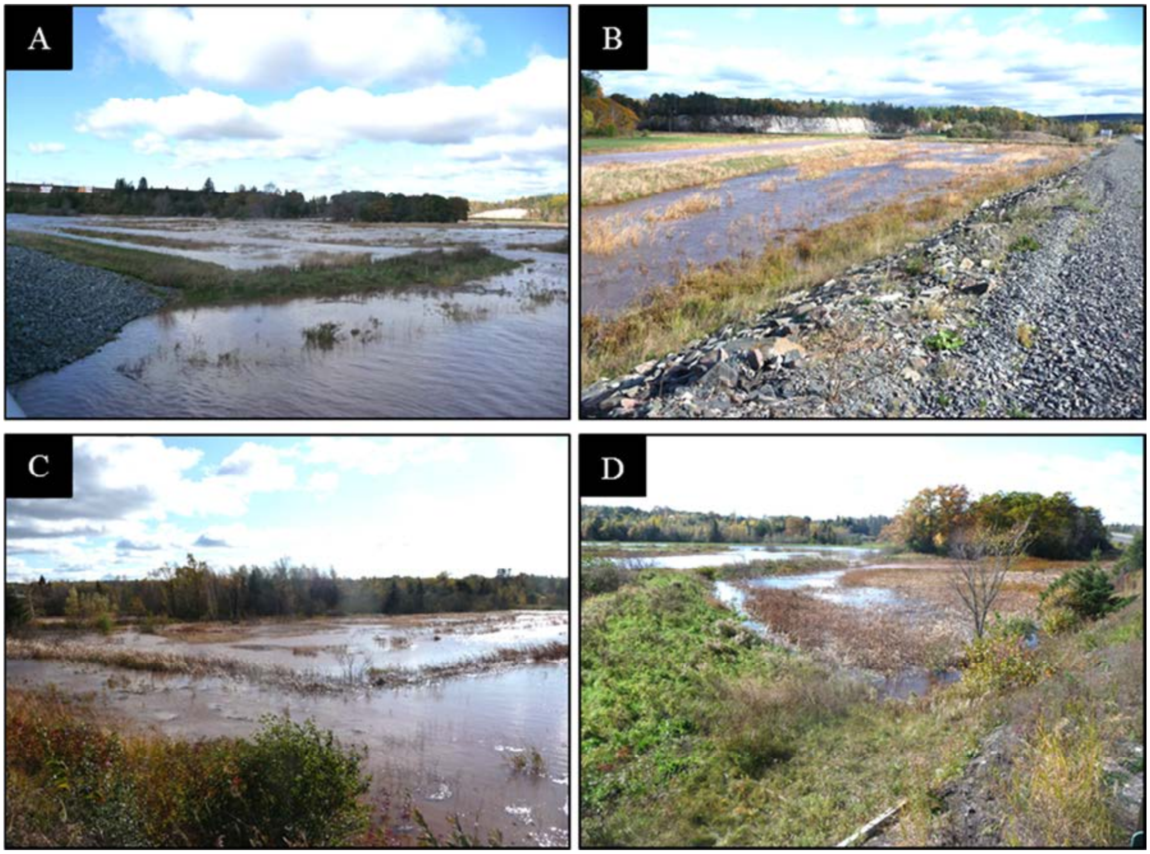

Figure 5 Spring tide event flooding the marsh surface at A) SCW; B) SCE; C) SCP; D) SCS. Photographs were taken on 26 October 2011 at approximately peak high tide. Predicted tide elevation at Hantsport, NS was 14.75 m (Chart Datum). Photographs taken by CBWES Inc.

2.3 Reference Site (SCR)

A section of marsh along the north branch of the St. Croix (Herbert River) was identified as a suitable reference site for this project (Figure 6 and Figure 7). This site exhibited similar hydrological and sedimentological conditions as those present at the restoration sites. This reference site is one of the few remaining undyked sections along the tidal component of the St. Croix River system that was also readily accessible for study. The portion of the marsh that was used as the project reference site was 0.46 ha (4590.55 m^2). In addition, the fringe marsh areas between the dykes and the main river channel at the restoration site (St. Croix River and Thumbhill Creek) were also used as reference for elevation, soils and vegetation. The reference site is characterized by a mixture of pasture weeds (*Centaurea nigrum*, *Cirsium arvense*, *Filipendula ulmaria*, *Equisetum* and *Solidago* sp.) in some areas with a mixture of species characterized by brackish marsh species (*Calystegia sepia*, *Spartina pectinata*, *Galium palustre*, *Agrostis stolonifera)* in others.

Figure 6 SCR facing downstream near Line 2, 15 August 2012. Photograph taken by N. Neatt.

Figure 7 SCR facing upstream near Line 2, 15 August 2012. Photograph taken by N. Neatt.

3.0 Monitoring Program and Methods

3.1 Monitoring Program

A baseline and long-term monitoring program was developed for the St. Croix Restoration Project in 2007 to determine the baseline habitat conditions and to document the transition of the restoration sites (SCW[4], SCE, SCS, SCP) from non-tidal dykelands (agricultural pasture) to tidal wetland habitats following dyke removal (2009). The monitoring program for this project was based on the experience with similar restoration projects in the region (Bowron et al. 2011a; Neatt et al. 2013; Neckles et al. 2002; van Proosdij et al. 2010). The program was used in 2007 to document conditions at SCW, SCE and SCS and in 2008 at SCP to establish a baseline habitat condition against which future conditions could be compared, and to enable a comparison between reference site and restoration site conditions (Bowron et al. 2008; Bowron et al. 2009). Post-restoration monitoring activities commenced in the summer of 2010.

Annual monitoring during the first three years following restoration is critical because it is during these initial years following restoration that the greatest and most rapid changes are likely to occur. Monitoring of other tidal wetland restoration projects in the region have shown that although physical change can occur quite quickly and that the biological communities can be highly responsive, it can take many years, and be highly varied between sites, for conditions at restoration sites to approach those of reference sites (van Proosdij et al. 2010; Neatt et al. 2013). Monitoring beyond the first three years following restoration allows a greater period of time for change to occur, for the documentation of the longer term, often more gradual, changes in response to restoration and for conditions (e.g. soil salinity, vegetation species composition) to begin to show indications of parity with reference conditions (Able et al. 2008; Burden et al. 2013; Garbutt and Wolters 2008; Mitsch et al. 2012; Perry et al. 2001).

The monitoring program makes use of a suite of salt marsh indicators and data collection methods that have been tailored to this project, and which seek to characterize a broader range of tidal wetland ecosystem components. These indicators (geospatial attributes, hydrology, soils and sediments, vegetation, fish and invertebrates) are measures of wetland structure and function, and when applied pre- and post-restoration, collectively provide information on ecosystem status and response to restoration. The physical and biological parameters within each of these indicator categories and sampling schedule recommended for this project are identified in Table 1.

An adaptive management approach was integrated into the monitoring framework. For instance, if an indicator(s) appears to be developing as expected, the frequency at which the indicator is monitored can be decreased. Alternatively, if an indicator(s) is not progressing as expected, additional studies may need to be undertaken and/or the sampling frequency altered to better understand and quantify change in the indicator(s). In this way, the monitoring program will contribute to the overall management of the restoration site by identifying when the project is, or is not, reaching the expected outcome.

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[4] A greater emphasis will be placed on monitoring SCW and SCP as these sites are the largest of the four restoration sites, required the most manipulation, and which were anticipated to exhibit complex wetland habitat conditions.

Table 1 The St. Croix River Restoration monitoring program, including core and additional ecological indicators, methodologies, and sampling frequency (annual application indicated by X – all sites; S – restoration sites only; R – reference site only; Y – scheduled future sampling).

Category	Parameters	Sampling Method	Annual Sampling Frequency	Monitoring Year						
				Pre		Post-Restoration (2010-2014)				
				2007/08	2009	1	2	3	4	5
Hydrology	Tidal signal	Automated water level recorders (5 minute intervals) (Solinst Levelogger (Model 3001)	13/10/07 – 19/11/07; 02/12/10 – 21/12/10; 24/09/12 - 7/11/12	X	S	X		X		Y
	Surface water quality (flood waters)	YSI 650 MDS; YSI 556 MPS; pH Handheld DO Instruments	25/10/10; 31/08/11, 26/10/11; 17/09/12, 15/10/12; 20/09/13,7/10/13	S	S	S	S	S	S	Y
	Suspended Sediment Concentration	Teledyne ISCO 6712 Full Size Portable Sampler (SSC)	12/6/09 to 9/7/09 12/8/09 to 25/9/09		S					
Soils & Sediments	Marsh surface elevation	Digital Elevation Model (DEM). Total Station; Differential GPS; LiDAR	Once per required sampling year. SCW - 22/07/11	X		X	X	X		Y
	Interstitial pore water salinity	Sipper; Refractometer; FieldScout EC 110 Meter	SCW: 09/07 SCP: 11/09/08 SCR: 19/09/07; 11/09/08 All: 07/10 to 09/10; 06/11 to 09/11; 06/12 to 09/12; 07/13 to 09/13	X		X	X	X	X	Y
	Sediment elevation	Rod Surface Elevation Tables (RSET)	SCW: 6/08/09; 22/10/10; 18/11/11; 05/10/12; 25/10/13 SCP: 21/11/10; 24/10/11; 01/10/12; 23/10/13 SCR: 6/08/09; 21/11/10; 24/10/11; 01/10/12; 23/10/13	Installed (11/08)	SCW, SCR	X	X	X	X	Y
	Sediment accretion	Marker horizons (3 per RSET) sampled using a cryogenic corer (Cahoon et al. 1996).	SCW: 6/08/09; 22/10/10; 18/11/11; 05/10/12; 25/10/13 SCP: 21/11/10; 24/10/11; 01/10/12; 23/10/13 SCR: 6/08/09; 21/11/10; 24/10/11; 01/10/12; 23/10/13	X		X	X	X	X	Y
	Sediment Characteristics (bulk density, organic matter content, sediment type)	Sediment cores (soil samples) Paired samples: (30 ml syringe with base cut and 5 cm x 15 cm core). SCW-16; SCE-5; SCP-8; SCR-8	SCW: 21/11/07; SCE: 21/11/07; SCP: 30/10/08; SCR: 19/11/07 All: 08/10; 08/12	X		X		X		Y
	Soil Chemistry (Redox Potential)	Thermo Scientific Orion Star A221 milivolt meter with platinum	12/09/14, 16/09/14						S	Y

Category	Parameters	Sampling Method	Annual Sampling Frequency	Monitoring Year						
				Pre		Post-Restoration (2010-2014)				
				2007/08	2009	1	2	3	4	5
		electrodes & accument calomel reference electrode								
Vegetation	Composition Abundance Height	Point Intercept Method (1 m^2 plots)	SCW: 13 & 17/09/07; 08/10; 29/07/11, 4/08/11; 17/07/12; 12 & 28/08/13, 26/09/13 SCE: 14/09/07; 08/10; 28/07/11; 18/07/12; 7 & 12/07/13 SCS: 17/09/07; 08/10; 5/08/11; 13/09/12; 16/09/13 SCP: 11, 15 & 24/09/08; 08/10; 4 & 5/08/11; 14 & 15/08/12 & 13/09/12, 6 & 9/09/13 SCR: 18/09/07; 5/09/08; 08/10; 10/08/11; 15/08/12; 17/09/13	X		X	X	X	X	Y
	Habitat map	Aerial photograph, DGPS/GIS, Total Station, LiDAR, Low-altitude aerial photography (blimp)	8/06/11, 1/09/11; 27/10/12	X		X		X		Y
Nekton	Composition Species richness Density Length	Minnow traps in pannes/ponds, tidal channels (small fish); fyke net (30 m x 1 m; 6 mm mesh) on marsh surface (all sizes)	25/10/10; 31/08/11, 26/10/11; 17/09/12, 15/10/12; 20/09/13,7/10/13			S		S	S	Y
Benthic and Other Aquatic Invertebrates	Abundance/species richness of intertidal benthic invertebrates	Ekman Dredge (SCW/SCR)	22/10/07; 24/09/08; 28/09/10; 16/09/11; 23/08/12; 12&16/09/13	X		X	X	X	X	Y
	Abundance/species richness of aquatic invertebrates	Invertebrate Activity Traps (IAT: SCW/SCP)	20/07/10, 02/09/10; 21/07/11, 18/09/11; 25/07/12, 14/08/12, 17/07/13, 22/08/13			S	S	S	S	Y
Winter Conditions	Ice/snow conditions	Structured winter walk; photographs along each transect	Once per year – 31/02/-8; 06/02/09; 10/03/10, 15/03/11, 25/03/11; 24/02/12; 06/03/13; 21/02/14	X	S	X	X	X	X	Y

3.2 Methods

Sampling was conducted at both the restoration and reference sites using transects (Lines) established in a non-biased, systematic sampling design (Figure 8). At each site, a permanent benchmark was installed and used to establish the first Line. Each sequential Line was then set using the location of the one previous. The Lines were permanently marked by a pair of wooden stakes (labeled as front stake and back stake) installed at the upland end of the Line. These Lines served to locate the sampling stations for each of the ecological variables monitored: SCW 35 Stations; SCS 10 Stations; SCE 14 Stations; and SCP 35 Stations. The set-up of SCW, SCE and SCS are further described in Bowron et al. (2008) and SCP in Bowron et al. (2009).

At SCR a drainage channel bisects the data collection area. The permanent benchmark used for site set up was installed adjacent to the drainage channel and then a Line was established 20m to the east and one to the west of the benchmark. An additional two Lines were set up on either side of the first two. This set up established four Lines and 19 sampling stations at SCR (Figure 9).

On all four restoration sites, sampling stations were set up on the dyke, fringe marsh and river edge. These additional stations were established to increase the number of reference stations available for comparison to conditions inside the dyke overtime. These stations would also capture any changes in habitat conditions at the location of dyke removal (restoration activities), if the additional station landed in this area.

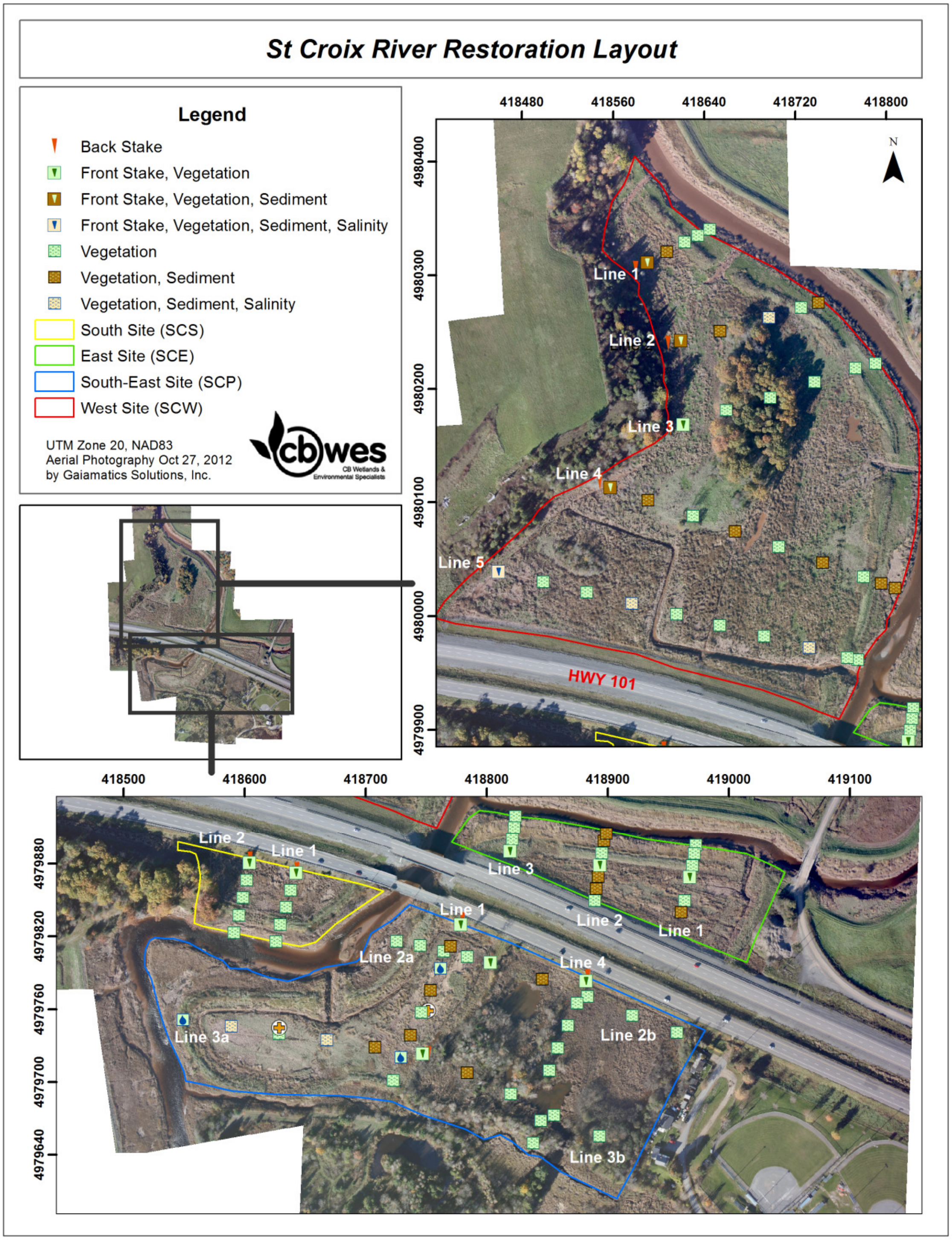

Figure 8 Sampling locations at the St. Croix restoration sites.

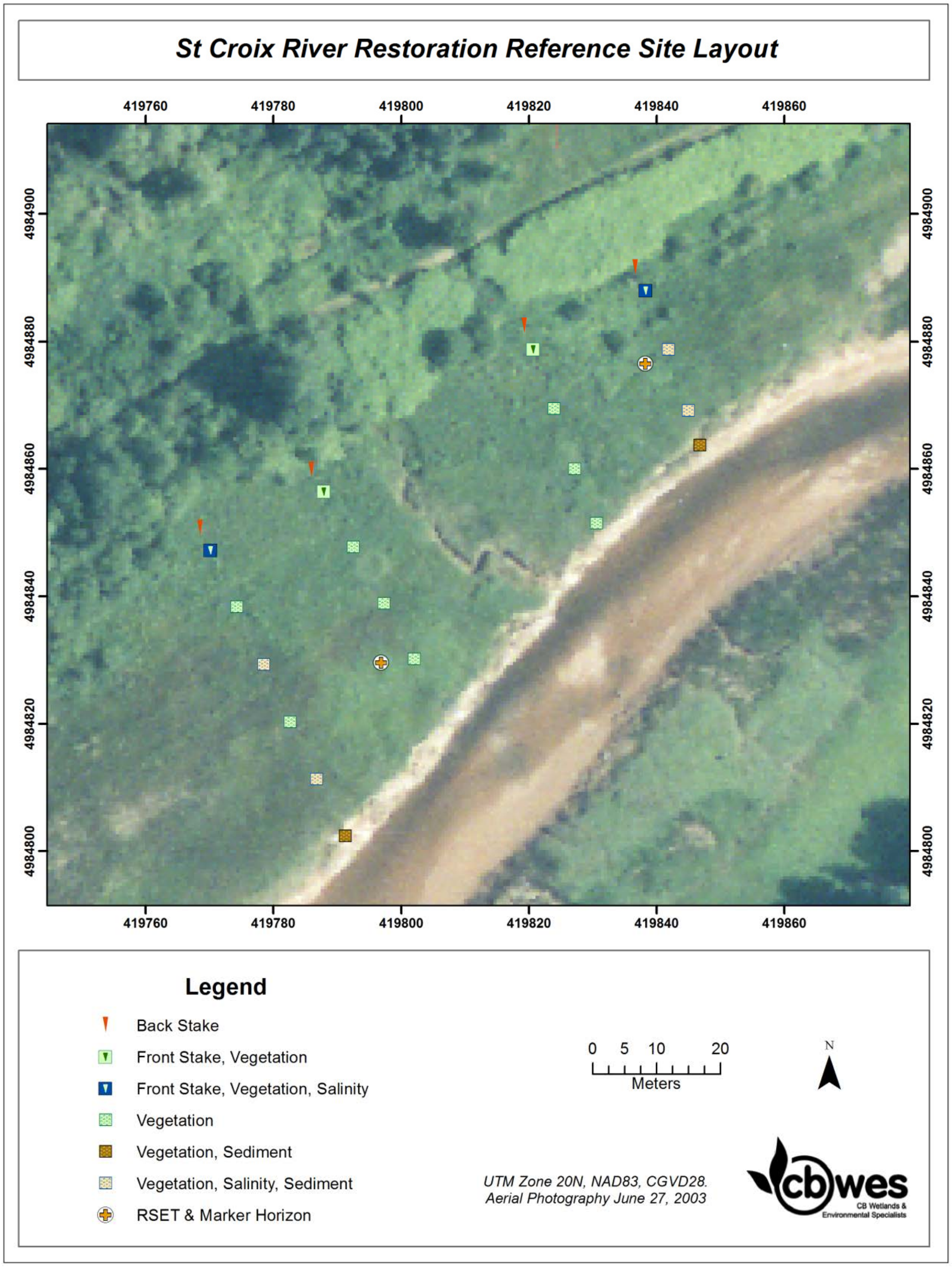

Figure 9 Sampling locations at St. Croix reference site.

3.2.1 Geospatial Attributes

Digital Elevation Model (DEM) and Habitat Map

Habitat maps were developed as part of the baseline monitoring program, to be updated during Year 1, 3, and 5 post-restoration and/or as new data was collected. Habitat maps provide a foundation for the monitoring activities and a baseline against which changes in habitat conditions post-construction can be compared.

The baseline habitat maps for the SC restoration and reference sites were developed/updated using LiDAR[5] data that was flown in April 2007, processed by the Applied Geomatics Research Group (Centre of Geographic Sciences), and provided to CBWES by SMU, NSTIR and NSDA (Bowron et al. 2008). The estimate of restorable area was determined using the original DEM for each site. In 2010 and again in 2012, the SC DEM and habitat maps were updated using surveyed elevation points (Trimble G8 GNSS RTK), contour data extracted from the LiDAR surface and aerial photography. The habitat maps and the SC DEM will be further updated in Year 5 (2014) with data collected during that monitoring season.

3.2.2 Hydrology

Hydroperiod and Tidal Signal

The hydroperiod (frequency and duration of tidal flooding) of the restoration site following restoration was modeled using the tidal signal (pattern of water level change with respect to a reference point) and marsh surface elevation (DEM). The tidal signal was measured in 2007 (pre-restoration), 2009 (for construction activities), 2010 (Year 1 post-restoration) and 2012 (Year 3 post-restoration) using a pair of Solinst Levelogger Gold (Model 3001[6]). The tidal signal will be measured again in Year 5 (2014) of the monitoring program.

Water Quality

A YSI 650 MDS Handheld Dissolved Oxygen Instrument[7] was used to measure four physical components of water: temperature (±0.1 C°), dissolved oxygen (DO) (± 0.1 mg/L), salinity (± 0.1 ppt) and pH. A minimum of two samples were taken per sampling event within 30 minutes of peak tide (spring tide). Sampling was matched in time with fyke net sampling (nekton survey): 20 September and 7 October 2013. Two measurements were taken within the main river channel (shallow and deep) and a series of measurements were taken at SCW (near the aboiteau channel) from the water’s edge bordering the toe of the Highway.

3.2.3 Soils and Sediments

Monitoring pore water salinity, sediment accretion rates, sediment elevation and soil characteristics can provide insight into the processes controlling vegetation type, cover, productivity and the vertical growth of a marsh following restoration (Neckles and Dionne 2000).

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[5] *LiDAR* (Light Detection and Ranging) ‘employs an airborne scanning laser rangefinder to produce detailed and accurate topographic surveys’ and provides superior accuracy to traditional survey methods in this context (USGS, 2007).

[6] www.solinst.com/Prod/3001/3001d2.html

[7] www.ysi.com

Pore Water Salinity

Interstitial pore water salinity is one of the main controls on the distribution and abundance of plants in a marsh (Niering and Warren 1980; Crain et al. 2004). Monitoring pore water salinity throughout the growing season can help explain changes in environmental conditions regulating plant growth, distribution, and abundance as well as overall habitat responses to restoration activities.

During the 2007 to 2010 monitoring seasons, shallow and deep pore water samples were taken using a soil probe (sipper; Roman et al. 2001) and a handheld temperature compensated optical refractometer (nearest 2 ppt). Since 2011, a FieldScout EC 110 Meter was used to collect data on pore water salinity (shallow and deep readings), as this meter allowed measurements to be taken *in situ*, and readings recorded in the field. Data was collected using both methods for at least one sampling event during the 2011 monitoring season.

Pore water salinity sampling was conducted monthly July to September at SCW (8 locations), SCP (7 locations) and SCR (6 locations), with an additional round of sampling in August due to a later start to the monitoring season. Sampling locations were matched with a select number of vegetation and sediment sampling stations (Figure 8 and Figure 9). Sampling was conducted at low tide during the neap tide cycle.

For SCW, SCP and SCR, descriptive statistics (mean, range, and standard error) were calculated for shallow and deep samples. These values were used to create histograms to illustrate temporal patterns. For tests comparing the study and reference sites (shallow and deep) a two-sample test was run, assuming unequal variances. All t-tests were run at a 95% Confidence Interval ($p<0.05$) in Microsoft Excel software.

Sediment Accretion and Elevation

Accretion of inorganic and organic material deposited onto the marsh surface by floodwaters and vegetation is one of the main processes that allow marshes to build vertically over time, offsetting increased tidal flooding. Failure to keep pace with increased flooding could result in the loss of salt marsh features and functions important to fish (loss of productivity and extent of habitat). Monitoring sediment accretion rates, elevation and determining organic content of marsh soils prior to engaging in restoration activities can reveal insights regarding pre-restoration conditions of the marsh (subsidence due to oxidation of organic matter in sediments) and the process of recovery following restoration.

Marsh surface elevation change (+/-1 mm) will be measured once per year using four rod surface elevation tables (RSET; Cahoon et al. 2002) at SCW, two at SCP (Figure 12) and two at SCR (Figure 9). The RSETs were installed and measured according to the methods developed by Cahoon and Lynch (Cahoon et al. 2002; USGS 2005). The 2009 RSET measurements provided a baseline elevation against which annual changes over the next five years will be compared. To determine the change in surface elevation between sampling years (e.g., 2013 and 2010), the difference in elevation at each pin was first calculated by subtracting the value in 2013 from the value in 2010. It was important that the same point was measured (e.g., same measurement direction and pin position). A mean was derived from all 36 net change values to give a mean net change in surface elevation in cm per year or in this example, from 2010 to 2013.

Vertical accretion at all sites was measured using feldspar marker horizons and a cryogenic corer as described by Cahoon et al. (1996). Three 0.5 m^2 marker horizons per RSET station were established at each site. Vertical accretion at each marker will be measured annually in conjunction with RSET sampling.

Changes in surface elevation measured by the RSET incorporate both subsurface processes such as root production and sediment deposition whereas sediment accretion measured by the marker horizon cores represents the amount of inorganic and organic material deposited by tidal waters on the marsh surface. Subtraction of the RSET and marker horizon values should provide a measure of the amount of change in surface elevation due to shallow subsidence processes such as root growth, compaction, decomposition and pore water flux (Cahoon et al. 2002). Both surface (e.g., accretion) and subsurface processes will be highly influenced by the elevation of the marsh surface within the tidal frame which affects the frequency and duration of inundation by tidal waters. Sediment accretion will also be affected by other factors such as the proximity to sediment source, for example, the tidal creek network (van Proosdij et al. 2006).

The RSETs and marker horizons were installed at SCW (four) and SCR (two) in 2007 and SCP (two) in 2008 (Bowron et al. 2008; Bowron et al. 2009). RSET measurements were taken at the time of installation and again in August of 2009 prior to dyke breaching due to the presence of cattle on SCW and the time between RSET installation and restoration. The RSETs and marker horizons were sampled at SCP and SCR on 23 October 2013 and at SCW on 25 October 2013.

Table 2 Coordinates and elevations of the RSET stations installed at the St. Croix Restoration sites. Elevations are in meters relative to the CGVD28 vertical datum.

Site	Station	Easting	Northing	Elevation
SCW	RSET-01	418749.814	4979986.161	6.84
	RSET-02	418607.152	4980128.823	6.61
	RSET-03	418726.680	4980235.820	6.94
	RSET-04	418623.539	4980298.475	6.97
SCP	RSET-01	418751.519	4979758.864	7.06
	RSET-02	418628.242	4979739.760	7.28

Analysis

Dr. Danika van Proosdij (SMU) conducted the RSET and marker horizon analysis presented in Section 4.3.

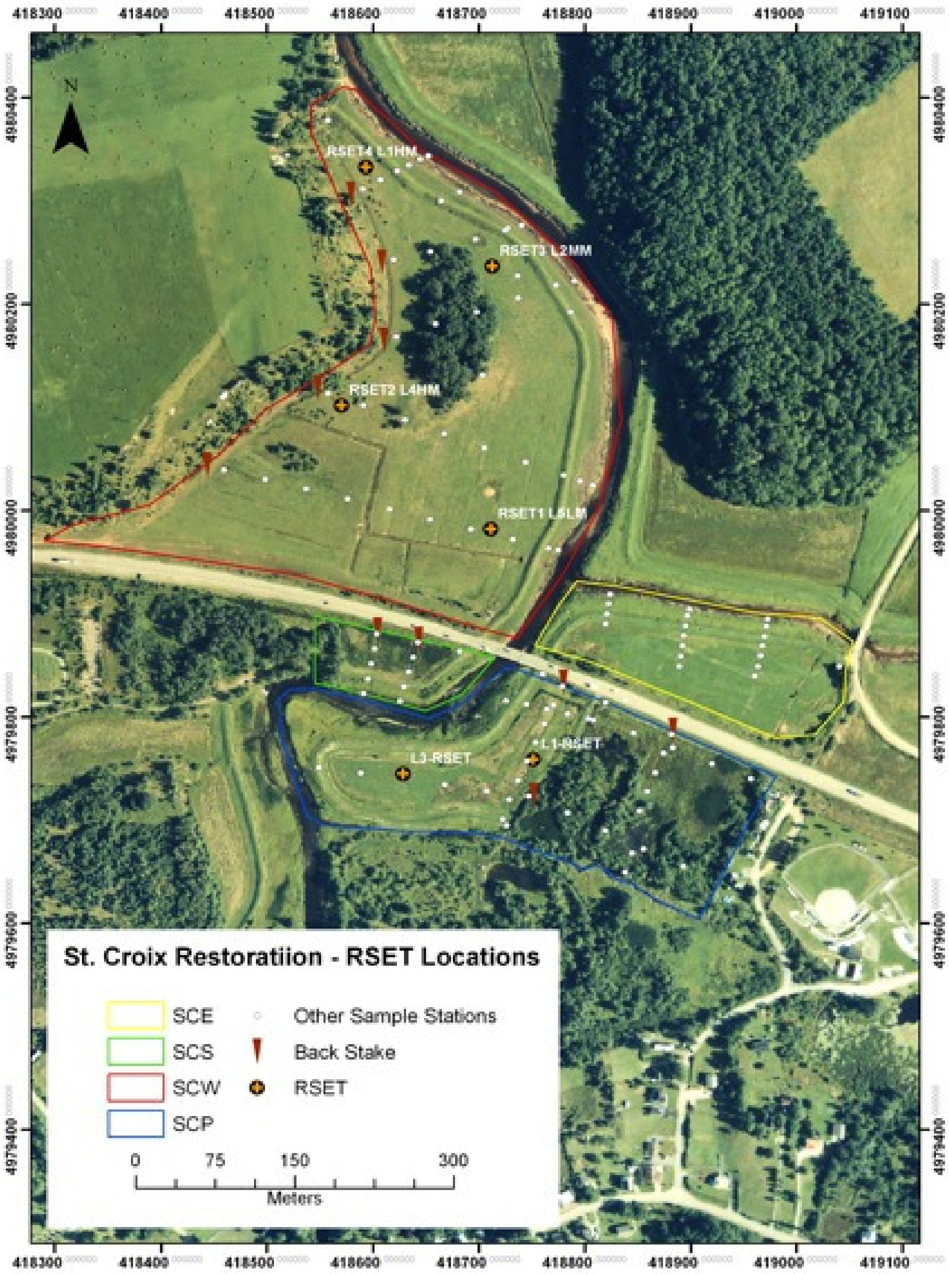

Figure 10 Position of RSET stations at SCW and SCP.

Sediment Characteristics

Marsh soil characteristics are determined by the sediment source and tidal current patterns (Mitsch and Gosselink 2007). Sediment type and particle size greatly influences soil aeration and drainage (Packham and Willis 1997). Silt, clay and sand are the different soil textures typical of salt marshes. Silt and clay materials tend to retain more salt than sand, and clay is the most absorptive (Mitsch and Gosselink 2007). Clay and silt are expected to dominate high marsh soils, while the low marsh is expected to have a higher proportion of sand (Packham and Willis 1997), however, this will vary depending on the source material.

Pre-restoration (2007/08), soil samples (cores) were collected at twenty-one locations within the restoration site (SCW: 16, SCE: 5, SCP: 8) and eight locations at SCR. Sampling locations were paired with vegetation sampling plots and analyzed for bulk density, organic content, soil texture (grain size & type as a percentage) and water content at the lab facilities at In_CoaST. The locations noted above were sampled in August 2010, August 2012 and will be sampled again during the fifth year (2014) of the monitoring program.

Soil Chemistry (Redox Potential)

Restoration of tidal water to a previously tide restricted site has been shown to drastically alter the biogeochemistry of marsh sediments, ultimately affecting vegetation re-colonization (Anisfeld 2012). The site conditions prior to restoration will govern the soil chemistry and long-term success of the restoration project. Reddy and DeLaune (2008) define biogeochemistry as "the study of the exchange or flux of materials between living and nonliving components of the biosphere". The processes that occur within wetlands at the surface or near-surface layers of sediments govern the biogeochemical cycles, productivity of plants, microbial transformations, nutrient availability, pollutant removal, exchange between atmosphere, water and sediment, and sediment transport (Reddy and DeLaune 2008).

Oxidation and reduction reactions represent a transfer of electrons either through donating or accepting an electron respectively. For microbial communities the most preferred electron acceptor is oxygen (Craft 2001; Reddy and DeLaune 2008; Portnoy 1999); however, oxygen found within the soil is rapidly consumed leading to a high electron pressure or reduced state (Colmer and Flowers 2008; Koch and Mendelsshn 1989). Alternative electron acceptors include (in order of decreased energy provided): nitrate (NO_3^-), manganese (IV) oxides (MnO_2), iron (III) oxides ($Fe(OH)_3$), sulfate (SO_4^{2-}), and carbon dioxide (CO_2) (Craft 2001; Reddy and DeLaune 2008). The reduction of these alternative electron acceptors not only reduces the amount of energy accessible to the microbial community, but many produce phytotoxins (e.g. hydrogen sulfide) that are detrimental to vegetation growth (Koch and Mendelsshn 1989).

Redox potential can be used as an indicator for the intensity of anaerobic conditions within the sediments (de la Cruz et al. 1989; Reddy and DeLaune 2008) and represents the dominant oxidation reduction reaction occurring at the time of the measurement (Reddy and DeLaune 2008; Table 3). Measuring redox potential of soils at representative locations throughout a restoration site reflect the interaction between hydrology, microbial activity, rhizome activity, sediment characteristics and amount of available organic matter and nutrients (Catallo 1999; Reddy and DeLaune 2008).

Table 3 Electron acceptors used by microbial communities and associated range of redox potential (Reddy and DeLaune, 2008).

Electron Acceptor	Reduced To	Redox Potential (mV)
Oxygen (O_2)	H_2O	> +300
Nitrate (NO_3^-)	N_2, NH_4^+	+300 to +100
Manganese (Mn^{4+})	Mn^{2+}	+300 to +100
Iron (Fe^{3+})	Fe^{2+}	+100 to -100
Sulfate (SO_4^{2-})	S^{2-}	-100 to -200
Carbon dioxide (CO_2)	CH_4	-200 to -300

Field Methods

Redox potential was measured at both sites on 12 and 16 September 2014 using a series of platinum electrodes, an accument calomel reference electrode and Thermo Scientific Orion Star A221 Millivolt Meter[8] (Figure 11). Platinum electrodes (probes) were constructed based on the design by Vepraskas and Cox (2002). Probes were calibrated in a mixture of quinhydrone and pH 4.00 buffer before use in the field to ensure accurate readings. Sampling locations (SCW 8; SCP 5; SCE 3; SCR 6) were matched with sediment sample locations (Figure 8 and Figure 9). A shallow and a deep measurement were taken at each sampling location using two probes inserted into the marsh sediment 2 cm and 30 cm respectively. At SCR soil compaction at some sampling locations hindered probe insertion to 30 cm; therefore, the probes were inserted to 20 cm. Probes were deployed 30 minutes before readings were taken to allow the probes to equilibrate. The reference electrode was inserted into the soil close to the probes at the time of measurement. Measurements from the two probes were taken by individually connecting the probe to the Meter and waiting for the Meter to stabilize (max five minutes). Redox potential was determined by adding +244 mV to each field measurement to account for the potential of the reference electrode.

Figure 11 Constructed platinum electrodes (probes: top), accumet calomel reference electrode (bottom) and Thermo Scientific Orion Star A221 Millivolt Meter. Photograph taken by C. Skinner 2013.

3.2.4 Vegetation

The primary food source in estuaries originates in the vegetation of salt marshes. The majority of this plant material is consumed indirectly as detritus (dead plant material) by decomposers and invertebrate consumers. It is through the production and export of detritus that salt marshes help to sustain commercial and non-commercial fish species by forming the base of coastal food webs. Salt marshes are characterized by their plant communities, with specific plants dominating the different salt marsh zones (high marsh, mid marsh, low marsh). It is the plants of a salt

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[8] www.coleparmer.com/buy/product/96392-thermo-scientific-orion-star-a221-ph-portable-meter-kit.html

marsh, along with the physical conditions (hydrology, geology and chemical) that create the template for a self-sustaining coastal wetland system and which enable the biological components of the broader ecosystem (invertebrates, fish, birds and animals) to benefit from these habitats.

Field Methods

The vegetation survey was completed at SCW (35 plots), SCS (10 plots), SCE (14 plots), SCP (35 plots) and SCR (19 plots) during the months of August and September 2013. Sampling plot numbers include those inside the dyke, on the dyke and along the fringe of the site. The fringe marsh plots were used as additional reference samples.

Vegetation sampling was conducted using a modified version of the point intercept method (Roman et al. 2001; Roman et al. 2002). At each sample plot a 1 m^2 quadrat was offset 1 m to the left of the Line (facing the river) and oriented towards the upland. The quadrat was divided into a grid of 25 squares (20 cm x 20 cm) and the top left-hand corner of each grid square was used as the intercept or sampling points. Lists of all plant species present in the sample quadrat were produced and representatives of each species encountered during the survey were collected for identification confirmation. A wooden dowel (3 mm in diameter) was then held vertical to the first sampling point and lowered through the vegetation to the ground below. All species that touched the rod were recorded as a hit for that point and the process was repeated for all 25 points. Categories other than plants (water, bare ground, rock or debris) were also recorded if hit by the dowel. Photographs of the marsh along each transect were taken from the permanent markers at the upland end, as well as a close-up of the quadrat at each plot.

Statistical Analysis

Species richness, halophyte richness and abundance and unvegetated area were compared between 2007/2008 (pre-restoration) and all years post-restoration using repeated measures ANOVA. Non-metric multidimensional scaling was performed to show overall similarities between vegetation composition between plots. Only two dimensions were required to adequately represent the differences in vegetation (stress = 0.16). Ordination diagrams are presented in Appendix B. Each graph depicts the plot ordination for a single site over the five years, compared with the reference site (reference site data from 2013 only shown for clarity).

The vegetation data was analyzed by Dr. Jeremy Lundholm (SMU) and is presented in Section 4.4.

3.2.5 Nekton

Tidal wetlands support a wide range and abundance of organisms that swim collectively referred to as nekton, which include fish and many types of invertebrates. Fish and macrocrustaceans are an important ecological link between the primary producers of the marsh (plants) and near shore fisheries (Neckles and Dionne 2000). Their position in the upper levels of the coastal food webs and their dependence on a wide range of food and habitat resources serve to integrate ecosystem elements, processes and productivity (Kwak and Zedler 1997).

Fish surveys were conducted on 20 September and 7 October 2013 at SCW, using a combination of minnow traps and fyke net (Figure 12). Sampling of ponds and tidal creeks was conducted using a set of four minnow traps, baited with bread. The traps were anchored to the marsh surface and set by tossing the trap into the middle of the pond or creek. The minnow traps were left to fish only during the high tide (approximately three hours). SCW was chosen as the site to conduct the fish surveys as it had constructed ponds and a greater water depth on a greater number of tides than the other restoration sites.

The fyke net construction and [modified] methodology followed those used by Dionne et al. (1999). The fyke net was set at low tide with the wings at approximate 45 degree angles and retrieved when the water drained low enough to approach the net, ensuring that the cod end of the net was still under water. All captured fish were held in buckets, identified to species using identification guides (Audubon Society 1993; Graff and Middleton 2002; Scott and Scott 1988), counted (to a maximum of 300 per species), and measured for length (15 individuals per species).

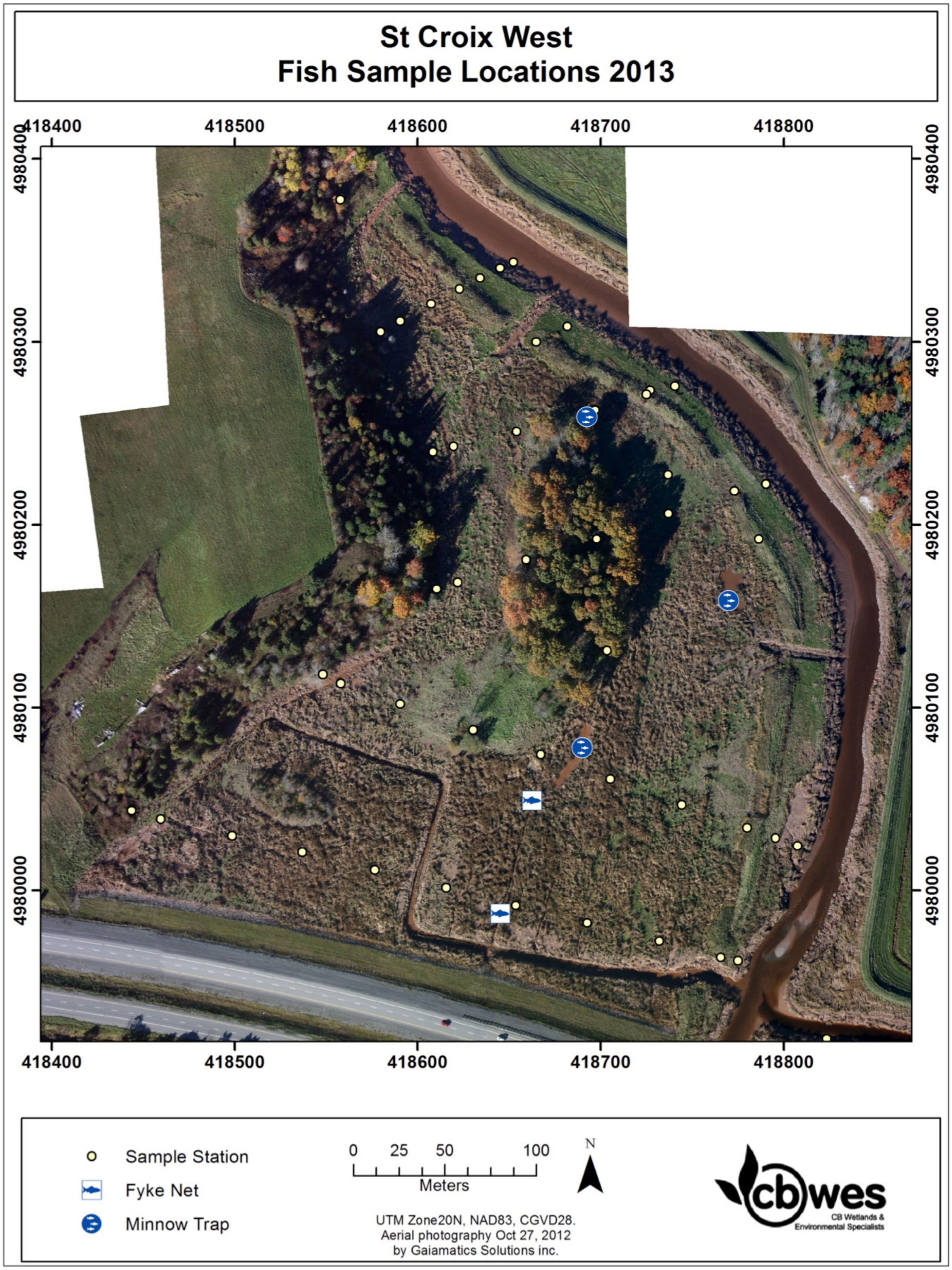


Figure 12 Location of fyke net and minnow traps during fish surveys at SCW.

3.2.6 Benthic and Other Aquatic Invertebrates

Benthic invertebrates, in association with benthic microbial communities, are largely responsible for providing the food resources that help fuel coastal and offshore marine ecosystems. In addition to directly being fish food, these organisms perform the important task of converting the rich productivity of salt marsh vegetation into a form (detritus) that is more palatable to other species such as fish. Benthic marine invertebrates and various freshwater and saltwater invertebrates such as insect larvae are well-known indicators of changes in hydrology, chemical characteristics and productivity (see the Canadian Aquatic Biomonitoring Network (CABIN) program website for more information on the use of aquatic invertebrates to monitor the health of aquatic ecosystems - www.ec.gc.ca/rcba-cabin/).

Benthic Invertebrates

Field Methods

Benthic invertebrate samples were taken at two locations on 12 September 2013 at SCW and SCR, as well as a single sample within the main river channel downstream of both areas near the bridge crossing (Trunk 14) at Sweet's Corner (Figure 1). The benthic samples were 0.023 m^2 taken by a standard 6" x 6" Ekman Dredge. Sampling locations at SCW were along the edge/bank of the main river channel and were taken at low tide. The bulk benthic sediment samples were obtained by deploying the Ekman Dredge within the river channel along the associated Transect, at a depth less than 0.5 m. An additional three sediment cores (5 cm x 15 cm) were taken within the main drainage ditch at SCW on 16 September 2013 in order to sample invertebrates within the study site. The SCR bulk samples and the Sweet's Corner sample were taken in the same manner as those at SCW (Herbert River; Figure 1). Each sample was individually bagged, labeled and placed in a cooler containing ice for transport to the laboratory facilities at Envirosphere Consultants Ltd. in Windsor, NS where the samples were sorted and analyzed for species composition and abundance.

Aquatic Invertebrates

Sampling of other aquatic invertebrates within the water column of the pannes occurred at SCW and SCP. Two samples were taken at each site on 25 July and 14 August 2012 using Invertebrate Activity Traps (IAT; passive sampling). The IAT were left to sample a 24 hour period during a neap tide cycle. These traps were constructed from 2 L clear plastic bottles; the top portion was cut off, inverted and taped in place with duct-tape (Figure 13). The IAT were placed in four pannes (two at SCW and two at SCP), submerged and anchored to ensure the trap remained within the panne. The samples were emptied into a 0.5 mm sieve and the remaining materials and organisms were field preserved in 70% isopropyl alcohol. Envirosphere Consultants Ltd. then performed the species identification.

Figure 13 Disassembled Invertebrate Activity Trap (IAT). Photograph by T. Bowron 2007.

3.2.7 Structured Winter Site Walk

A structured winter site-walk was conducted on the reference and four restoration sites of SC on 21 February 2014. Landscape photographs were taken along each transect from the upland end (back stake). At each of the restoration quadrants the structured walk included the perimeter of the site (dyke and upland edge), with photographs being taken of key features such as breaches, excavated channels, ponds, ice, areas of erosion or deposition, and creek networks.

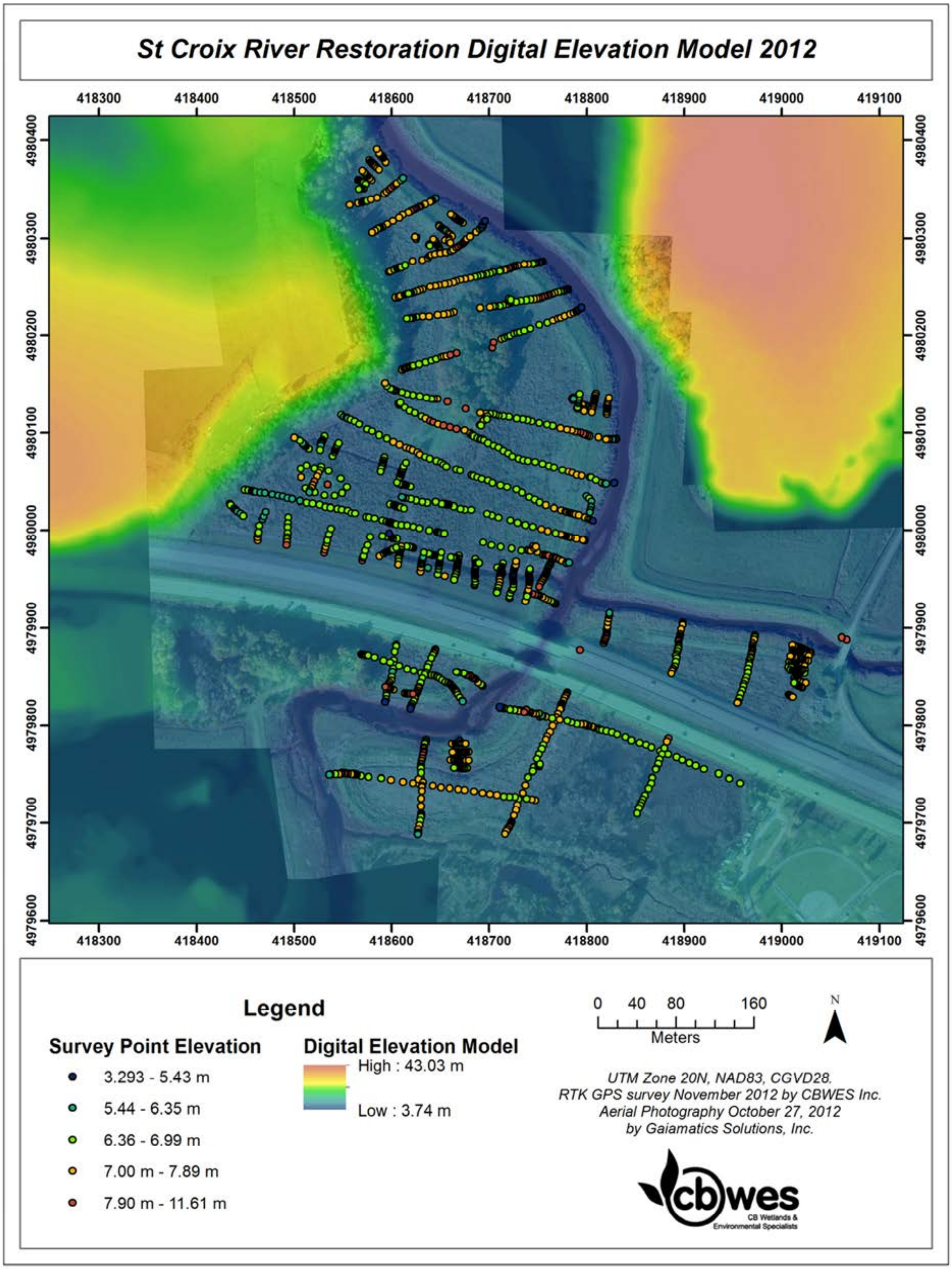
4.0 Results of the 2013 Monitoring Program

4.1 Geospatial Attributes

Digital Elevation Model (DEM) and Habitat Maps

The DEM for the SC restoration sites and SCR were updated in 2012 and are shown in Figure 14 and Figure 15. The additional data collected and processed in 2012 resulted in the delineation of the SC restoration sites to a total area of approximately 18.13 ha (Figure 49; *Section 5 Summary*), whereas in 2010 the total area was estimated to be 19.29 ha. Low-altitude aerial imagery was obtained for the SCP, SCE and SCS study sites in 2012, which enabled a refinement of the area estimates for these sites.

The habitat maps for the SC restoration sites were created using aerial photography taken in October 2012 (Figure 16 to Figure 19). These maps show the morphological features, creek networks and vegetation communities.



UTM Zone 20N, NAD83, CGVD28.
RTK GPS survey November 2012 by CBWES Inc.
Aerial Photography October 27, 2012
by Gaiamatics Solutions, Inc.

Figure 14 DEM of SC Restoration sites.

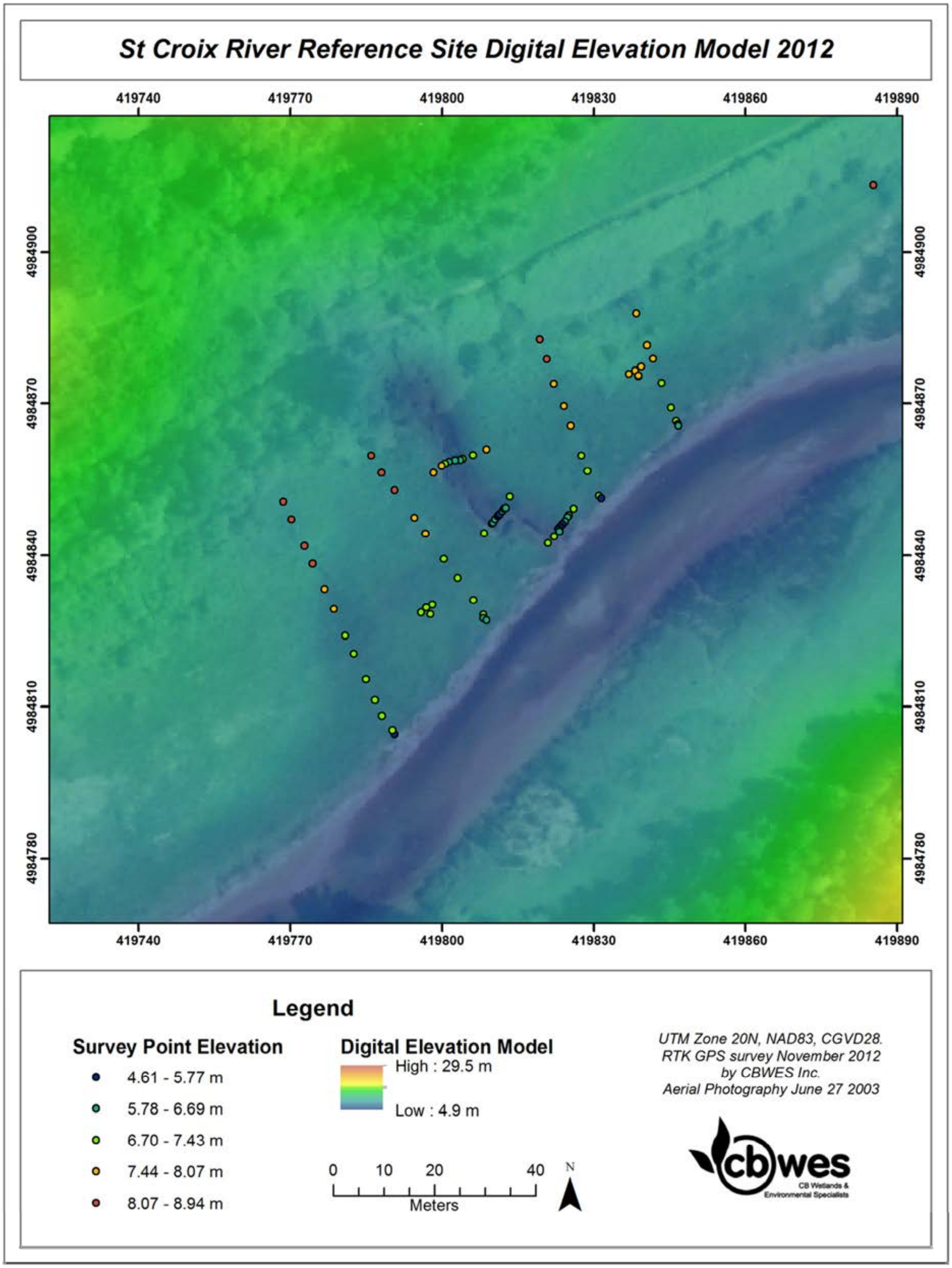


Figure 15 DEM of SC Reference site.

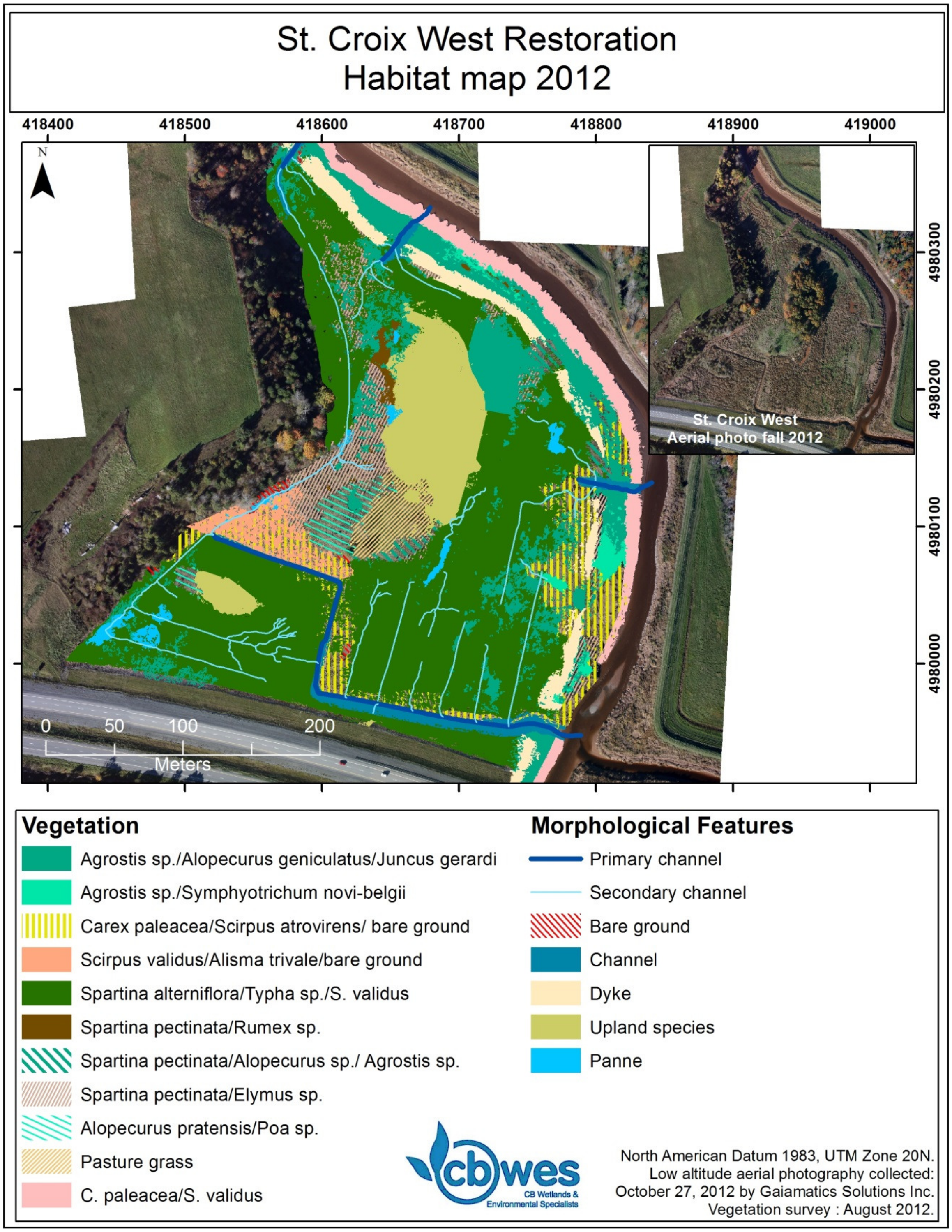


Figure 16 Habitat map of SCW showing vegetation communities and morphological features.

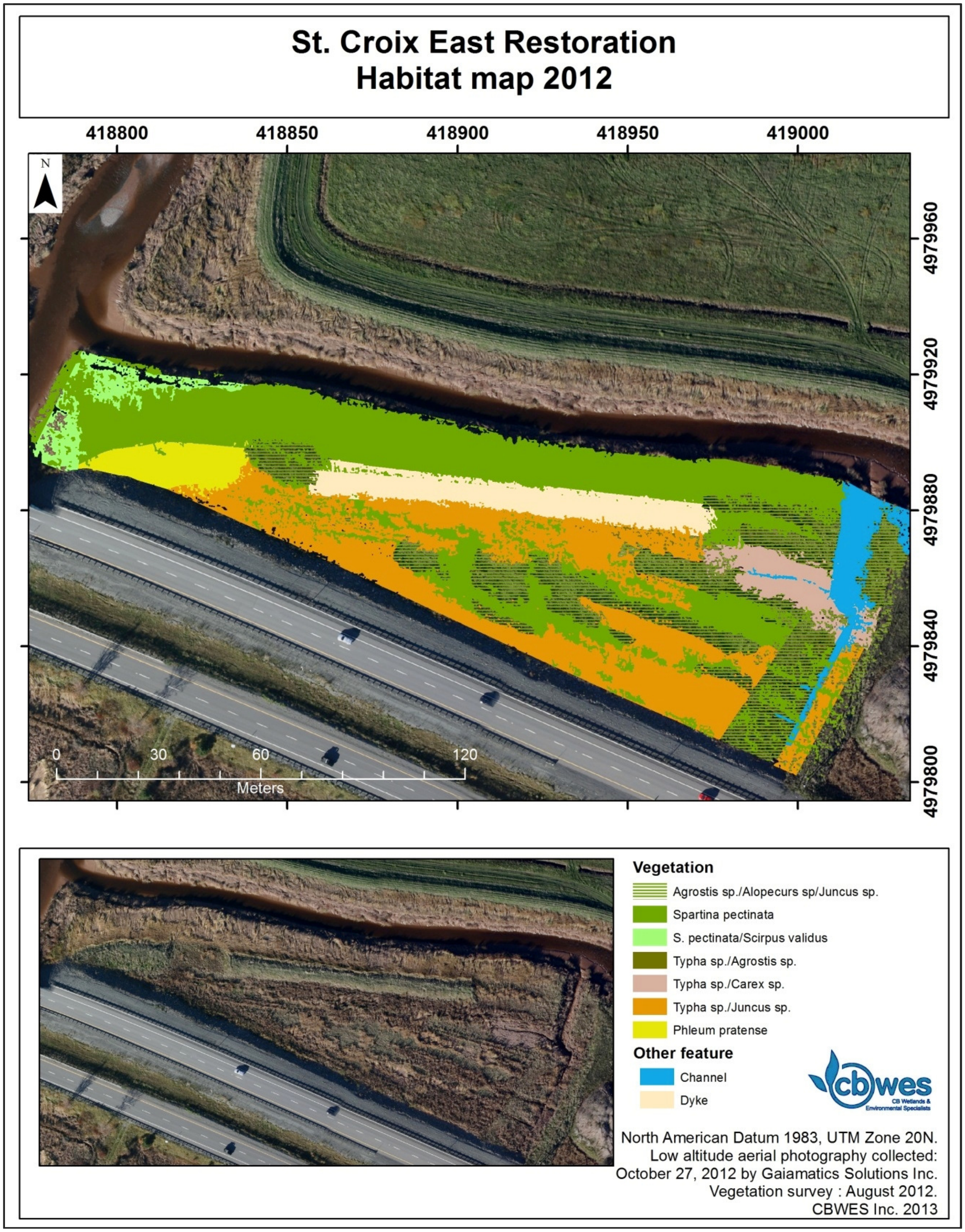


Figure 17 Habitat map of SCE showing vegetation communities and other features.

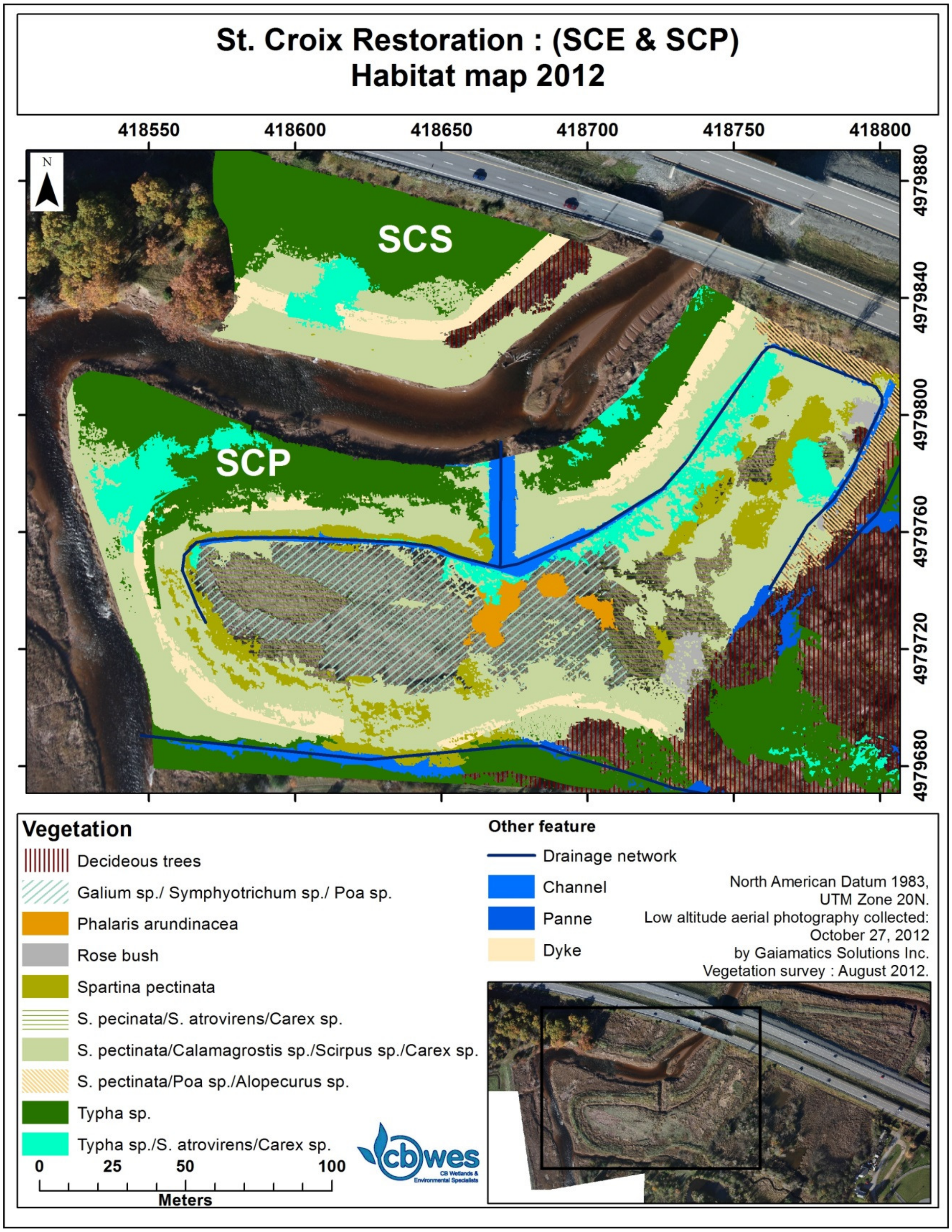


Figure 18 Habitat map of SCS and SCP (front portion: A), showing vegetation communities and other features.

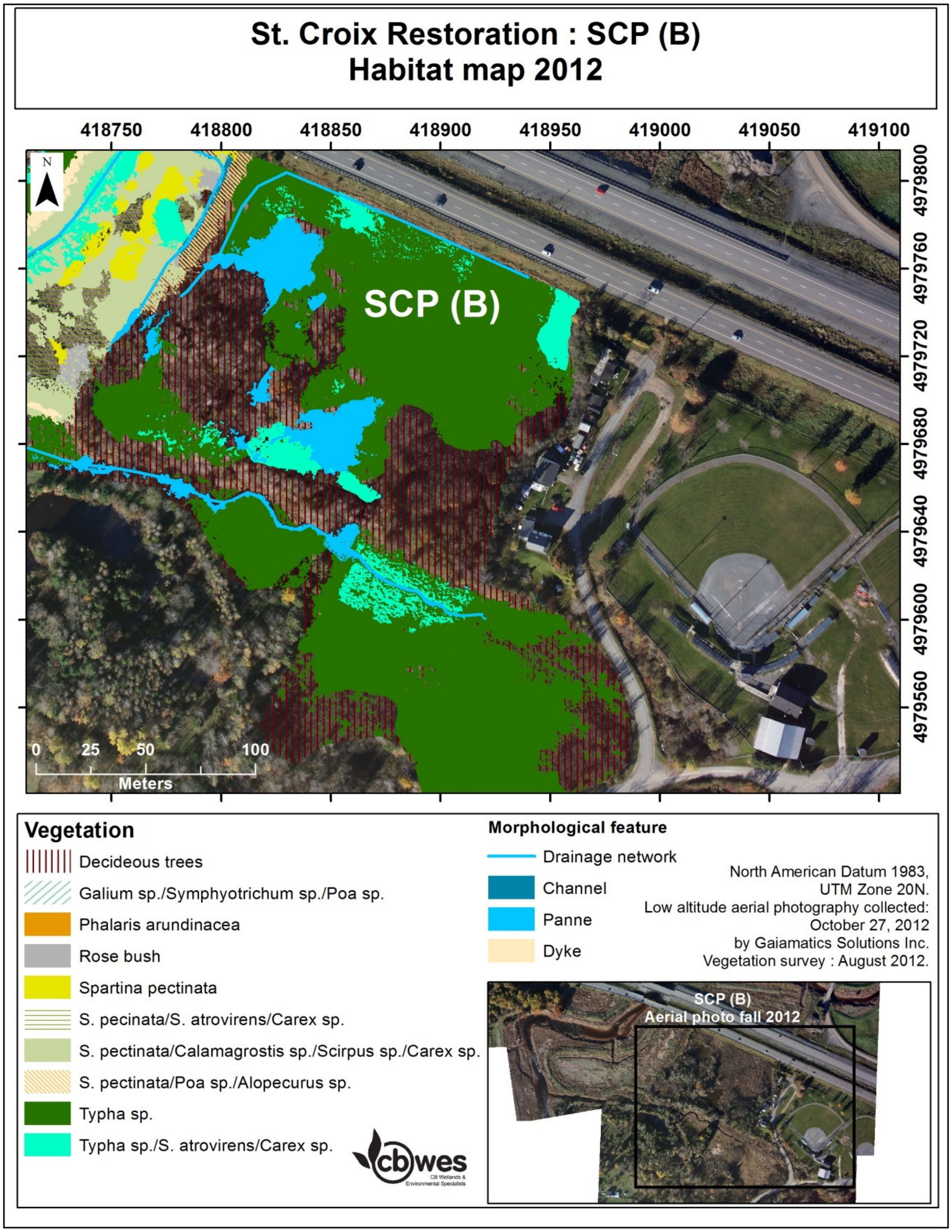


Figure 19 Habitat map of SCP (back portion: B) showing vegetation communities and morphological features.

4.2 Hydrology

Hydroperiod and Tidal Signal

Tide levels were not recorded during Year 4 of the monitoring program, but will be recorded during the fifth (2014) and final year of post-restoration monitoring. The highest tide level recorded for the sampling period 24 September to 07 November 2012 (Year 3) for SCW, SCP and the St. Croix River was 7.86 m, 8.01 m and 7.07 m respectively (Table 4).

As discussed in Bowron et al. (2013c), on a minimum high tide the constructed creeks reached bankful stage, with water moving up the full extent of the aboiteau channel at SCW to the back portion of the site. On a mean tide, approximately 40% of SCW (4.16 m: Table 4) was covered as tidal water entered the aboiteau channel (Creek 1) and the excavated creek furthest downstream (Creek 4: Figure 21). A mean high tide at SCP and SCE floods into the ditches onsite (Figure 21). The rest of SCW and the restoration sites (17.40 ha) were covered by a maximum high tide (recorded in 2012: Table 4). Figure 20 shows the channels along the back of the site connecting to Creek 4 and the back end of the aboiteau channel (Creek 1). These channels have become more defined over the period of the monitoring program as Creek 1 and 4 of SCW are inundated by tidal water more frequently than the other SC restoration excavated creeks.

Figure 21 shows the difference in inundation frequencies per plot at SCP compared to SCW. The plots at SCP were flooded on 0 – 20% of the high tides, compared to SCW which had a greater number of plots flooded at more than 30% of the high tides. The plot inundation frequency at SCR was similar to that of SCP (Figure 22).

Table 4 Total area (ha) covered by the tides for the 2012 tide level data for the SC restoration sites.

	Water Elevation (m)			**Area (ha)**				
	River	**SCP**	**SCW**	**SCP**	**SCW**	**SCE***	**SCS***	**Total**
Highest Tide	7.87	7.86	8.01	5.64	9.74	1.26	0.76	**17.40**
Mean High Tide	6.38	6.88	6.66	1.29	4.16	0.30	0.10	**5.85**
Min High Tide	4.71	6.39	5.58	0.68	0.62	0.17	0.03	**1.50**
Mean Water Level	4.29	6.54	5.58					
Min Water Level	3.53	6.27	5.34					

**Area flooded for SCE and SCS calculated from River tide levels.*

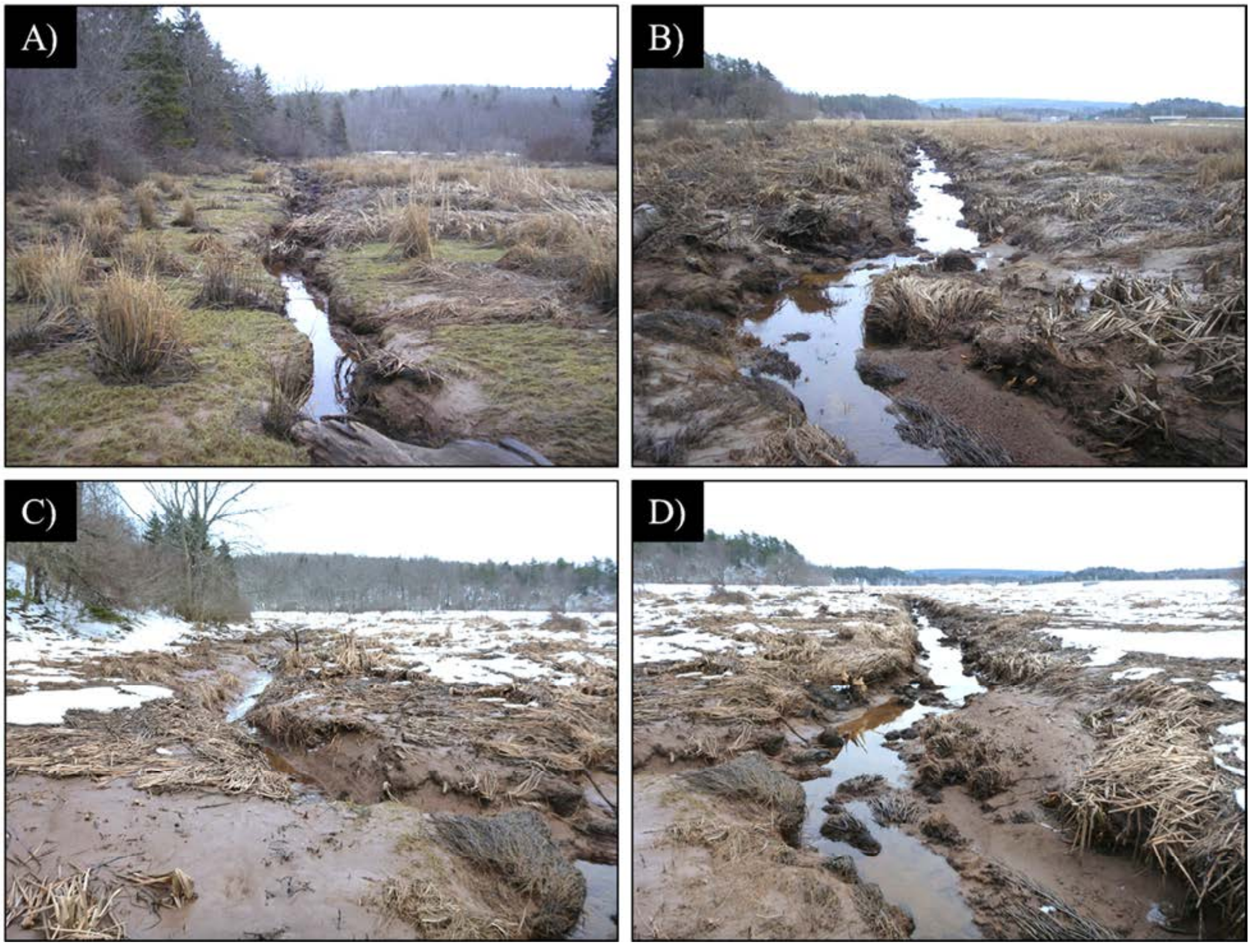


Figure 20 At SCW the back channel connecting Creek 4 with south of marsh a) 2013 and c) 2014. The top portion of aboiteau channel (Creek 1) that connects to back channel is shown in b) 2013 and d) 2014. Photographs taken by CBWES Inc. during winter site walks.

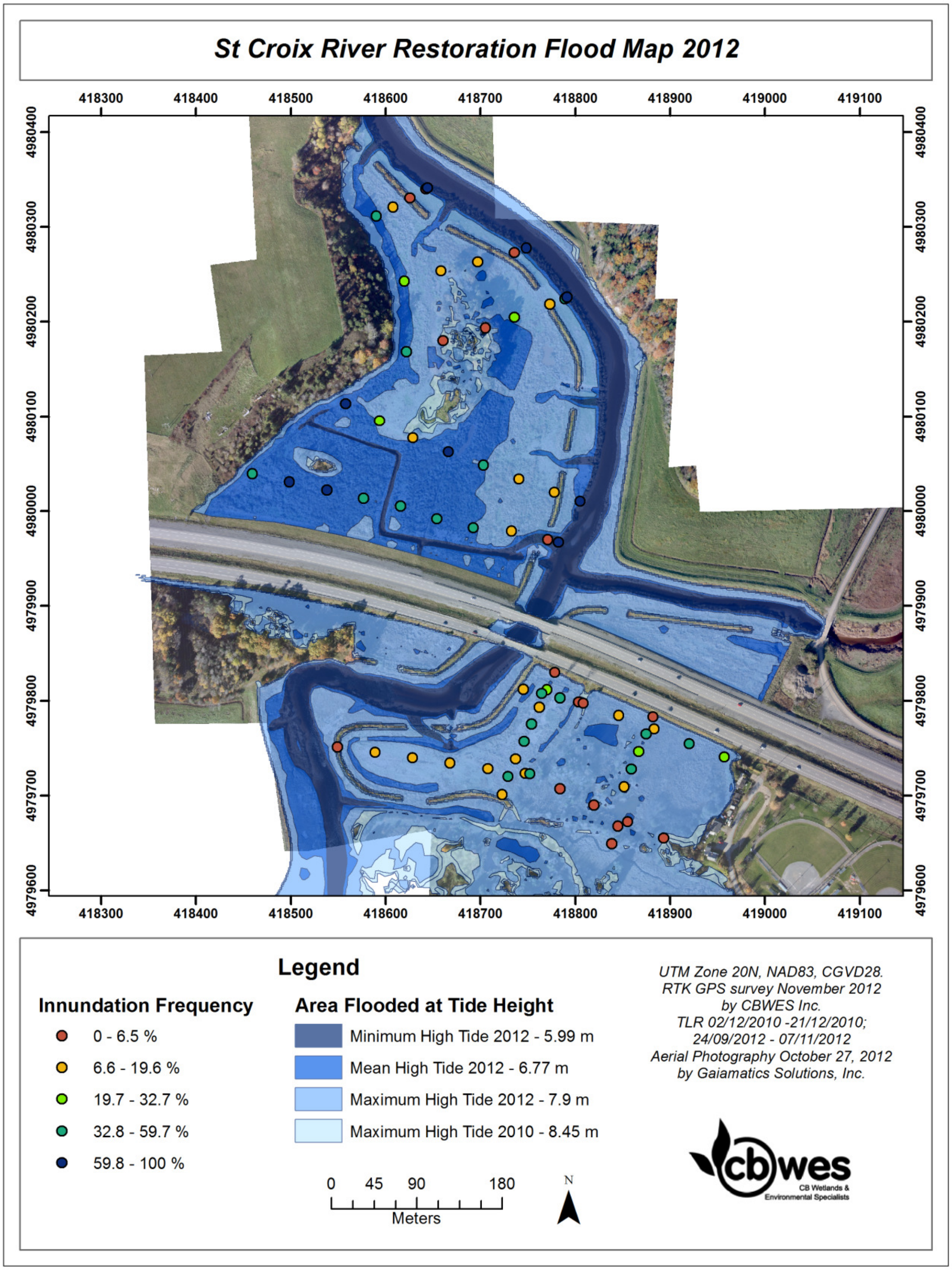


Figure 21 Flood map for SC restoration sites showing inundation frequency for SCW and SCP.

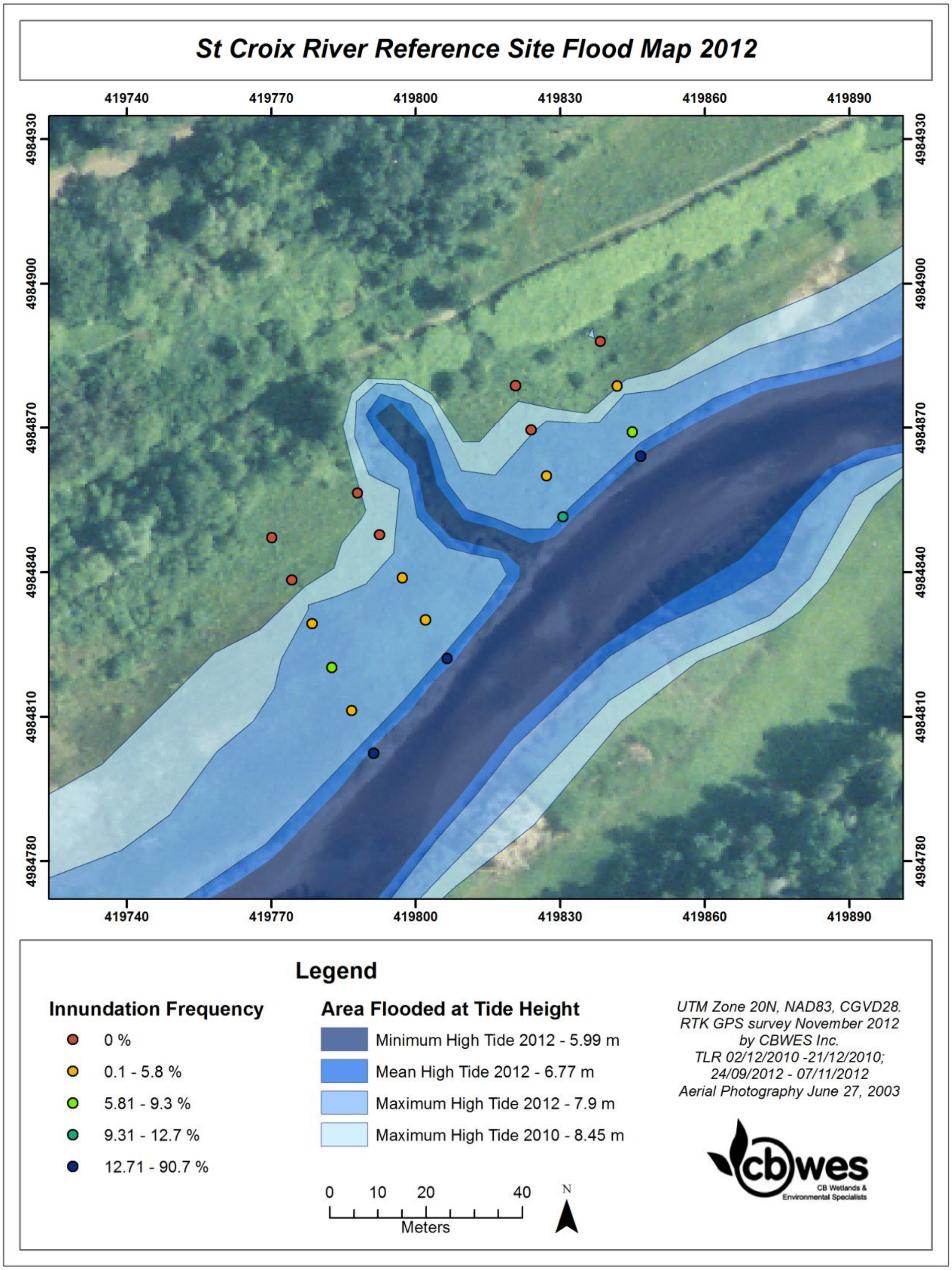


Figure 22 Flood map for SCR showing inundation frequencies.

Creek Morphology

Six channels were excavated at the SC restoration sites during earthworks in 2009 to restore tidal flow (Figure 16 to Figure 18). Tidal flow has been restored as a large portion of the site (4.16 ha) is flooded with a tide level of 6.7 m (CGVD28: Table 4). As discussed in Bowron et al (2013c), when designing the restoration at SC, Graham et al. (2008) took into consideration the initial channel specs and subsequent erosion at the Walton River restoration project (Neatt et al. 2013; van Proosdij et al. 2010); therefore, only two out of the six channels constructed have experienced significant erosion. Figure 24 shows the change overtime at four of the excavated channels at SC. The aboiteau channel (Creek 1 (furthest upstream; south): SCW T1 Figure 24) continues to erode; however, it appears that the creek is stabilizing given the shape of the profile compared to others in the system, especially SCW T2 (Creek 4; Figure 24). Although Creek 1 appears to be stabilizing at the mouth, migration towards the back of the site continues to occur (Figure 23; Figure 44; *Section 4.7 Structure Winter Walk*), deepening the current channel. SCW T2 (Creek 4: T2; Figure 24) was shown to be stable and although the shape of the channel has changed over the years, the cross-sectional area of the creek has shown minimal change. Although minimal erosion has occurred during the 2013/2014 winter season, measurements during the year five monitoring program will give a clearer picture of what has been happening during the past year.

The channel at SCP was shown to be relatively stable with slump blocks (2010-2011) based on the stepped nature of the bank. The excavated creek at SCE has been stable through all years.

Figure 23 The head of the aboiteau channel in a) 2009 and in b) 2014 (winter walk) showing how the channel has been eroding back overtime during the four years of post-restoration. The white arrows in each photo are pointing to the aboiteau structure for distance reference.

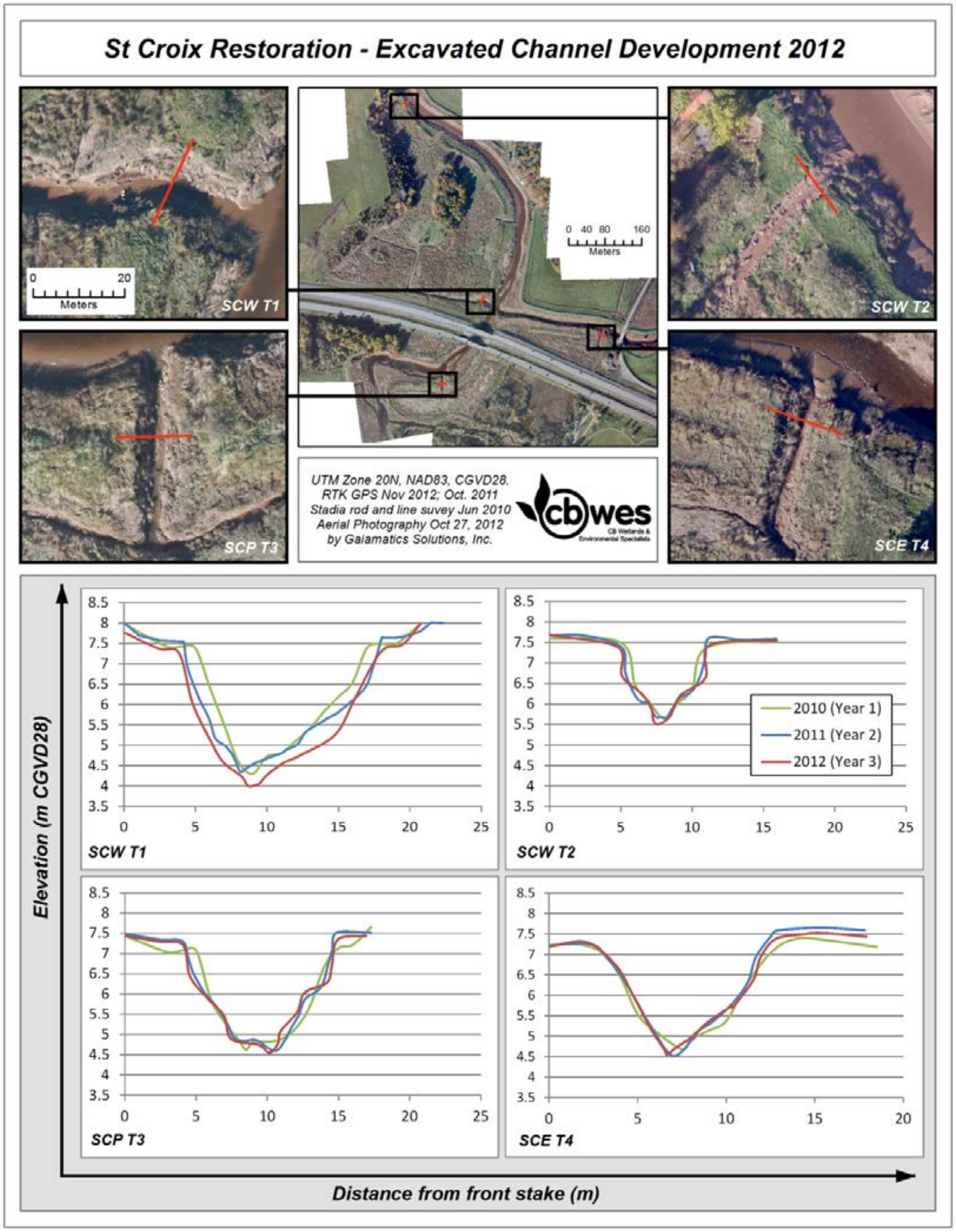


Figure 24 Creek development at the SC restoration sites comparing years 2008, 2010, 2011 and 2012.

Water Quality

Water quality conditions (salinity, temperature, DO and pH) were measured for tidal floodwaters at SCW in conjunction with the nekton survey as well as the River (Table 5).

The normal pH range for seawater is 7.5 to 8.5 and the pH of floodwaters at SCW and in the River fell within this range for all measurements in 2011 and 2012. Although the measurements were a month apart, water temperatures in October were lower than those of September. Water temperatures were expected to be higher in summer and lower in the fall.

Salinity levels of tidal flood waters vary across the tide cycle (flood, peak/slack, ebb) and within the water column. The expected salinity range for a brackish environment is 0.5 – 30 ppt and for seawater >30 ppt. For the sampling events that occurred within the restoration site (AC: Table 5) the highest salinity value range was recorded in 2012: 9.5 ppt in September to 13.7 ppt in October. The salinity of floodwaters at other Minas Basin sites ranged from 18 to 31 (Cheverie Creek: Bowron et al. 2013a; Walton River: Neatt et al. 2013; Cogmagun River: Bowron et al. 2014a) for all post-restoration years. In 2013 the salinity range for tidal waters within the study site was 1.0 ppt to 2.7 ppt (AC: Table 5). The salinity of the River water ranged from 0.0 ppt (surface) to 15.1 ppt (at depth; 2.5 m) over all years post-restoration. This demonstrates that the St. Croix restoration sites are near the upper reaches of the salt wedge and the salinity data recorded from SCW and the River may show varying salinity readings due to fluctuations of freshwater input to the system affecting the upper reaches of the tide.

Cold water has a higher oxygen saturation point than warm water and, therefore, one can expect DO levels to vary daily and seasonally. Most estuarine fish species can survive at concentrations of 4 ppm and can exist comfortably at concentrations of 6 to 8 ppm (Kaill and Frey 1973). Mummichogs (*Fundulus heteroclitus*) can survive at levels much lower than this; hence their ability to thrive in the often poor water quality conditions present in impaired wetlands. The DO measurements at SCW (all years) ranged from 7.3 mg/l to 10.8 mg/l, increasing into the fall as the water temperature decreased. The measurements for DO of the River (all years) ranged from 6.3 mg/l to 10.3 mg/l, also increasing into the fall.

Table 5 Water quality of tidal floodwaters at SCW (AC: aboiteau channel within site) and in the St. Croix River (SC River).

Date	Sampling Site	Sample Location	Salinity (ppt)	Temp (^{o}C)	Dissolved Oxygen (mg/l)	pH
21-Aug-11	SCW*	AC	6.8	22.8	7.3	7.8
21-Aug-11	SC River	Bridge (surface)	0.4	22.9	8.3	7.7
21-Aug-11	SC River	Bridge (at depth)	14.6	22.3	6.3	7.6
21-Aug-11	SC River	From SCW Dyke	14.6	22.2	6.9	7.6
26-Oct-11	SCW*	AC	2.7	10.7	10.8	7.6
26-Oct-11	SC River	Bridge (surface)	0.8	11.4	10.1	8.0
26-Oct-11	SC River	Bridge (at depth)	4.4	10.7	10.3	7.7
17-Sept-12	SCW	AC	9.5	17.2	7.5	7.4
17-Sept-12	SC River	Bridge (surface)	2.8	16.3	8.6	7.5
17-Sept-12	SC River	Bridge (at depth)	9.6	17.5	7.5	7.1
15-Oct-12	SCW	AC (surface)	12.7	12.4	9.1	7.7
15-Oct-12	SCW	AC (at depth)	13.7	12.7	9.5	7.8
15-Oct-12	SC River	Bridge (surface)	8.4	12.7	9.1	7.9

Date	Sampling Site	Sample Location	Salinity (ppt)	Temp (^oC)	Dissolved Oxygen (mg/l)	pH
15-Oct-12	SC River	Bridge (at depth)	15.1	12.6	9.2	7.8
20-Sept-13	SCW	AC (surface)	2.5	19.0	8.4	6.8
20-Sept-13	SCW	AC (at depth)	2.7	18.7	8.5	6.9
20-Sept-13	SC River	Bridge (surface)	0.1	19.2	9.2	7.8
20-Sept-13	SC River	Bridge (at depth)	5.8	18.1	8.3	6.8
07-Oct-13	SCW	AC (surface)	0.8	15.1	9.6	7.3
07-Oct-13	SCW	AC (at depth)	1.0	15.2	9.3	7.3
07-Oct-13	SC River	Bridge (surface)	0.0	15.6	9.4	8.6
07-Oct-13	SC River	Bridge (at depth)	2.6	14.8	9.4	7.3

*Average of two or more sampling events.

4.3 Soils and Sediments

Pore Water Salinity

Pre-restoration samples were too few to make any pre versus post-restoration comparisons, in addition to the change in data collection methods. However, all salinity readings that were collected pre-restoration for SCP and SCW were found to be 0 ppt for all stations. 2013 descriptive statistics for pore water salinity at each sampling station for SCW, SCP and SCR, as well as for each site overall, are found in Table 6 and Table 7.

For all readings, SCW had a mean of 1.58 ppt with a range of 0.19 to 3.31 ppt and a standard deviation of 0.79 ppt (Table 7). SCP had a mean of 0.70 ppt and a range of 0.10 to 1.84 ppt and a standard deviation of 0.35 ppt (Table 7). SCR had a mean of 0.97 ppt with a range of 0.19 to 2.25 ppt and a standard deviation of 0.44 ppt (Table 7). Similar to previous post-restoration years, SCW had the highest mean salinity values and greatest range. The highest salinity readings at SCW in 2013 were again found at L1S2 and L2S3 as well as L3S4 (Table 6). The salinity readings taken at SCW Lines 4 and 5 follow the pattern one would expect to find at a tidal wetland habitat with lower readings closer to the upland and higher towards the river (Table 6). At SCP the highest salinity readings in 2013 were again found at L2bS3 (back portion: Figure 19), as well as the Line 1 stations (Table 6).

No significant differences were detected between shallow and deep readings at any site (SCR $t(23) = -0.11$, $p=0.91$; SCP $t(24) = 0.33$, $p=0.76$; SCW $t(30) = -1.97$, $p=0.06$). Significant differences were detected between sites for deep readings (SCW to SCR $t(47) = -3.25$, $p<0.05$; SCP to SCR $t(45) = 2.36$, $p<0.05$; SCP to SCW $t(42) = -5.01$, $p<0.05$) and shallow readings (SCW to SCR $t(43) = 2.33$, $p=0.02$; SCP to SCR $t(50) = -3.96$, $p<0.001$; SCP to SCW $t(44) = -6.05$; $p<0.001$). To compare changes over time ANOVA was performed at each site for 2011-2013. 2010 readings were excluded due to an insufficient number of readings to support the analysis for that year. For deep readings no significant differences were found between years at SCR or SCP (SCR $F(2, 63) = 2.3$, $p = 0.12$; SCP $F(2, 69) = 0.26$, $p = .76$), while shallow readings showed significant differences (SCR $F(2, 63) = 4.46$, $p = 0.02$; SCP $F(2, 70) = 6.03$, $p = 0.004$). SCW showed the opposite pattern, with deep readings showing significant differences and shallow readings showing no differences (deep F(2, 83) = 2.46, p = 0.09); shallow F(2, 62) = 0.27, p = 0.76).

The histograms for shallow and deep readings show that at SCW in 2013 there were more readings in the higher salinity values than SCR and SCP (Figure 25 and Figure 26). SCP has more readings in the lower salinity values than the other two sites, although all three sites have most of their readings in the lower salinity values. Of note is the increase in the salinity values of the deep reading shown at SCW in 2013, as it was found that there was significant difference overtime in the deep readings at SCW (Figure 26). For SCP, the shallow readings histogram shows a decrease in the percent frequency in the lower salinity value range (0 - 0.5 ppt).

The increase in the salinity values of the deep readings at SCW could be attributed to the depth of the saline sediment that has accumulated on top of the pre-restoration agricultural layer. When taking the deep readings, the EC Probe may no longer be penetrating the agricultural layer, but staying within the accreted sediment. In addition, the increased readings of higher salinity values at SCW and SCP, shown by the histograms (Figure 25 and Figure 26), could be attributed to the higher tides experienced in 2013, closer to the peak of the 18.61 year nodal tidal cycle (October 2015; Haigh et al. 2011).

The salinity values at the SC restoration sites and SCR continue to be very low when compared to other dyke breach restoration projects and reference sites in the Bay of Fundy region. This was expected as the other sites are salt marsh systems and located well within the tidal prism of their respective systems, compared to SC which is at the upper limit of tidal influence. The other breach projects have salinity means of 8.8 ppt (Cogmagun: Bowron et al. 2014a) and 7.6 ppt (Walton: Neatt et al. 2013) with maximum readings of 14 – 17 ppt. Tidal water readings at Cogmagun (2013) and Walton (2012) during fish surveys revealed 26 ppt and 27 ppt respectively. The highest reading at SCW during fish surveys was 13.7 ppt with a reading of 15 ppt in the River (at Depth: Table 5). The lowest reading at SCW during fish surveys was 0.8 ppt and a reading of 2.6 ppt in the River (at Depth: Table 5). SCW and SCP were more brackish in comparison to other restoration project sites, with greater salinity readings at SCW compared to SCP most likely associated with its location in the River system. As discussed in *Section 4.3 Soils and Sediments*, the SC restoration sites are within the zone of the estuarine turbidity maximum (ETM) or the location of vertical mixing between fresh and salt water. SCW appears to be low enough in the system that it receives a greater amount of saline sediment from the River on high tides compared to SCP.

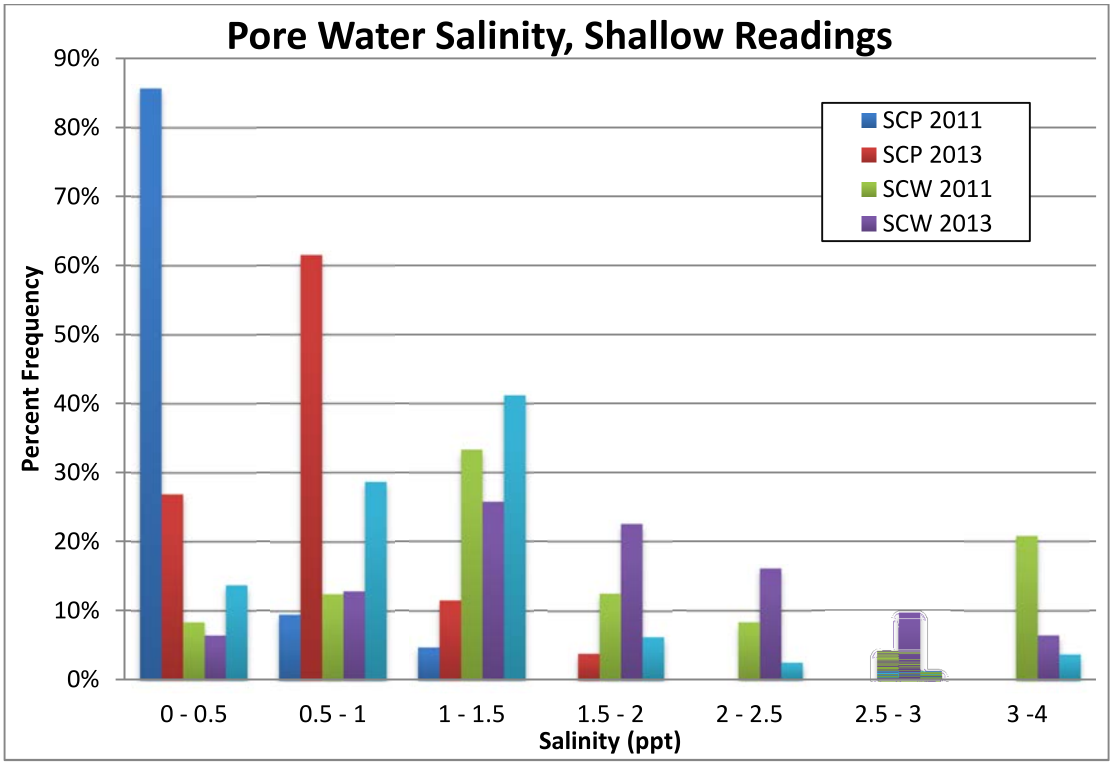


Figure 25 Frequencies for pore water salinity shallow readings at SCW, SCP and SCR for Year 2 (2011) and Year 4 post-restoration (2013).

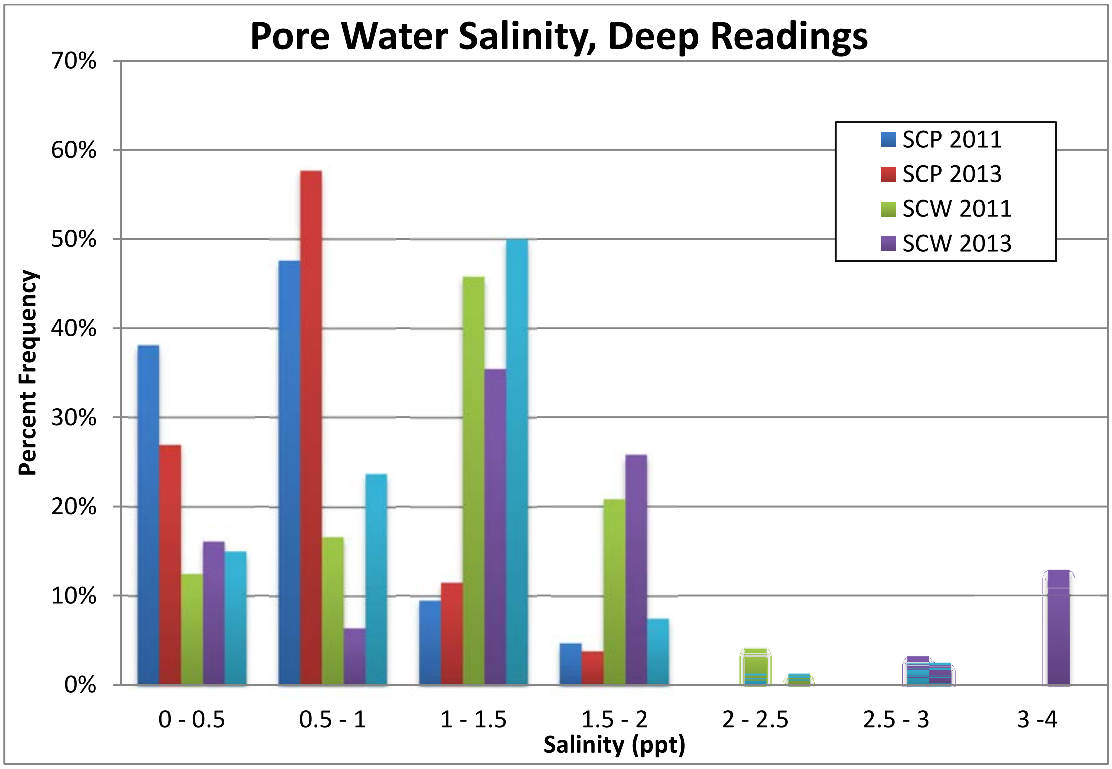


Figure 26 Frequencies for pore water salinity deep readings at SCW, SCP and SCR for Year 2 (2011) and Year 4 post-restoration (2013).

Table 6 Pore water salinity statistics for SCW, SCP and SCR sampling locations for deep, shallow and all readings for 2013.

Sample Location	**Deep**					**Shallow**					**All**				
	Count	*Min*	*Max*	*Mean*	*St. dev*	*Count*	*Min*	*Max*	*Mean*	*St. dev*	*Count*	*Min*	*Max*	*Mean*	*St. dev*
SCW L1S2	4	0.20	3.12	2.23	1.37	4	0.09	3.31	2.12	1.43	8	0.09	3.31	2.17	1.30
SCW L2S3	4	1.21	3.11	2.21	0.99	4	1.34	3.19	2.49	0.80	8	1.21	3.19	2.35	0.85
SCW L3S4	4	1.15	1.30	1.24	0.06	4	1.57	2.15	1.87	0.26	8	1.15	2.15	1.55	0.38
SCW L4S2	4	0.43	0.50	0.47	0.03	4	0.39	0.76	0.61	0.16	8	0.39	0.76	0.54	0.13
SCW L4S5	3	1.24	1.34	1.30	0.05	3	1.72	1.76	1.73	0.02	6	1.24	1.76	1.52	0.24
SCW L5S1	4	0.91	1.22	1.05	0.15	4	0.98	1.26	1.10	0.13	8	0.91	1.26	1.08	0.13
SCW L5S4	4	1.49	1.76	1.65	0.12	4	1.25	2.31	1.62	0.48	8	1.25	2.31	1.64	0.32
SCW L5S8	4	1.56	1.96	1.80	0.20	4	1.37	2.02	1.72	0.35	8	1.37	2.02	1.76	0.26
SCP L1S3	4	0.58	0.71	0.67	0.06	4	0.65	1.12	0.92	0.20	8	0.58	1.12	0.80	0.19
SCP L1S7	4	0.83	1.01	0.93	0.07	4	0.52	0.71	0.63	0.08	8	0.52	1.01	0.78	0.18
SCP L2bS1	2	0.18	0.72	0.45	0.38	3	0.10	0.61	0.30	0.27	5	0.10	0.72	0.36	0.28
SCP L2bS3	4	0.77	1.56	1.29	0.35	4	0.83	1.84	1.32	0.42	8	0.77	1.84	1.30	0.36
SCP L3aS3	4	0.36	0.58	0.49	0.09	4	0.50	0.70	0.61	0.10	8	0.36	0.70	0.55	0.11
SCP L3aS5	4	0.43	0.51	0.47	0.03	4	0.42	0.54	0.48	0.05	8	0.42	0.54	0.47	0.04
SCP L3aS7	4	0.49	0.66	0.57	0.07	4	0.31	0.58	0.47	0.12	8	0.31	0.66	0.52	0.10
SCR L1S1	4	1.12	1.55	1.28	0.19	4	0.75	1.11	0.92	0.15	8	0.75	1.55	1.10	0.25
SCR L1S2	4	0.71	1.11	0.93	0.16	4	0.76	1.18	0.96	0.17	8	0.71	1.18	0.95	0.16
SCR L1S3	4	0.59	1.42	1.08	0.35	4	0.71	2.25	1.46	0.63	8	0.59	2.25	1.27	0.51
SCR L4S1	4	0.21	0.27	0.24	0.02	4	0.19	0.24	0.21	0.02	8	0.19	0.27	0.22	0.02
SCR L4S3	4	1.05	1.43	1.25	0.16	4	0.80	1.28	1.06	0.20	8	0.80	1.43	1.16	0.20
SCR L4S5	4	0.71	1.34	1.00	0.28	4	0.79	1.37	1.20	0.28	8	0.71	1.37	1.10	0.28

Table 7 Summary pore water salinity statistics for SCW, SCP and SCR for deep, shallow and all readings for years 2010 to 2013.

Year	Site	Deep					Shallow					All				
		Count	*Min*	*Max*	*Mean*	*St.dev*	*Count*	*Min*	*Max*	*Mean*	*St. dev*	*Count*	*Min*	*Max*	*Mean*	*St. dev*
2010	SCR	14	0.00	2.70	1.36	0.49	12	0.00	3.22	1.49	0.71	26	0.00	3.22	1.42	0.59
	SCP	12	0.00	2.18	1.31	0.34	14	0.00	3.22	1.55	0.65	26	0.00	3.22	1.44	0.53
	SCW	15	0.00	3.22	1.66	0.62	21	0.00	4.25	2.23	0.96	36	0.00	4.25	1.99	0.87
2011	SCR	18	0.00	1.33	0.78	0.41	18	0.00	1.60	0.75	0.39	36	0.00	1.60	0.77	0.40
	SCP	21	0.00	1.54	0.64	0.37	21	0.00	1.23	0.36	0.29	42	0.00	1.54	0.50	0.36
	SCW	24	0.10	2.24	1.20	0.53	24	0.10	3.79	1.74	1.03	48	0.10	3.79	1.47	0.85
2012	SCR	24	0.19	2.59	1.10	0.56	24	0.16	3.28	1.29	0.78	48	0.16	3.28	1.19	0.68
	SCP	25	0.17	1.34	0.68	0.33	25	0.27	1.32	0.62	0.33	50	0.17	1.34	0.65	0.33
	SCW	29	0.17	2.26	1.17	0.49	30	0.32	3.48	1.82	0.81	59	0.17	3.48	1.50	0.74
2013	SCR	24	0.21	1.55	0.96	0.41	24	0.19	2.25	0.97	0.48	48	0.19	2.25	0.97	0.44
	SCP	26	0.18	1.56	0.71	0.33	27	0.10	1.84	0.69	0.37	53	0.10	1.84	0.70	0.35
	SCW	31	0.20	3.12	1.50	0.79	31	0.09	3.31	1.65	0.79	62	0.09	3.31	1.58	0.79

Sediment Accretion and Elevation

Since the 2009 RSET measurements were taken prior to breaching, it was not surprising that the RSET stations at SCW did not indicate any amount of accretion (Table 8). Marker horizons were also visible on the surface of SCW. However, the RSETs do capture significant surface compaction, which was expected from a dyked marshland soil. These rates range from -0.55 (±0.09) to -2.28 (± 0.12) cm·yr^{-1} (± SE) (Table 8) at SCW_RSET-02 and SCW_RSET-01 respectively. These data suggested that rates of sediment accretion would likely be high in the first year after breaching since the surface elevation of the marshland was lower than the foreshore marshes seaward of the dyke. These sites were also susceptible to disturbance from cow trampling and defecation. It is recommended that in future instances where a dyke will be breached during the monitoring year, the time of sampling be postponed until immediately after the breach in an effort to capture the initial sediment rates of sediment deposition and cows be excluded from the site once RSETs are established.

By October 2010, approximately 14 to 17 months post-restoration, the RSET stations and marker horizons at both SCW and SCP recorded significant changes in surface elevation (Table 8 and Table 9), mostly through sediment accretion (Table 11a,b). In general stations at SCW recorded almost double the rates of surface elevation change when compared to SCP (Table 8 and Table 9). It should be noted that the changes in surface elevation for SCP presented in Table 9 represent changes over a two year period. SCW_RSET-01 located near the main excavated channel recorded the highest rate of change in surface elevation (23.04 ± 0.39 cm·yr^{-1}±SE) and SCW_RSET-03 recorded the lowest (13.09 ± 0.35 cm·yr^{-1}±SE) (Table 8, Figure 27b,j). The latter is situated the furthest away from a direct source of sediment (e.g. creek or breach). The majority of these changes were due to sediment accretion (e.g. SCW_RSET-02 14.8 cm; Figure 32b) rather than sub-surface processes. The SCW_RSET-02 receiver was actually completely buried by sediment (Figure 32b). SCW_RSET-02 located at the back of the marsh showed similar rates of change in surface elevation as SCW_RSET-01 (Table 8). SCW_RSET-04, situated at the back of the marsh close to the final breach, recorded 16 ± 0.2 cm·yr^{-1}(±SE) of change in surface elevation one year post-restoration (Figure 27n).

By 2011, the rate of change in surface elevation had decreased markedly compared with the previous year. SCW_RSET-04 now recorded the highest rate of change in surface elevation (7.2 ± 0.11 cm·yr^{-1}±SE) (Figure 27o, Table 8) with approximately 1.2 cm due to subsurface processes. SCW_RSET-03 recorded the lowest rate of change in surface elevation (0.35 ± 0.44 cm·yr^{-1}±SE) yet greatest variability within the plot (Figure 27k, Table 8). In addition, the mean accretion rate was 2.10 cm·yr^{-1} indicating that there has been approximately 1.75 cm of compaction, which suggested that the below ground biomass was decaying. This will require careful monitoring since it suggests the formation of anoxic conditions unsuitable for plant growth. SCW_RSET-02 recorded (4.12 ± 0.14 cm·yr^{-1}±SE) and SCW_RSET-01 recorded (3.25 ± 0.43 cm·yr^{-1}±SE) of surface elevation change (Figure 27c,g). Neither showed evidence of below ground decomposition. By 2012 however, evidence of below ground decomposition was present at all SCW RSET locations. The change in surface elevation remains high, increasing to 6.09±0.90 cm·yr^{1} and 2.57±028 cm·yr^{1} at RSET-01 and RSET-03 respectively (Table 8). Minimal change from 2011 was observed at RSET-02, which had previously seen some of the highest rates of surface elevation change (Table 8, Figure 27h). The inorganic sediment deposition measured by the marker horizons ranges from 3.24 cm·yr^{1} (RSET-03) to 11.18 cm·yr^{1} at RSET-01. Interestingly, RSET-01 therefore experienced just over five cm of below ground decomposition or settling.

The 2012-13 monitoring season saw a marked increase in the rate of surface elevation change at stations SCW_RSET-01 and SCW_RSET-04, more than double the previous year (Table 8). Conversely, values recorded at SCW_RSET-02 and RSET-03 were close to half of the values reported in 2012. The highest value, 12.47 ± 5.17 cm was recorded at SCW_RSET-01 and lowest 1.43 ±1.24 cm·yr^{1} at SCW_RSET-03. Figure 4 illustrates that over time the rates of sediment accretion have decreased at all stations, which was to be expected as the marsh platform rises within the tidal frame. The exception was at SCW_RSET-01 and RSET-04 where greater amounts of sediment (11.15 and 10.56 cm·yr^{-1}) were deposited in 2012-13 than the annual change recorded in the preceding two years. This may potentially be explained by the higher than normal tides experienced this year, which would have increased the frequency of inundation and most importantly inundation time. Longer inundation time provides more opportunity for fine sediments in suspension to flocculate and settle out of the water column. Additionally, SCW floods primarily via Creek 1 (Aboiteau Channel) and Creek 4 (most northerly excavated channel) (Figure 24: *Section 4.2 Hydrology – Creek Morphology*), which correspond to SCW_RSET-01 and RSET-04 respectively. Therefore, it is not surprising that these two RSETs have greater amounts of sediment deposition given their close location to a sediment source.

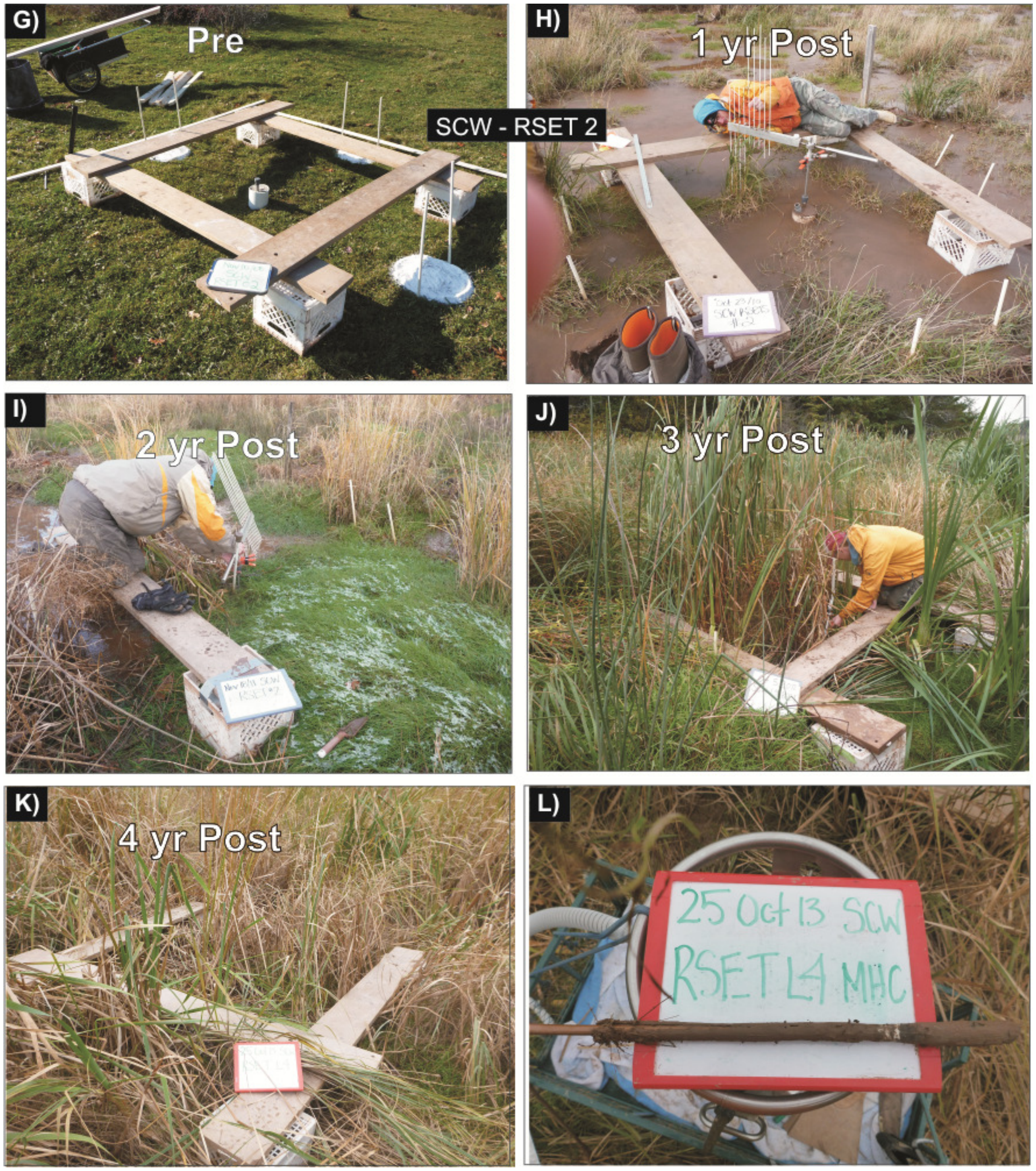
Despite SCP RSET values representing a two year period, they were still greater than most other marshes in the region on a per annum basis. Rates of accretion were 9.27 cm and 2.53 cm at SCP_RSET-01 and RSET-02 respectively (Table 11b). Approximately 3 cm of surface elevation change at SCP-RSET-02 could be attributed to sub surface processes, likely as the marsh soil became saturated (Table 9 and Table 11) in 2010. These overall accretion values were compared to significantly lower rates of change recorded at the reference site (Table 10). Surface compaction was still on-going (Table 10) despite greater than 1 cm of accretion at SCP_RSET-01 (Table 11b). They were also significantly higher than rates recorded in marshes within the region which are typically on the order of 0.5 to 2 cm per year. As was seen at SCW, the rate of change in surface elevation at SCP decreased markedly in 2011 yet SCP_RSET-01 still recorded the highest value (1.13 ± 0.22 cm·yr^{-1}±SE) and SCP_RSET-02 the lowest (-0.74 ± 0.20 cm·yr^{-1}±SE) (Table 9). However, when the marker horizons were examined (Table 11b) it was clear that below ground decomposition or compaction was occurring at both sites. This trend changed in 2012 with very low values of sediment accretion (Table 11a), yet greater changes in surface elevation (1.46 cm·yr^{1} and 0.34 cm·yr^{1}) compared to the previous year. This suggests a below ground contribution of 1.87 and 0.31 cm at SCP_RSET-01 and RSET-02 respectively. However, during the 2012-13 monitoring season, SCP recorded more than double the rates of surface elevation change at both stations with the highest (5.24 ±0.16 cm·yr^{-1}) recorded at SCP-RSET-01. Similar to SCW, higher rates of sediment accretion were also recorded in this year, particularly at SCP_RSET-01 (7.28 cm·yr^{-1}); however, this station also saw approximately 2 cm decrease in elevation due to subsurface processes. Vegetation composition at these sites, as well as redox potential, will need to be examined. This may be further evidence of a strong coupling between vegetative recovery and sediment input as explored by Lemieux (2012) and warrants further investigation.

Analysis of the changes in surface elevation at the reference site illustrated some of the annual variability over time, which was also to be expected at the restoration sites. SCR_RSET-01 has ranged from -0.85 (2008-09) to 0.16 (2012-13) $cm \cdot yr^{-1}$ and SCR_RSET-02 recorded the lowest value (-1.13 $cm \cdot yr^{-1}$) in 2008-09 as well but highest 0.62 $cm \cdot yr^{-1}$ in 2010-11. Therefore, it is important to compare reference and restoration rates within the year that the measurement was taken and signals the importance of maintaining coupling of data collection. RSET measurements at both SCW and SCP greatly exceeded the rates recorded at SCR one year post-restoration (Table 8, Table 9, Table 10). This was not surprising given the lower topographic elevation of the newly breached marsh and high rates of sedimentation. All restoration stations at SCW and SCP, with the exception of SCP_RSET-02, continued to record surface elevation changes that were much greater than the reference site. SCP_RSET-02, however, has displayed the closest values (less than 1 $cm \cdot yr^{-1}$) to those at the reference site in all years except 2012-13 with 1.77 ±0.14 $cm \cdot yr^{-1}$ (Figure 31).

It was anticipated that the SC restoration sites would record high rates of sediment accretion given the subsided pasture surfaces and high suspended sediment concentration recorded in 2009 (Bowron et al. 2010). However the shear amount of deposition and large spatial extent was not anticipated, nor were the differences in magnitude between SCW and SCP. The SC restoration sites appear to be situated within the zone of the estuarine turbidity maximum (ETM) or the location of mixing between fresh and salt water. The interaction between the fresh and salt water induces a process of flocculation where very high values of suspended sediment concentration may be recorded and deposited along the riverbed and adjacent lands. Any value in excess of 20 $g \cdot l^{-1}$ falls with the range of fluid mud as defined in Guan et al. (1998) and will have an influence on the sediment transport. Suspended sediment concentrations recorded in 2009 show that approximately 14% of the samples measured fell within this range. Other authors indicate that the fluid mud limit is 10 $g \cdot l^{-1}$ (Kineke et al. 1996; Ross and Mehta 1998). Six tides remain above the fluid mud level on the outgoing tide. Approximately 280 grams for every litre of water was deposited within the St. Croix system during the sampling period. The timing of this turbidity maximum coincides primarily with spring tides when we have a relatively larger volume of water entering the river. This coincides with visual observations of sedimentation beginning in early Fall 2009 during the high spring tides. Other rivers in the Minas Basin have recorded similar high values of suspended sediment concentration. For example, suspended sediment concentration values in the Salmon River ranged from 0 to 946 $g \cdot l^{-1}$ with a mean of 172 $g \cdot l^{-1}$ (Crewe et al. 2005) and in the Cornwallis River measured 20 $g \cdot l^{-1}$ (Daborn and Penechetti 1979) and recent measurements in the same river of 3.5 $g \cdot l^{-1}$ in the tidal bore (Milligan pers. comm.). A mean of 1.7 $g \cdot l^{-1}$ was measured in the flood tide in the Avon River (Daborn et al. 2003). All of these values are known to vary seasonally (Crewe et al. 2005). Close observation of the vegetative re-colonization will be necessary due to the potential for sulfide toxicity at the interface between the sediment and old agricultural surface, which may induce plant die-back in subsequent years (Portnoy, 1999). Sub surface processes were evident at all RSET sites in 2012 which could be attributed to decomposition of the below ground root mat, and/or compaction and de-watering of the sediment that has been accreting on the sites.

The decrease in the rate of change in surface elevation is directly associated with the re-distribution of sediment within the system and the rising of the marsh surface within the tidal frame. As the surface rises within the tidal frame, it is inundated for shorter periods of time resulting in less sediment availability and inundation time. Figure 32 provides an overview of the impacts of sediment accretion facilitating vegetation growth around the excavated pond at SCW. In addition, deposited sediment can act as a disturbance agent that facilitates vegetative colonization by re-setting the 'clock' to zero (Figure 33). Refer to Lemieux, 2012 for a detailed discussion of the sequence of vegetative recovery within the St. Croix system and the role of sedimentation. The opening of a new area for tidal waters to occupy through dyke breaching, can also have an effect on the tidal prism of the area. The very low rates of sediment accretion at SCP yet markedly higher values at SCW in 2012 may potentially be explained by sediment being sequestered on the incoming tide at SCW and not be available to feed SCP. The higher rates at both sites during 2012-13 may be associated with increased tidal height, duration and frequency of inundation. However, without measures of suspended sediment concentration and tide records throughout the year at both sites this remains a hypothesis.


SCW - RSET 1
A
Pre
B
1 yr Post
Oct 23/10 SCW RSETS #1
C
2 yr Post
Nov 18/11 SCW RSET#1 MHC
D
3 yr Post
05/10/12 SCW L5RSET
E
4 yr Post
F
25 Oct 13 SCW RSET L5 MAB


G)
Pre
SCW - RSET 2
H)
1 yr Post
I)
2 yr Post
J)
3 yr Post
K)
4 yr Post
L)
25 Oct 13 SCW
RSET L4 MHC


M)
Pre
N)
1 yr Post
SCW - RSET 3
O)
2 yr Post
P)
3 yr Post
Q)
4 yr Post
R)
25 Oct 13 SCW
RSET L3 MHC

Figure 27 RSET stations at SCW pre- (2008), and year 1 (23 October 2010), year 2 (18 November 2011), year 3 (5 October 2012) and year 4 (23 October 2013) post-restoration. Photographs taken by CBWES Inc.

Table 8 Mean annual change in surface elevation 2008 to 2013 measured by the RSET at SCW.

St. Croix West (SCW)				Net change in elevation between sampling period (cm)								
RSET-01 Line 5		**Position**	**Bearing**	**Pin 1**	**Pin 2**	**Pin 3**	**Pin 4**	**Pin 5**	**Pin 6**	**Pin 7**	**Pin 8**	**Pin 9**
2008-09		1	342	-1.7	-2.8	-2.5	-2.6	-2.7	-2.1	-3.1	-2.9	-3.0
mean	-2.28	3	72	-2.5	-1.8	-2.5	-2.5	-2.9	-3.1	-2.8	-3.1	-3.2
stdev	0.70	5	162	-2.2	-2.1	-2.3	-1.9	-1.7	-2.3	-2.1	0.0	-0.1
SE	0.12	7	252	-2.2	-2.1	-2.3	-2.0	-2.2	-1.6	-2.3	-2.2	-2.6
2009-10		1	342	24.3	25.6	25.2	25.6	25.3	24.9	25.8	25.7	25.0
mean	23.04	3	72	20.5	19.9	20.4	20.4	20.9	20.4	20.5	20.6	21.0
stdev	2.32	5	162	21.8	21.2	21.7	21.5	21.4	22.0	22.4	19.5	19.4
SE	0.39	7	252	25.0	24.5	24.5	24.8	25.2	25.3	25.9	25.9	25.6
2010-11		1	342	-1.9	-0.7	-1.1	0.2	-0.9	-0.3	-1.9	-0.2	-0.1
mean	3.25	3	72	4.9	6.8	6.2	7.1	6.4	5.1	5.8	5.4	4.9
stdev	2.56	5	162	4.4	4.6	4.2	3.9	3.9	3.5	3.3	4.8	4.1
SE	0.43	7	252	3.1	4.1	4.8	3.9	3.6	3.6	3.6	3.7	4.2
2011-12		1	342	11.2	9.5	3.9	8.2	9.2	8.1	9.8	8.3	8.0
mean	6.09	3	72	8.5	-24.4	6.6	5.5	5.4	6.4	5.7	5.6	6.2
stdev	5.41	5	162	6.4	5.9	6.8	6.6	6.2	6.7	6.6	5.9	6.5
SE	0.90	7	252	6.8	6.6	6.1	6.3	6.7	6.5	6.6	6.8	7.6
2012-13		1	342	10.7	11.2	17.1	11.2	11.1	11.4	11.6	11.7	12.0
mean	12.48	3	72	10.8	41.5	11.2	11.6	12.2	12.3	12.1	12.1	12.4
stdev	5.17	5	162	11.6	12.4	11.4	12.9	13.1	12.8	13.1	13.0	12.9
SE	0.86	7	252	11.2	10.5	10.2	10.6	10.2	10.2	10.2	9.7	8.9
RSET-02 Line 4		**Position**	**Bearing**	**Pin 1**	**Pin 2**	**Pin 3**	**Pin 4**	**Pin 5**	**Pin 6**	**Pin 7**	**Pin 8**	**Pin 9**
2008-09		1	342	-0.9	-0.5	-0.3	-1.0	-1.5	-1.1	-0.9	-0.5	-1.3
mean	-0.55	3	72	-0.9	-0.5	-0.6	-0.7	-0.1	-0.3	-0.4	-0.4	0.5
stdev	0.52	5	162	-0.6	0.3	-1.0	0.8	0.2	-0.8	-0.5	-0.4	-0.3
SE	0.09	7	252	-0.7	-0.5	-1.1	-1.1	-1.2	0.4	-0.8	-0.5	-0.7
2009-10		1	342	24.3	24.2	24.0	24.1	25.0	25.3	24.8	24.5	24.8
mean	22.98	3	72	25.2	22.3	21.9	22.3	21.8	22.0	21.9	21.6	20.7
stdev	1.25	5	162	24.5	23.8	22.3	21.7	22.6	22.0	21.9	21.5	21.9
SE	0.21	7	252	22.6	23.1	23.1	23.0	22.8	22.1	23.1	22.3	22.2
2010-11		1	342	4.3	4.9	4.2	4.1	3.9	3.8	4.1	4.1	3.8
mean	4.12	3	72	4.9	4.6	3.4	5.4	4.7	1.9	4.9	3.9	2.6
stdev	0.85	5	162	5.9	5.4	4.8	5.0	4.9	4.9	4.4	4.5	4.4
SE	0.14	7	252	4.1	3.6	3.1	3.1	3.3	3.6	3.5	3.1	3.1
2011-12		1	342	2.1	4.5	4.1	4.3	4.5	1.8	2.2	1.9	2.0
mean	4.04	3	72	5.5	5.8	6.7	4.6	7.6	7.0	4.3	5.4	6.5
stdev	1.48	5	162	4.5	2.4	4.0	3.6	3.4	3.3	4.2	3.6	3.6
SE	0.25	7	252	3.0	4.4	4.9	4.6	3.8	2.4	2.5	3.2	3.2
2012-13		1	342	4.8	1.7	2.9	2.6	2.2	5.3		3.8	5.2
mean	2.75	3	72	1.7	1.9	1.1	1.5	-0.1	2.6	3.0	2.6	2.5
stdev	1.10	5	162	1.5	3.8	3.0	3.4	2.7	3.6	2.9	2.6	2.5
SE	0.18	7	252	3.9	2.3	2.2	2.1	2.0	3.3	3.3	3.1	2.6

St. Croix West (SCW)				Net change in elevation between sampling period (cm)								
RSET-03 Line 2		**Position**	**Bearing**	**Pin 1**	**Pin 2**	**Pin 3**	**Pin 4**	**Pin 5**	**Pin 6**	**Pin 7**	**Pin 8**	**Pin 9**
2008-09		1	342	-1.5	-0.9	-1.2	-0.3	-0.9	-1.5	-1.1	-1.1	-1.6
mean	-1.25	3	72	-1.1	-1.5	-1.3	-1.4	-1.1	-1.3	-1.2	-0.9	-1.1
stdev	0.35	5	162	-1.3	-0.8	-1.1	-1.2	-1.0	-1.1	-1.1	-1.3	-1.3
SE	0.06	7	252	-1.9	-1.4	-0.9	-1.3	-1.2	-1.6	-2.3	-1.8	-1.3
2009-10		1	342	12.5	13.6	13.8	12.0	13.6	11.1	10.4	14.2	14.0
mean	13.09	3	72	12.2	14.7	14.0	14.3	14.4	12.4	14.1	15.1	13.2
stdev	2.10	5	162	15.5	13.9	15.2	13.1	15.1	14.2	13.4	19.0	15.1
SE	0.35	7	252	8.0	9.3	11.3	12.6	13.8	10.7	10.8	10.6	10.0
2010-11		1	342	0.7	-1.1	-1.5	-0.4	-1.9	0.1	0.1	-3.2	-2.6
mean	0.35	3	72	0.5	-2.2	-1.4	-2.1	-1.6	0.0	-5.0	-3.8	-1.4
stdev	2.61	5	162	0.5	2.9	2.4	4.1	2.0	1.3	2.3	-2.6	-1.6
SE	0.44	7	252	5.3	4.1	1.8	1.1	0.0	3.4	4.4	4.1	3.8
2011-12		1	342	0.9	1.5	1.1	-0.1	2.2	1.7	1.7	2.1	4.7
mean	2.57	3	72	1.3	3.0	2.1	2.6	3.1	5.0	8.3	5.2	3.8
stdev	1.68	5	162	2.2	2.6	2.0	2.0	-0.3	1.5	-0.5	1.7	1.5
SE	0.28	7	252	2.6	2.7	2.8	2.5	3.2	3.6	4.6	3.7	3.8
2012-13		1	342	1.1	1.1	2.8	4.9	2.1	1.7	2.0	1.7	0.8
mean	1.43	3	72	2.3	2.0	2.4	2.4	1.5	0.6	0.6	0.1	2.3
stdev	1.24	5	162	0.6	0.1	0.5	0.7	3.7	2.8	3.6	1.0	2.7
SE	0.21	7	252	0.8	1.1	1.0	0.8	0.7	0.1	-0.8	0.2	-0.7
RSET-04 Line 1		**Position**	**Bearing**	**Pin 1**	**Pin 2**	**Pin 3**	**Pin 4**	**Pin 5**	**Pin 6**	**Pin 7**	**Pin 8**	**Pin 9**
2008-09		1	342	-2.2	-1.8	-1.9	-1.9	-1.8	-2.0	-1.9	-1.6	-2.7
mean	-2.17	3	72	-2.1	-2.0	-2.3	-2.3	-2.3	-2.5	-2.2	-2.3	-2.2
stdev	0.35	5	162	-2.8	-2.5	-3.1	-2.5	-2.4	-2.1	-2.0	-2.6	-2.8
SE	0.06	7	252	-1.7	-2.0	-1.9	-1.6	-2.0	-1.8	-2.1	-2.1	-2.2
2009-10		1	342	14.1	13.9	14.3	14.7	15.0	15.2	15.0	15.2	16.3
mean	15.99	3	72	15.6	15.5	16.1	16.1	16.5	16.7	17.0	17.1	17.1
stdev	1.24	5	162	15.4	15.8	16.8	16.7	17.0	17.4	17.4	18.0	18.2
SE	0.21	7	252	13.3	14.2	14.8	15.1	15.9	16.4	16.9	17.4	17.6
2010-11		1	342	7.6	7.5	8.1	7.6	7.7	7.3	7.3	7.1	6.8
mean	7.16	3	72	7.5	7.7	7.2	7.5	7.0	6.8	6.8	7.2	7.4
stdev	0.81	5	162	6.1	7.2	5.5	6.4	5.5	4.6	5.8	8.3	7.2
SE	0.13	7	252	7.5	7.3	7.3	7.8	8.1	7.5	8.2	7.9	7.3
2011-12		1	342	3.2	3.5	3.9	3.5	3	2.7	2.9	2.9	4
mean	3.82	3	72	3.1	3.1	3.3	3.5	3.6	5.6	7.9	6.3	3.5
stdev	1.82	5	162	8.7	8.3	0	0	0	0	0	0	0
SE	0.30	7	252	3	3.2	3.4	3.1	2.4	2.9	1.9	0.9	3.6
2012-13		1	342	10.2	10.2	10.9	11.3	12	12.4	13	13.7	11.1
mean	10.19	3	72	11.6	10.7	11	10.3	13.6	12	9.8	10.2	12.2
stdev	2.16	5	162	5.3	4.3							
SE	0.36	7	252	9	9.2	8.9	8.6	8.5	8	8.6	10.3	8.7

Table 9 Mean annual change in surface elevation 2008 to 2013 measured by RSET at SCP. RSETs at SCP not measured in 2009 due to road construction and limited access to site.

St. Croix (SCP)				**Net change in elevation between sampling period (cm)**								
RSET-01 Line 1		**Position**	**Bearing**	**Pin 1**	**Pin 2**	**Pin 3**	**Pin 4**	**Pin 5**	**Pin 6**	**Pin 7**	**Pin 8**	**Pin 9**
2008-10*		1	112	5.9	14.4	12.8	11.5	6.7	12.9	12.5	12.1	13.3
mean	10.74	3	200	12.2	10.5	9.5	8.8	12	10.8	11.1	12.3	10.2
stdev	1.91	5	290	10.3	8.3	11.7	9.7	9.7	8.5	9	8.2	8.3
SE	0.32	7	19	10.5	10.3	13.1	12.4	11.4	11	12.1	11.2	11.5
2010-11		1	112	7.8	0.9	0.1	1.3	0.9	0.8	0.9	1.6	1.1
mean	1.13	3	200	1.2	2.1	0.1	0.3	0.2	0.2	0.8	0.3	0.6
stdev	1.33	5	290	1	1.6	1.9	1.8	1.4	2.7	1.2	1.6	1.6
SE	0.22	7	19	0.7	0.7	1.1	0.9	1	-0.3	0.6	0.2	-0.4
2011-12		1	112	3.5	2.5	2.1	1.2	2.3	1.8	2	0.3	-0.1
mean	1.46	3	200	2.9	3.1	3.1	3	2.6	1.9	1.6	2	1.4
stdev	1.01	5	290	1.7	1.6	1.6	0.8	0.9	0.8	1.3	1.3	1.5
SE	0.17	7	19	0.7	0.4	1.4	0.1	-0.3	0.9	0.1	0.2	0.2
2012-13		1	112	5.7	6.1	6.4	6.8	6.6	6.8	5.1	6.5	6.8
mean	5.24	3	200	5	4.6	5.1	4.9	5.7	6.3	5.5	5.4	6.1
stdev	0.99	5	290	4.9	4	3.6	4	3.8	3.6	5.2	4.4	4.3
SE	0.16	7	19	6.1	4.5	3.4	4.4	5.2	5	5.3	5.9	5.5
RSET-02 Line 3		**Position**	**Bearing**	**Pin 1**	**Pin 2**	**Pin 3**	**Pin 4**	**Pin 5**	**Pin 6**	**Pin 7**	**Pin 8**	**Pin 9**
2008-10*		1	300	3.9	3.7	5.3	4.4	5.9	2.7	4.6	5.1	4.3
mean	5.01	3	30	0.6	4.1	3.7	2.8	2.2	2.5	11.7	4.7	4.5
stdev	2.35	5	120	3.5	4.7	5	6.1	7.3	6.5	6	4.3	5.8
SE	0.39	7	210	3.5	6.2	11.6	3.4	7.7	8.3	7.5	2.1	4.1
2010-11		1	300	0.2	1.6	-0.8	-0.9	-1.7	0.9	-2	-1.1	-0.6
mean	-0.74	3	30	1.4	-1.9	-0.8	-0.6	-0.3	0.2	-0.4	-0.3	-0.3
stdev	1.19	5	120	0.2	-1	-1.5	-1.2	-2.3	-1.6	0.4	-0.9	-1.8
SE	0.20	7	210	0.6	-3.1	0.8	0.5	-2.4	-2.4	-2.9	0.5	-1.2
2011-12		1	300	0.3	-0.3	0	1.6	0.5	0.6	0.7	1.3	2.6
mean	0.34	3	30	-0.4	0.1	0	0	0	-0.3	-0.1	-1.4	-0.5
stdev	0.83	5	120	0.1	0.8	0.5	0.2	1.5	1.2	-1.1	1	1.6
SE	0.14	7	210	-0.3	0.2	-0.3	0.2	-0.3	-0.2	0	1.8	0.6
2012-13		1	300	2.2	3.1	1.4	0.7	1.4	1.6	1.3	0.6	0.3
mean	1.77	3	30	2	2.6	2	2	1.5	1.6	2.8	2.2	1
stdev	0.84	5	120	1	1.7	0.9	1.4	1.5	3.2	2.2	1.1	1.7
SE	0.14	7	210	1.5	1.9	1.5	1.8	2	2	2.3	0.8	4.8

Table 10 Change in surface elevation from 2008 to 2013 measured by the RSET at SCR.

St. Croix Reference (SCR)				Net change in elevation between sampling period (cm)								
RSET-01 Line 1		**Position**	**Bearing**	**Pin 1**	**Pin 2**	**Pin 3**	**Pin 4**	**Pin 5**	**Pin 6**	**Pin 7**	**Pin 8**	**Pin 9**
2008-09		1	342	1.8	-0.1	-1.6	-1.2	-0.9	-1.8	-1.7	-1	-1.4
mean	-0.85	3	72	-0.7	0.4	-1.4	-1.3	-0.8	-1.8	-2.7	-2.1	-2.5
stdev	1.29	5	162	-1.2	-0.4	-1	-0.7	-2.1	-2.4	-1.4	-1.5	-1.7
SE	0.22	7	252	-0.1	-1.3	1.1	-1.8	-0.7	-0.2	1.6	3.4	0.5
2009-10		1	342	0.8	-0.9	0.3	-0.5	0	-0.7	-0.3	-1.3	-0.1
mean	-0.29	3	72	0.5	-0.3	0.5	0.6	0.8	-0.5	0.3	1.1	2.2
stdev	1.06	5	162	0	-0.6	-0.6	-1.1	0.1	1	0.2	-0.4	-0.5
SE	0.18	7	252	-1.9	-1.1	-1.8	-4.1	-0.9	0.3	-0.5	-0.4	-0.8
2010-11		1	342	-0.9	-0.2	-0.4	0.2	0.5	0.3	-0.3	0.4	0.6
mean	0.03	3	72	0.1	0	0.8	0.2	-0.2	0.1	0.2	0.4	0.2
stdev	0.70	5	162	0.2	0.2	-0.4	1	-0.2	-0.3	-0.6	-0.3	0
SE	0.12	7	252	0	-0.7	-2.2	0	0.3	0.2	-0.1	-0.5	2.6
2011-12		1	342	0.3	-0.3	0	0.5	-0.2	0	-0.6	-0.2	-0.3
mean	-0.08	3	72	-0.6	0.5	-0.1	0.8	-0.6	-0.8	-0.2	1.1	-0.2
stdev	0.47	5	162	0.2	0.1	-0.2	-0.7	-0.1	0.5	0.3	0.1	-1.2
SE	0.08	7	252	-0.6	0.5	-0.1	0.1	-0.5	-0.2	0.3	-0.3	-0.2
2012-13		1	342	-0.2	0.1	0.7	-0.3	0.2	0.8	-0.2	0.2	0
mean	0.16	3	72	-0.6	-1.1	-0.4	-0.3	0.7	1.4	2.1	-0.5	-0.5
stdev	0.69	5	162	0.6	0.4	0.7	0.1	0.5	0.3	-0.1	-0.5	1.2
SE	0.11	7	252	-0.3	-0.3	1.1	-0.2	0.5	0.8	-0.4	-1.1	0.2
RSET-02 Line 3		**Position**	**Bearing**	**Pin 1**	**Pin 2**	**Pin 3**	**Pin 4**	**Pin 5**	**Pin 6**	**Pin 7**	**Pin 8**	**Pin 9**
2008-09		1	120	-2	-1.5	-0.9	-0.9	-0.2	-1.2	-1.1	-0.7	-0.3
mean	-1.13	3	210	-1.2	-1.8	-1	0.4	-2	-1.9	-1.6	-0.5	-0.6
stdev	1.27	5	28	-0.9	-2.2	-1.3	-1.3	-1	-1.1	-1	-0.5	-0.8
SE	0.21	7	24	1.4	-2.9	2.2	-2	-1.8	-6	-1.4	-0.2	-0.7
2009-10		1	120	-0.1	1.1	2.7	0.6	-1.1	-0.1	-0.5	-1	1.9
mean	0.47	3	210	-0.8	2.5	0	0.9	-0.5	0.4	0.4	0.7	0.2
stdev	1.00	5	28	2.2	1.1	1	0.8	0.8	1.1	0.5	0.5	0.6
SE	0.17	7	24	-2.4	0.3	0	0.2	0	1.2	0.2	0.7	0.7
2010-11		1	120	0.3	-1.1	0.1	1.4	2.1	1.1	1.4	1.1	-0.1
mean	0.62	3	210	1.7	-1	2.3	1.2	3.8	1.4	0.6	0.9	1.1
stdev	1.03	5	28	-1	0	-0.1	0.2	0.6	-0.3	0.6	0.4	0.5
SE	0.17	7	24	0.4	0.8	0.7	-1.1	0.7	1.2	1.2	0.3	-1.2
2011-12		1	120	1.4	0.9	-5.6	-0.4	-1.5	-1.3	0	0.1	-1.1
mean	-0.19	3	210	0.5	0.1	0.5	0.5	-0.2	0.5	-0.2	-1	-0.6
stdev	1.28	5	28	0.5	-0.4	0	0.5	-0.1	1.3	0.1	-0.4	-1.2
SE	0.21	7	24	0.1	1.4	-1	2.7	-0.2	-0.5	-0.3	-0.8	-1
2012-13		1	120	0.1	-0.1	5.6	0.9	0.7	0.6	0.2	0.9	-0.3
mean	0.11	3	210	2.2	-0.3	-1.4	-2.3	-1.7	-1.1	-2.2	0.9	2
stdev	1.52	5	28	-0.1	0.7	0.7	-1.3	-0.6	-0.3	-0.2	-1	0.2
SE	0.25	7	24	1.7	-0.6	0.7	-0.2	0.1	-2.3	-0.5	-0.6	2.7

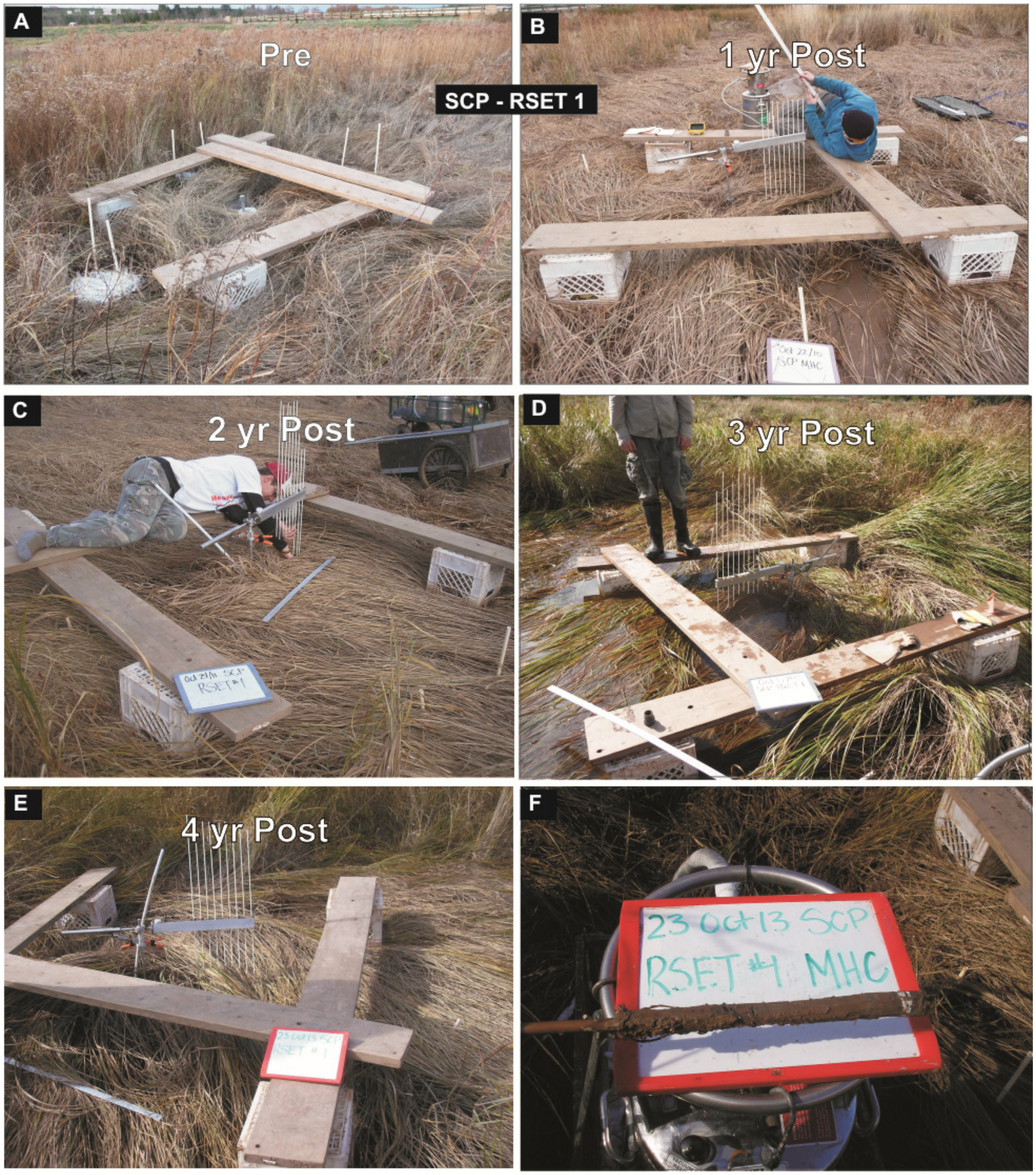


Figure 28 SCP_RSET-01 measurements pre-, and year 1 (22 October 2010), year 2 (24 October 2011), year 3 (1 October 2012) and year 4 (23 October 2013) post-restoration. Photographs taken by CBWES Inc.

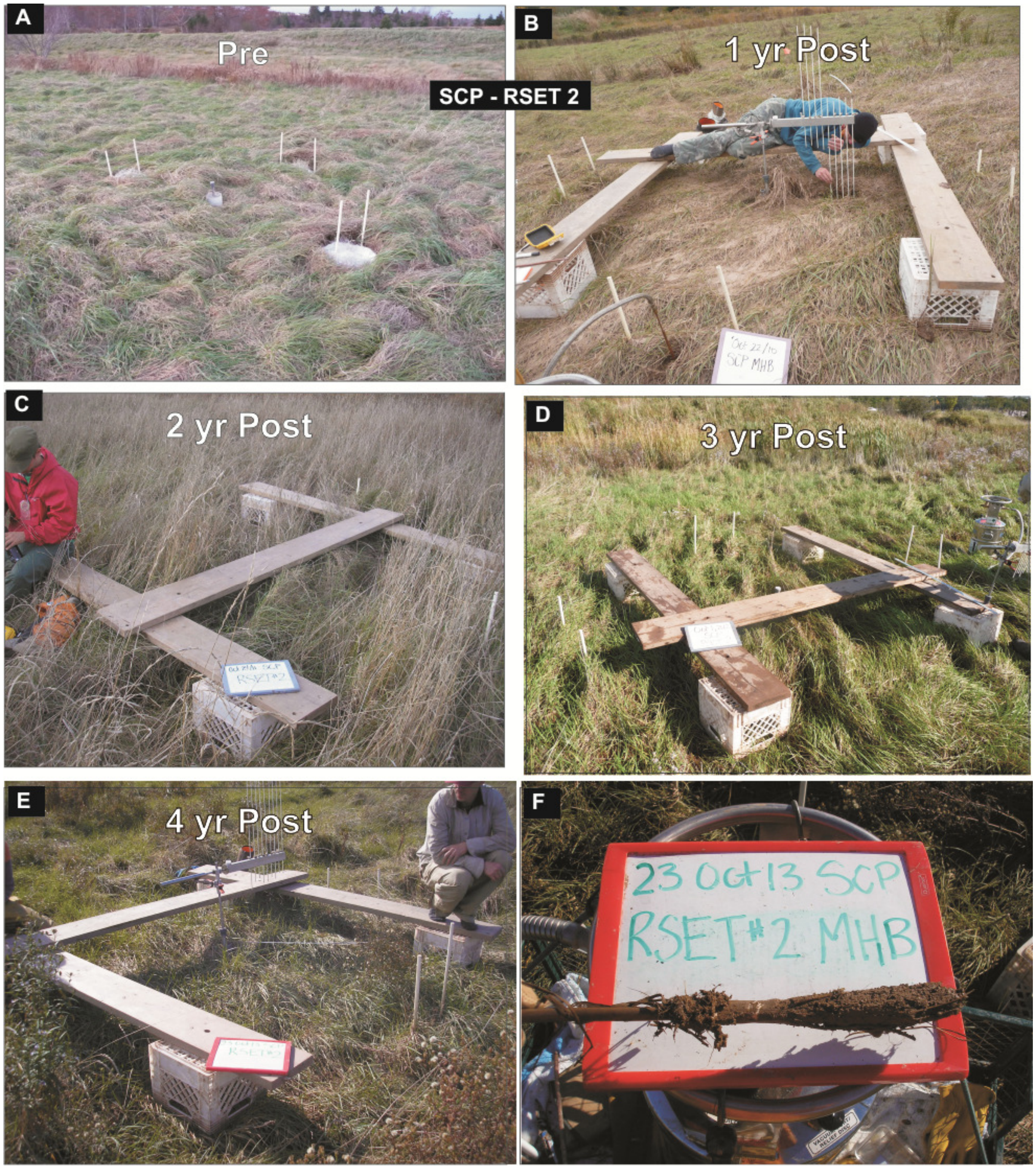


Figure 29 SCP_RSET-02 measurements pre-, and year 1 (22 October 2010), year 2 (24 October 2011), year 3 (1 October 2012) and year 4 (23 October 2013) post-restoration. Photographs taken by CBWES Inc.

Figure 30 RSET and marker horizon measurements at SCR in 2009 and 2013. Photographs taken by CBWES Inc.

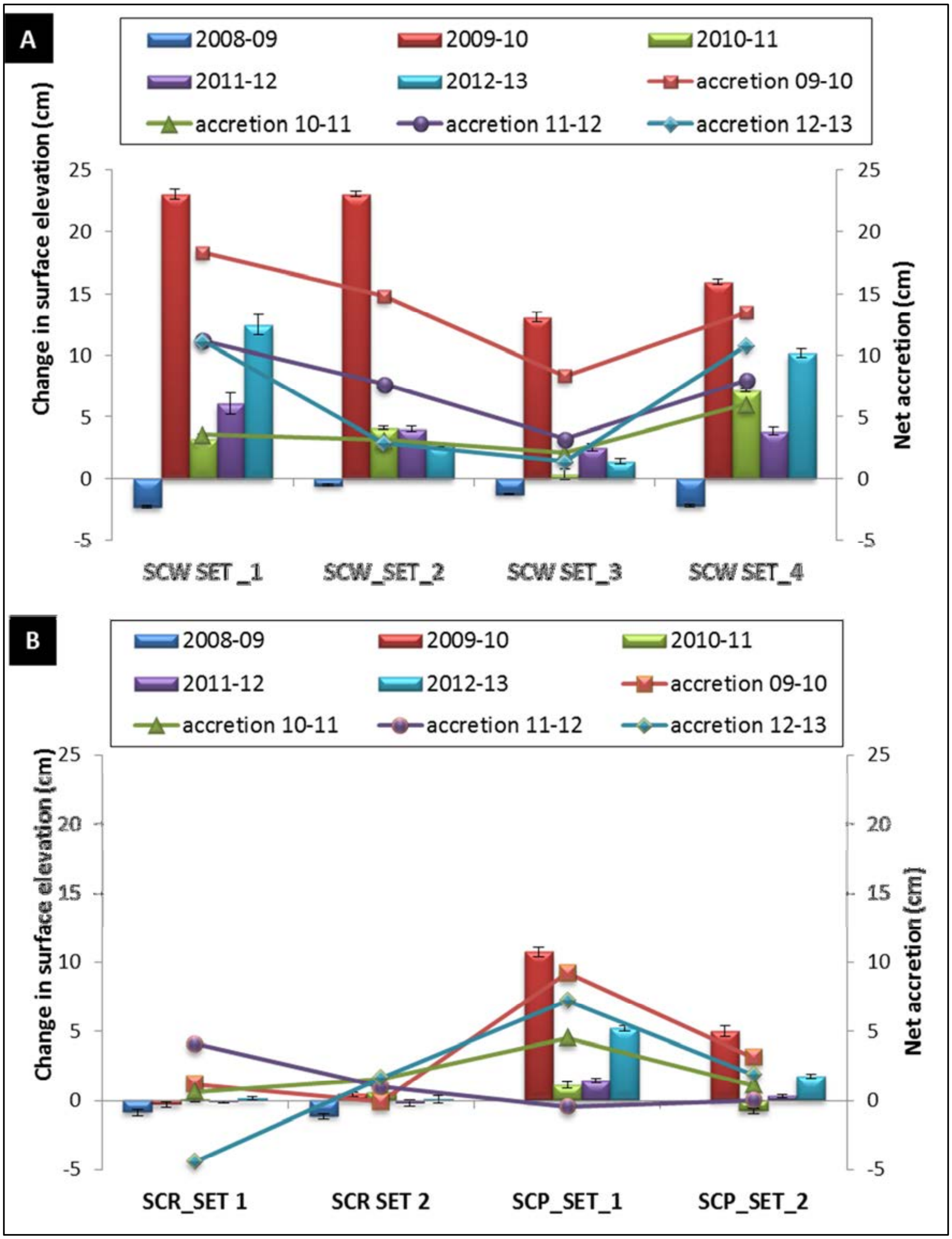
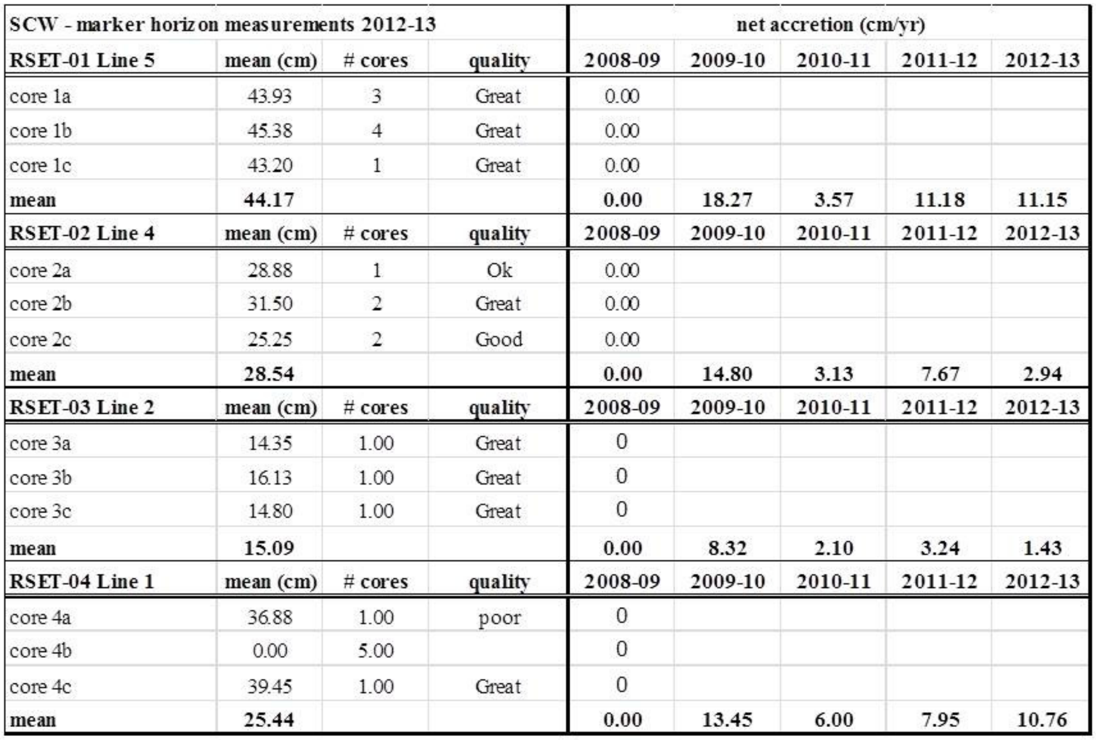


Figure 31 Comparison of change in surface elevation measured by RSET and sediment accretion using marker horizons at a) SCW and b) SCP and SCR from 2008 to 2013.

Table 11 Net sediment accretion measured by marker horizons at a) SCW b) SCP and c) SCR**.**

A

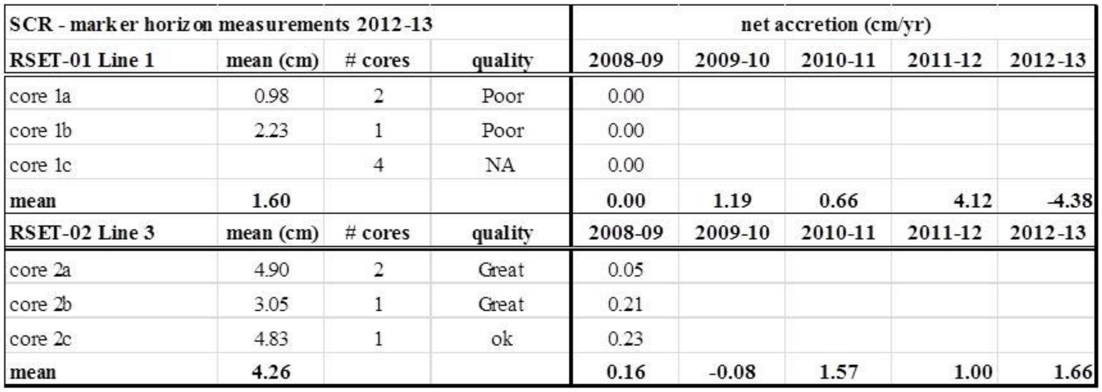


SCW - marker horizon measurements 2012-13				net accretion (cm/yr)				
RSET-01 Line 5	**mean (cm)**	**# cores**	**quality**	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**2012-13**
core 1a	43.93	3	Great	0.00				
core 1b	45.38	4	Great	0.00				
core 1c	43.20	1	Great	0.00				
mean	**44.17**			**0.00**	**18.27**	**3.57**	**11.18**	**11.15**
RSET-02 Line 4	**mean (cm)**	**# cores**	**quality**	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**2012-13**
core 2a	28.88	1	Ok	0.00				
core 2b	31.50	2	Great	0.00				
core 2c	25.25	2	Good	0.00				
mean	**28.54**			**0.00**	**14.80**	**3.13**	**7.67**	**2.94**
RSET-03 Line 2	**mean (cm)**	**# cores**	**quality**	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**2012-13**
core 3a	14.35	1.00	Great	0				
core 3b	16.13	1.00	Great	0				
core 3c	14.80	1.00	Great	0				
mean	**15.09**			**0.00**	**8.32**	**2.10**	**3.24**	**1.43**
RSET-04 Line 1	**mean (cm)**	**# cores**	**quality**	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**2012-13**
core 4a	36.88	1.00	poor	0				
core 4b	0.00	5.00		0				
core 4c	39.45	1.00	Great	0				
mean	**25.44**			**0.00**	**13.45**	**6.00**	**7.95**	**10.76**

B

SCP - marker horizon measurements 2012-13				net accretion (cm/yr)				
RSET-01 Line 1	**mean (cm)**	**# cores**	**quality**	**2008-09**	**2008-10***	**2010-11**	**2011-12**	**2012-13**
core 1a	23.05	2	Great	NA				
core 1b	17.00	1	Great	NA				
core 1c	21.95	2	Great	NA				
mean	**20.67**			**NA**	**9.27**	**4.54**	**-0.41**	**7.28**
RSET-02 Line 3	**mean (cm)**	**# cores**	**quality**	**2008-09**	**2008-10***	**2010-11**	**2011-12**	**2013-13**
core 2a	6.80	1	Poor	0.00				
core 2b	4.78	1	Ok	0.00				
core 2c	7.08	1	Great	0.00				
mean	**6.22**			**0.00**	**3.15**	**1.14**	**0.03**	**1.89**

C



SCR - marker horizon measurements 2012-13				net accretion (cm/yr)				
RSET-01 Line 1	**mean (cm)**	**# cores**	**quality**	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**2012-13**
core 1a	0.98	2	Poor	0.00				
core 1b	2.23	1	Poor	0.00				
core 1c		4	NA	0.00				
mean	**1.60**			**0.00**	**1.19**	**0.66**	**4.12**	**-4.38**
RSET-02 Line 3	**mean (cm)**	**# cores**	**quality**	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**2012-13**
core 2a	4.90	2	Great	0.05				
core 2b	3.05	1	Great	0.21				
core 2c	4.83	1	ok	0.23				
mean	**4.26**			**0.16**	**-0.08**	**1.57**	**1.00**	**1.66**

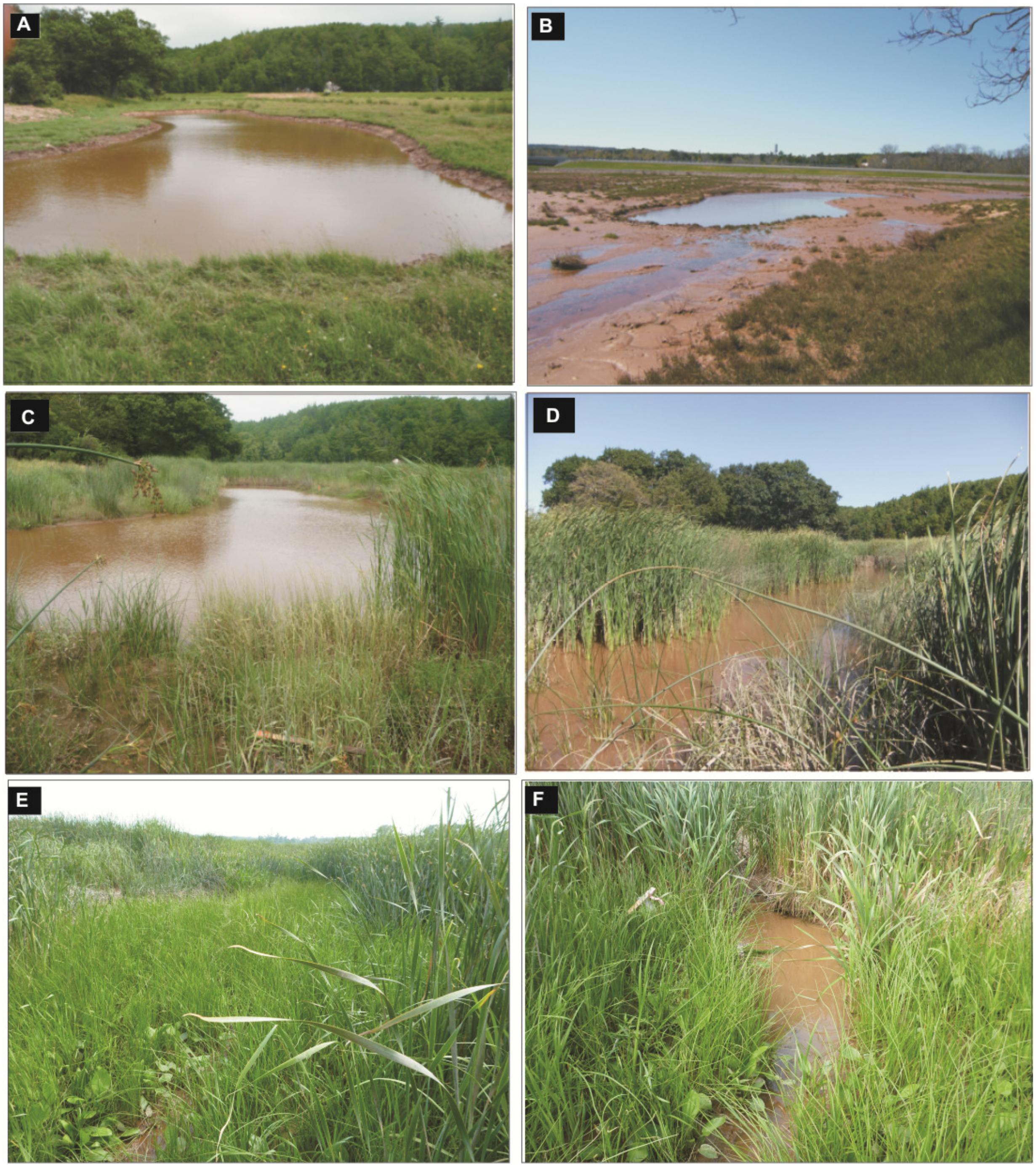


Figure 32 The excavated pond (south) at SCW a) 17 July 2009, b) post-restoration 4 May 2010; c) 22 July 2011; d) 17 September 2012; and e) 17 July 2013. Photographs taken by CBWES Inc.

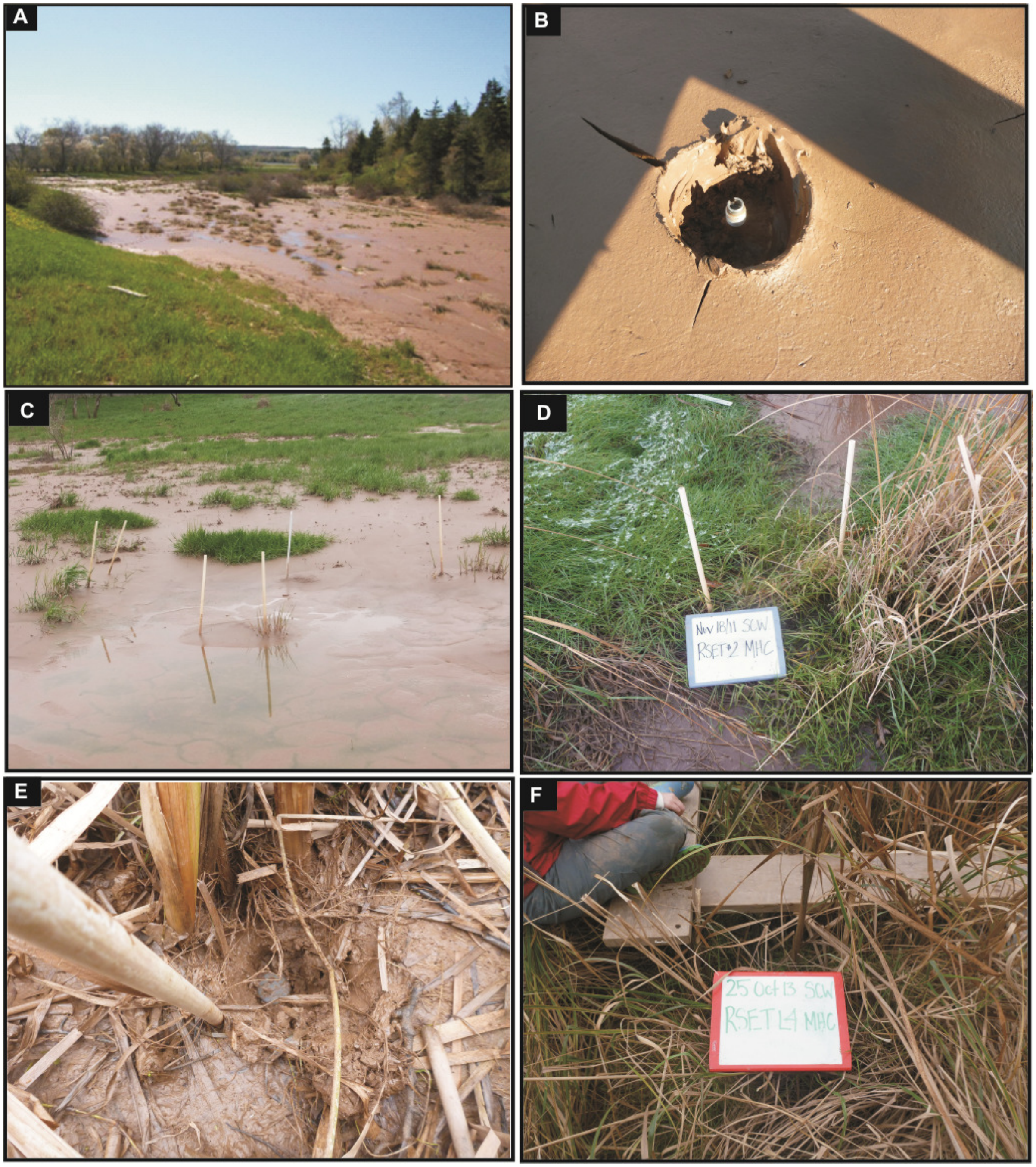


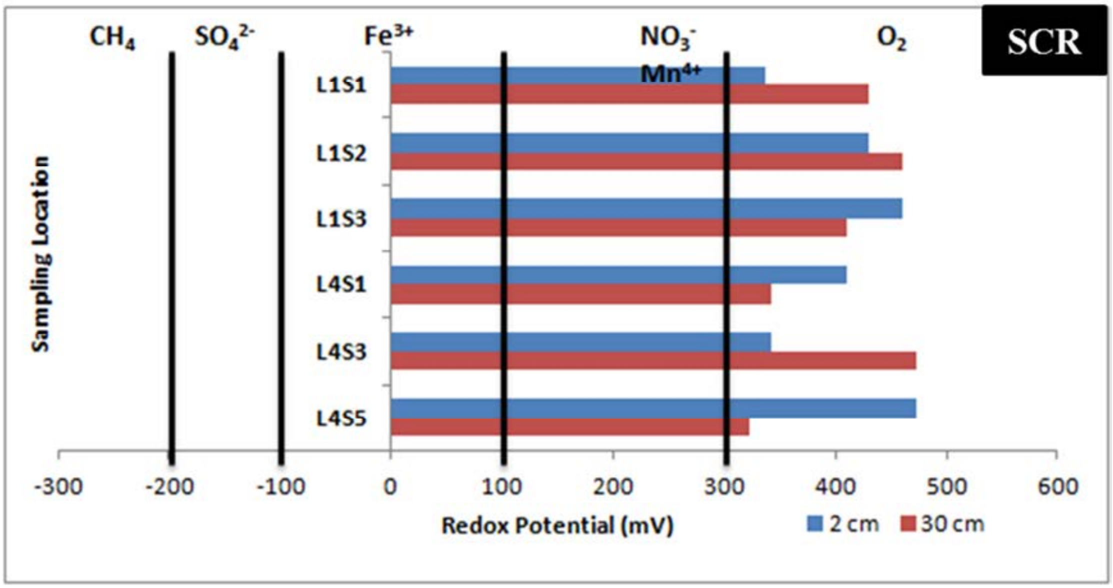
Figure 33 SCW a) Sediment deposition from northern breach (creek 4) affecting RSET-02 and RSET-04 in 2010; b) RSET-02 receiver on 23 October 2010; c) RSET-02 area on 17 May 2011; d) MHC RSET-02 on Line 4 on 5 October 2012; e) receiver cap for RSET-02 Line 4 on 13 October 2013 and f) MHC RSET-02, 13 October 2013. Photographs taken by CBWES Inc.

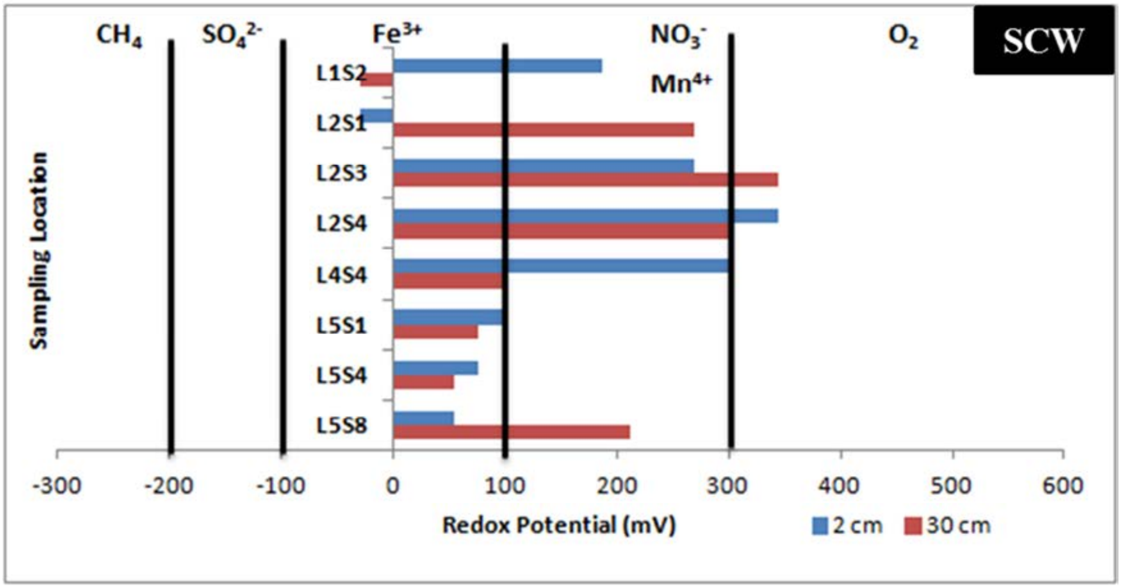
Soil Chemistry (Redox Potential)

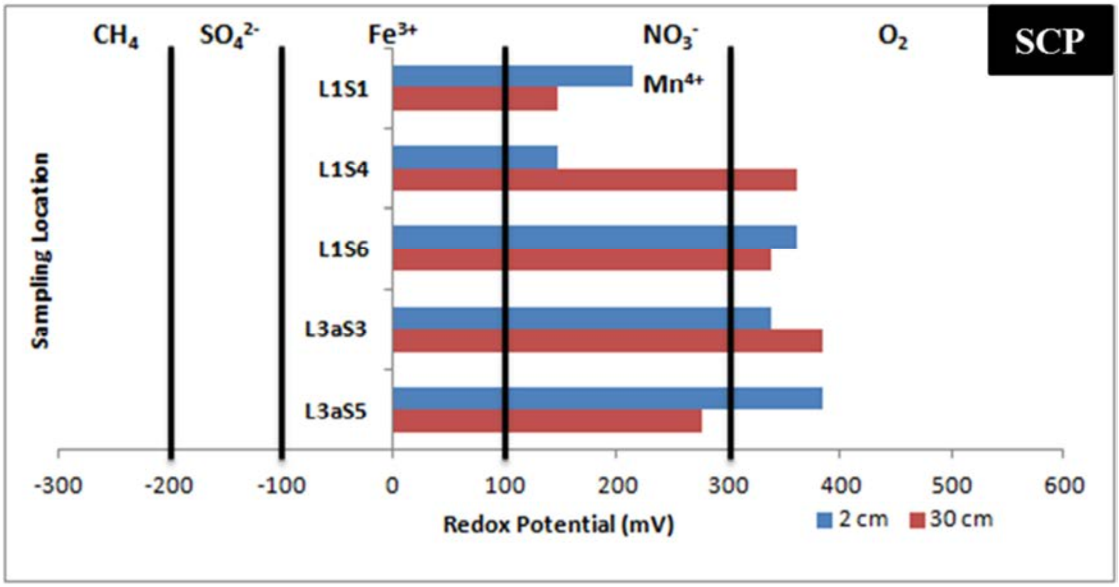
2013 was the first year for soil chemistry data sampling at the SC restoration and reference sites. Additional data for this parameter will be collected in year five of the post-restoration monitoring program, which will allow for a between year comparison.

The mean for the redox potential, in relation to the dominant reduction oxidation reaction occurring at 2 cm and 30 cm depth, can be found in Figure 34. The values were broken into ranges of dominant reduction reactions as specified by Reddy and DeLaune (2008). At SCR the values indicated that aerobic respiration was occurring at all sampling locations. This was the only site at which this was the case. The sediment at SCR was moist, but not extremely wet as compared to some of the locations at the restoration sites. At SCW, out of the eight readings taken, values indicated that aerobic respiration was only experienced at two locations: L2S3 at 30 cm and L2S4 at 2 cm. At SCP, values indicating aerobic respiration were found at all locations except L1S1 at 2 and 30 cm depth, L1S4 at 2 cm depth and L3aS5 at 30 cm depth. Therefore, SCP had the closest values to SCR compared to the other restoration sites. At SCE, values indicating anaerobic respiration were found at all of the locations, depending on the depth, and experienced aerobic respiration at 20 cm at L2S2 and 2 cm at L2S3. No trends could be inferred from the data as this was the first year of data collection.

Overall, the values indicated moderate anaerobic stress on vegetation with the potential for moderate decomposition rates to occur within the soil under these anaerobic conditions. There is potential for sulfide, a known phytotoxin, to accumulate within the soil, as the soil is heterogeneous and multiple redox reactions occur at one time. However, sulfate reduction was not the dominant redox reaction being measured at any of the SC restoration sites; therefore, high levels of sulfide are not expected to accumulate. The areas that experienced oxygen reduction could allow for the oxidation of the reduced compounds (i.e. sulfide) and decrease the level within the soil. The values indicate appropriate drainage and lack of water logging at the sampling locations; therefore, the high anaerobic conditions needed for high sulfide levels to accumulate were not present at the time the readings were taken. An additional year of data collection should provide some insight into whether or not the SC restoration sites are trending towards conditions at the reference or if a greater anaerobic stress is expected in the future.


SCR
CH4
SO4 2-
Fe3+
NO3-
Mn4+
O2
Sampling Location
L1S1
L1S2
L1S3
L4S1
L4S3
L4S5
-300
-200
-100
0
100
200
300
400
500
600
Redox Potential (mV)
2 cm
30 cm


SCW
CH4
SO4 2-
Fe3+
NO3-
Mn4+
O2
Sampling Location
L1S2
L2S1
L2S3
L2S4
L4S4
L5S1
L5S4
L5S8
-300
-200
-100
0
100
200
300
400
500
600
Redox Potential (mV)
2 cm
30 cm



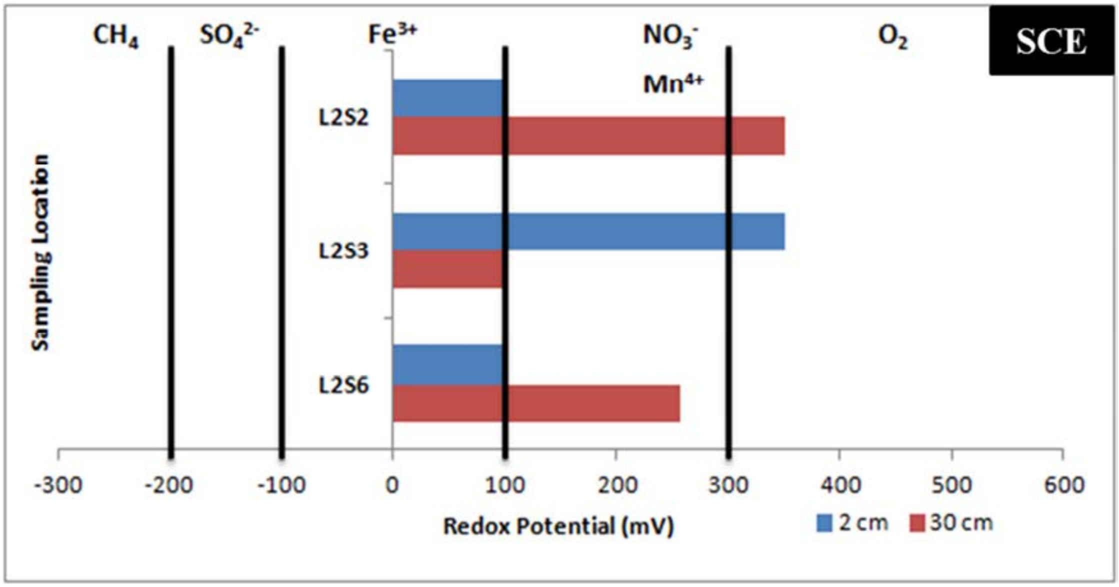


Figure 34 Mean redox potential values in relation to dominant reduction oxidation reaction occurring at 2 cm and 30 cm depth broken into ranges of dominant reduction reactions as specified by Reddy and DeLaune (2008) at SCR and the SC restoration sites.

4.4 Vegetation

SCR is characterized by plots dominated by a mixture of pasture weeds (*Centaurea nigrum*, *Cirsium arvense*, *Filipendula ulmaria*, *Equisetum* and *Solidago* sp.; Appendix B1, C1) with others dominated by a mixture of species characterised by brackish marsh species (*Calystegia sepia*, *Spartina pectinata*, *Carex paleacea*, *Galium palustre*, *Agrostis stolonifera*; Appendix B1, C1). Two plots (L1S4, L2S4) were previously dominated by *Spartina alterniflora*, but only one plot contained this species in 2012 and 2013. There were limited species that could be classified as (low or high) salt marsh vegetation at SCR. There has been little change at the reference site between 2008 and 2013 (outside of fluctuations in minor species over the five-year period). SCR is useful as key variables such as halophytic richness and abundance have changed substantially at portions of the restoration sites, but not at the reference site (Figure 36 and Figure 37).

SCP, similar to the reference site, contained plots with pasture grasses and weeds, and a set of brackish species. This site had the most overlap with SCR than the other SC restoration sites. Changes at SCP included large increases in *Alopecurus pratensis* and *Spartina pectinata*. There were few recent changes at the site (Appendix C2). The SCP fringe plots were dominated by freshwater marsh species (*Scirpus*, *Typha*) and showed no significant changes between years, except for the colonization of *S. pectinata* in 2010 which has occurred at low densities since then (Appendix B1, C2).

SCS had some areas dominated by brackish species (*Agrostis stolonifera, S. pectinata*) and others with a mix of pasture weeds or freshwater wetland vegetation (Appendix B2, C3). There is great overlap between community structure at SCS and the reference site. There have been few changes at SCS. The fringe plots at SCS contained mostly freshwater wetland vegetation (*Typha*) or brackish species (*S. pectinata*) and showed no easily interpretable changes over the study period (Appendix B2, C3).

SCE contained plots with a mixture of brackish and pasture species. Changes included colonization by *Alopecurus geniculatus* and *A. pratensis*, and freshwater wetland species such as *Polygonum hydropiper*, *P. persicaria*, *Rorippa palustris* and *Scirpus acutus* (Appendix C4). There have also been losses or declines of some pasture weeds such as *Filipendula ulmaria* and *Taraxacum officinale*, and the invasive *Phalaris arundinaria*, which occurred at 7 plots prior to restoration (Appendix C4), but was not detected in the plots between 2010 and 2012. This species showed up in one plot in 2013. There was a notable increase in *S. pectinata* in 2011, a decline in 2012, and a large increase in 2013 (now found in 14 plots; Appendix B3, C4). The ordination diagrams (Appendix B3) show a notable shift in community composition from pre-restoration when many plots were characterized by ruderal or pasture vegetation, to 2012 when the same plots were covered by a range of freshwater or brackish vegetation types. In 2013, the plots were more tightly clustered near the bulk of the reference plots, reflecting the greater abundance of *S. pectinata* (Appendix B3). The fringe plots were similar to the other SC restoration site fringe plots and showed no significant changes over the study period, although there were slight increases in *S. pectinata*, *Carex paleacea* and *Agrostis stolonifera* in 2013 (Appendix B3, C4).

SCW was initially characterized by wet pasture (*Juncus effusus* etc.) and brackish vegetation, with the largest shifts post-restoration seen of any of the SC sites (Appendix B4, C5). Notable changes included colonization by *Alopecurus geniculatus* and *A. pratensis*, which seem to do well in brackish conditions although both species showed a decline in 2013. Other colonists since the restoration of tidal flow include *S. alterniflora*, *S. pectinata, Atriplex sp., Elymus repens* (not native but common in the upper edges of salt marshes), *Polygonum hydropiper* and *Scirpus validus*. Species that have shown a decline include *Taraxacum officinale, Juncus effusus* and *Rumex crispus* (along with some other pasture weeds). Although there was some evidence of an increase in 2012 for some, most had lower abundances again in 2013. There has been a consistent increase in *S. pectinata* post-restoration (Appendix B4, C5). *Carex paleacea*, a high-marsh/brackish species was observed for the first time in 2012. Other major changes in 2013 included a substantial increase in *Agrostis stolonifera* and *Typha* spp., an increase in *S. pectinata* and a slight decrease in *S. alterniflora*. The detection of *Phalaris arundinacea* for the first time at the site (plot: SCW L4S2_40m; Appendix C5) is consistent with colonization and increased dominance of freshwater wetland species (*P. arundinacea* can be considered invasive in wet pastures and the edges of freshwater wetlands). Decreases in *Atriplex* sp. (an early successional species, it might be outcompeted by the taller species) were consistent with this trend toward greater vegetation heights and more productive species, which are characteristic of a brackish community.

The ordination diagrams showed a strong shift in community composition from pasture species to wetland species during the first four years post-restoration (Appendix B4). Based on the co-occurrence at the plot level of freshwater and salt marsh species (e.g. SCW L3S4_120m, which was colonized in 2011 by both *Scirpus validus* and *S. alterniflora*), it is clear that this site has not reached any kind of ecological steady-state and we can anticipate changes to continue into the future. This was evident in the continued large spread of plots across the community space on the ordination diagram in 2013 (Appendix B4). Individual plots showed highly heterogeneous dynamics. L1S2 was colonized by *Alopecurus* sp. post-restoration, and then *S. alterniflora* was found there, followed by *S. pectinata* in 2013. Some plots were colonized by *S. alterniflora* and *S. pectinata* in 2012 and still have high abundances of both species in 2013 (SCW L1S1_FS). Whereas other plots showed colonization of non-native wet pasture species (with some salt tolerance) such as *Alopecurus geniculata* and *Elymus repens* (e.g. SCW L3S1_FS, SCW L3S2_40m), or more brackish species such as *Agrostis stolonifera* and *S. pectinata* (SCW L3S5_160m), and some plots were initially colonized by Typha in 2011 (SCW L4S5_160m). As discussed in *Section 4.3: Sediment Accretion and Elevation*, sediment deposition, particularly on SCW, could be having a disturbance affect and creating openings for vegetation to colonize. This could be one reason that a steady state has yet to occur at this site. The fringe plots did show some changes here over the study period (gradual increases in *Agrostis stolonifera* and *S. pectinata*). It is not clear why these shifts have occurred, but could be due to a combination of changing hydrological conditions (i.e. long-term [multi-year] tidal cycles and restoration site changes due to breaching the dyke), sedimentation, and an increased source population (*S. pectinata* within the restoration site seeding the fringe). The fringe plots at other SC restoration sites also experienced an increase of *S. pectinata* in 2013.

Univariate Analyses

Species richness increased between pre- and post- sampling at most sites, but this may be a result of increased ability to detect species (Figure 35 and Table 12). There were significant site differences, but they were largely consistent across years, with some declines in 2012 and 2013.

Halophytic richness increased significantly at SCP, SCW and SCP-fringe between pre- and post-restoration sampling, especially at SCW, but has been relatively constant since 2011 at these sites (Figure 36 and Table 13). Halophytic abundance was greatest at SCS-fringe (Figure 37), which contains just two plots that have relatively high abundances of *S. pectinata*. Halophytic species abundances increased significantly at SCW and SCP over the study period (Figure 37); SCE showed an increase in 2011 followed by decline to previous levels by 2012, and an increase again in 2013 (due to fluctuations in *S. pectinata* plot frequency). The largest increase was between 2010 and 2011 for SCW, with 2012 and 2013 levels staying high but not increasing. Most of these increases are accounted for by *S. pectinata*, which increased at SCW and SCP sites in both coverage and frequency (Appendix C2, C5). The other sites (reference, SCS and the fringe sites) did not show consistent changes over the same time period. The amount of unvegetated area was highly variable from year to year, with notable increases at SCW between pre-restoration and 2010, and then a decline between 2010 and 2013 (Figure 38). These changes at SCW were reflected in the changes in species composition as well, and were consistent with greater flooding and sedimentation post-restoration. SCS showed an increase in unvegetated area in 2013, with one plot that had high coverage of *Typha* up to 2012, but no plant cover in 2013.

Table 12 Repeated measures ANOVA for species richness.

Between plots	**Df**	**Sum Sq**	**Mean Sq**	**F**	**P**
Site	8	932.1	116.52	3.815	0.000594
Year	5	336.1	67.22	2.201	0.059957
Site x Year	4	279.0	69.76	2.284	0.065433
Residuals	101	3084.6	30.54		
Within plots					
Year	5	321.2	64.23	11.315	<0.0001
Site x Year	32	244.4	7.64	1.345	0.103
Residuals	432	2452.4	5.68		

Table 13 Repeated measures ANOVA for halophyte richness.

Between plots	**Df**	**Sum Sq**	**Mean Sq**	**F**	**P**
Site	8	34.20	4.275	4.103	0.000288
Year	5	4.54	0.908	0.871	0.503164
Site x Year	4	1.86	0.465	0.446	0.774963
Residuals	101	105.22	1.042		
Within plots					
Year	5	17.98	3.597	16.020	<0.0001
Site x Year	32	26.28	0.821	3.658	<0.0001
Residuals	432	97.00	0.225		

Table 14 Repeated measures ANOVA for halophytic abundance.

Between plots	**Df**	**Sum Sq**	**Mean Sq**	**F**	**P**
Site	8	6400	800.0	2.811	0.00745
Year	5	1577	315.5	1.108	0.36080
Site x Year	4	671	167.6	0.589	0.67136
Residuals	101	28747	284.6		
Within plots					

Year	5	3244	648.8	13.276	<0.0001
Site x Year	32	3636	113.6	2.325	<0.0001
Residuals	432	21113	48.9		

Table 15 Repeated measures ANOVA of unvegetated area.

Between plots	**Df**	**Sum Sq**	**Mean Sq**	**F**	**P**
Site	8	181.9	22.740	1.201	0.306
Year	5	44.8	8.951	0.473	0.796
Site x Year	4	81.2	20.291	1.072	0.374
Residuals	101	1911.9	18.929		
Within plots					
Year	5	135	27.023	3.020	0.010826
Site x Year	32	600	18.755	2.096	0.000579
Residuals	432	3865	8.948		

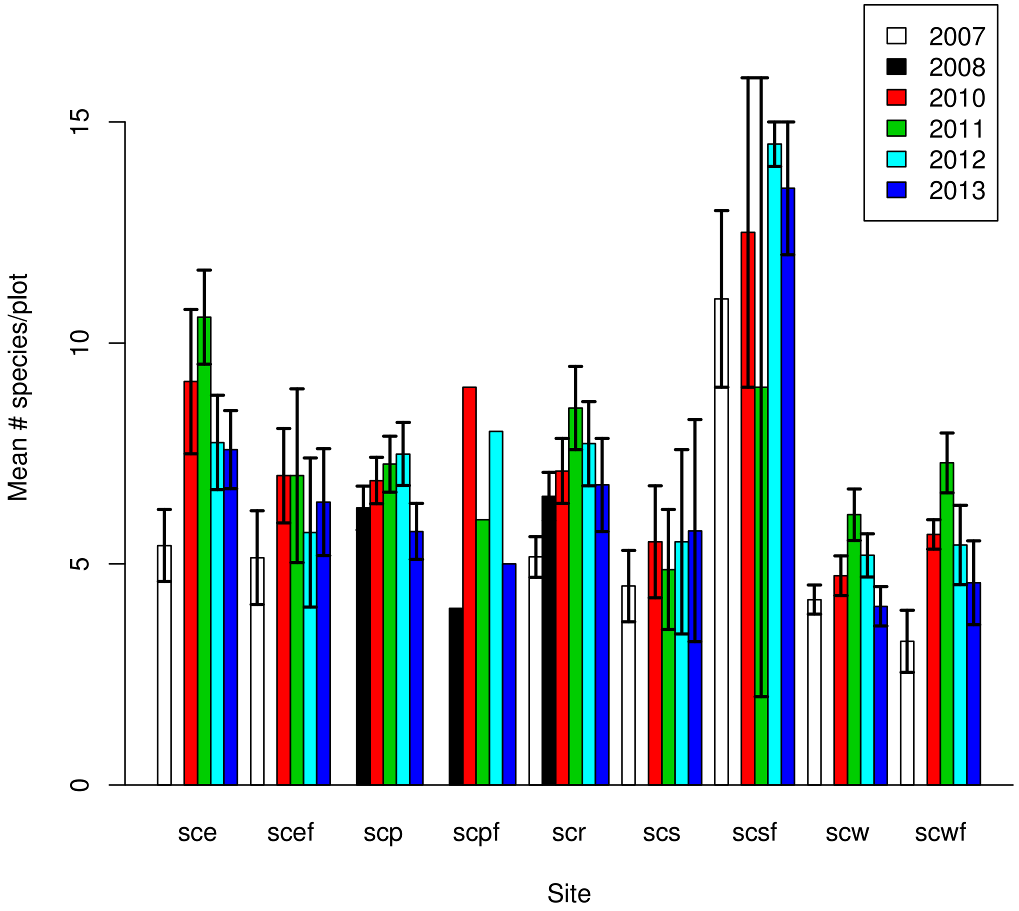


Figure 35 Mean plot species richness at SC restoration sites (including fringe) and SCR.

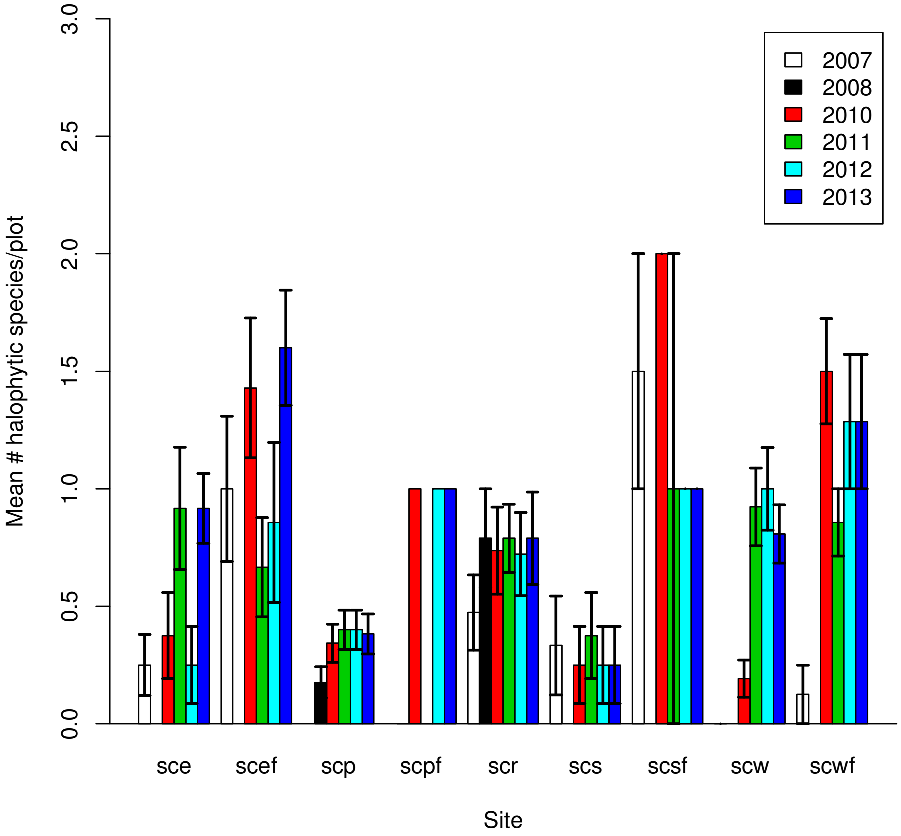


Figure 36 Mean plot richness of halophyte species at the SC restoration sites and SCR.

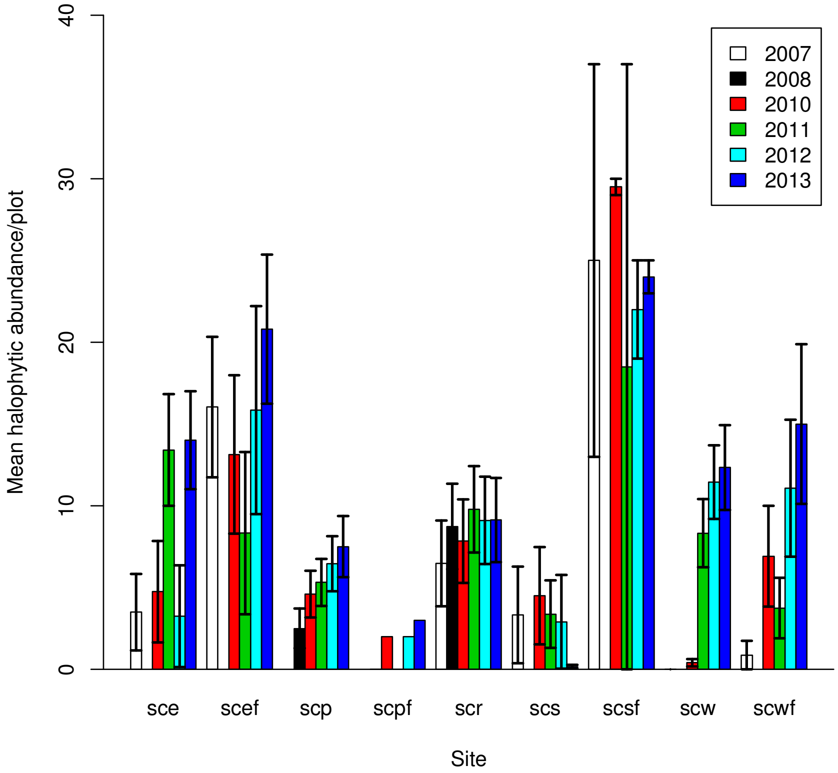


Figure 37 Mean plot abundance of halophyte species at the SC restoration sites and SCR.

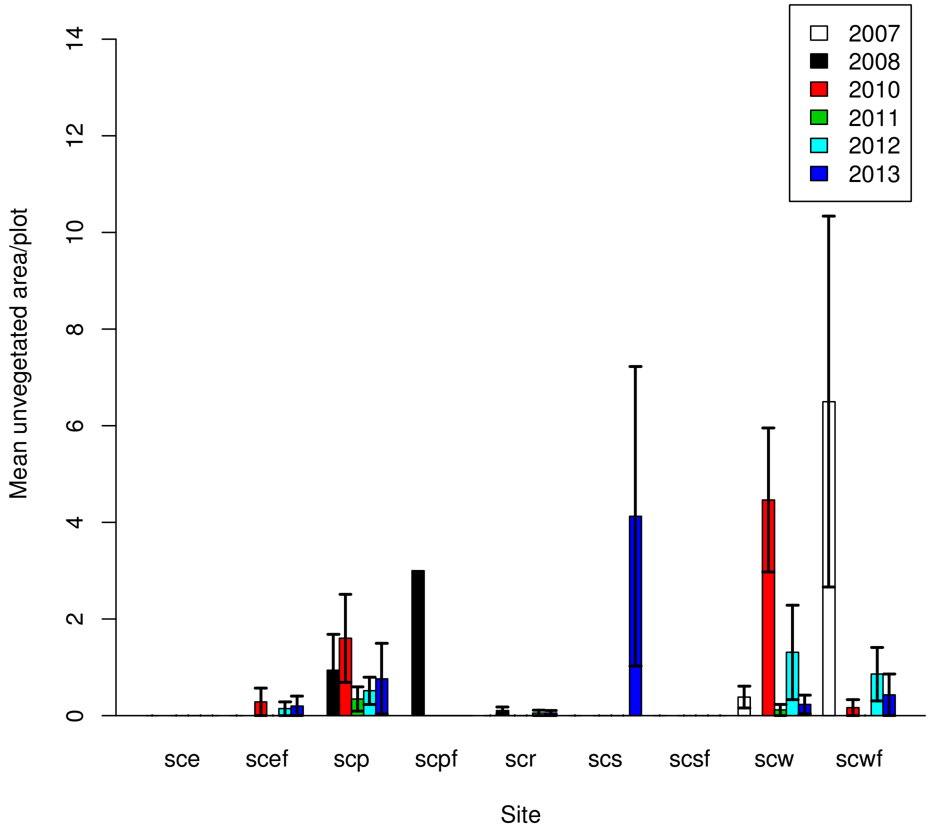


Figure 38 Mean plot unvegetated area at the SC restoration sites and SCR.

Invasive Species

A small population of *Phragmites australis* (common reed; elephant grass) was discovered at SCW in 2012. The *Phragmites australis* was growing amongst the *Typha* sp. in this location and was not observed prior to 2012. This species includes a native and an aggressive non-native (invasive) subspecies. The presence of either subspecies within SCW is of concern. These individuals were removed in October 2012 by members of a fourth-year undergraduate course offered by the Environmental Science Department at SMU (ENVS 4470 – Environmental Remediation and Restoration), taught by Dr. Jeremy Lundholm. *Phragmites australis* found at the Cogmagun River restoration site (Bowron et al. 2014a), was collected and identified as the native species. This would support that individuals found at St. Croix would also be native, but this will require samples of the species if found again.

Lythrum salicaria (purple loosestrife) individuals were also found at SCW (Figure 39). Both of these invasive species form extensive stands or colonies and crowd out other species such as *Typha* sp., decreasing biodiversity of the area. Control efforts (removal) were undertaken by CBWES and SMU students in both 2012 and 2013. As *Lythrum salicaria* individuals were encountered during the growing season, flowering parts were cut and disposed of and coordinates taken with a GPS, then removal of the remaining plant was conducted by the students. The difficulty with this approach was the availability of the class for on-site work one day in October of the respective year. To be effective, removal needs to occur earlier in the growing season, before the plants have the opportunity to produce seed. A focused invasive species management strategy should be developed and implemented for the site, if eradication is deemed a priority and is to be successful.

No individuals from either species have been found in the monitoring plots.

Figure 39 *Lythrum salicaria* (purple loosestrife) a) growing tall within the Typha (black arrow pointing to *L. salicaria* in a zoomed image of (a)) and b) on the fringe marsh at SCW.

4.5 Nekton

Over the first four years of post-restoration monitoring, six different species were caught in the minnow traps and fyke net (Table 16). The total catch (fyke net and minnow traps) was numerically dominated by tomcod (*Microgadus tomcod*) and mummichog (*Fundulus heteroclitus*). 2013 saw the greatest number of tomcod caught during the fish survey (all years) and the greatest number of American eel (*Anquillaro strata*) (all years). Two years post-restoration (2011), remains the year of the greatest diversity of species and greatest number of individuals caught (Table 16). Table 17 shows the relative abundance for the two survey methods used. For the minnow trap, 2012 had the greatest relative abundance and for the fyke net, 2011 had the greatest relative abundance. Table 18 shows that the average standard length of the mummichogs caught was within the mature size class. However, individuals from all age size classes (juveniles to adult) were captured. The tomcod and striped bass (*Morone saxatilis*) standard length average and range identified the individuals as juveniles (Table 18), as was the case in previous years.

The mummichog was expected to be the most abundant species captured in the minnow traps that were set in the ponds/pannes. This species can be found in estuaries, creeks, tide pools and even freshwater, but are most commonly found in salt marshes and shallow coastal waters (Gibson 2003). Mummichogs have been captured during fish surveys at other dyke breach restoration projects in the region, at times in great numbers (Cogmagun and Walton River: Bowron et al. 2013c; Neatt et al. 2013). It has been found that usually the greatest number of mummichogs have been captured in the minnow traps set in the pannes/ponds. Mummichogs have been the only species consistently caught in the minnow traps at SCW in all years. Nine-spine sticklebacks (*Pungitius pungitius*) were also caught in the minnow traps (albeit low numbers), but only during the first two years of post-restoration monitoring. 2013 saw the capture of a leach (*Class Hirudinea*) in the large constructed pond. This is note-worthy because of the observed presence of leaches in the wet areas of SCW prior to restoration. The rest of the species were captured in the fyke net, including a northern leopard frog (*Rana pipiens*) captured in 2013.

Compared to fish surveys completed at another dyke breach restoration monitoring site in the region (Cogmagun River; Bowron et al. 2014a), a greater number of tomcod were captured at SCW, but a lower number of mummichogs. At Cogmagun, a large number of Atlantic silverside (*Menidia menidia*) and mummichog individuals (>500 each species) were captured during the fish survey (Bowron et al. 2014a). Additionally, Atlantic silversides and gaspereau (*Alosa pseudoharengus*) were captured at Cogmagun, but not at SCW. At Walton, a dyke breach project where post-restoration monitoring has been completed, 74 mummichugs were captured and no tomcod or striped bass in 2012 (seven years post-restoration) (Neatt et al. 2013). The potential for greater numbers of these large prey species caught at SCW could be a consequence of the location of SCW within the larger Avon River system and the St. Croix River itself. Both Cogmagun and Walton were near the mouth of their respective Rivers and the habitat differed from SCW (salt marsh). The fyke net was placed in the main borrow pit at Cogmagun, whereas at SCW the fyke net was placed in a secondary channel leading to a created pond.

Overall, these nekton survey results are indicative of the improved creek network connectivity following restoration activities, allowing flood waters and fish to reach the excavated ponds and the marsh surface. Over the four years post-restoration, the presence of a large number of juvenile striped bass, tomcod and American eel (*Anguilla rostrata*) in the fyke net, a large number of mummichogs utilizing the ponds and the harbour porpoise discovered on SCW in 2009, are all evidence of the importance of tidal wetlands, and SCW in particular, as fish habitat. Additionally, it shows that tidal wetlands, including those in the early stages of recovery, are utilized by a wide range of estuarine and marine species.

Table 16 Percent composition of the total catch at SCW post-restoration for all years and all sampling methods.

Common Name	Species Name	Year 1 (10) SCW	Year 2 (11) SCW	Year 3 (12) SCW	Year 4 (13) SCW
Nine-spine stickleback	*Pungitius pungitius*	10.0	1.3		
Mummichug	*Fundulus heteroclitus*	90.0	25.3	91.8	39.7
American eel	*Anquillaro strata*		8.8		15.3
Rainbow trout	*Oncorhynchus mykiss*		1.3		
Tomcod	*Microgadus tomcod*		29.1	2.4	42.0
Striped Bass	*Morone saxatilis*		34.2	5.8	3.0
	TOTAL	100	100	100	100

Table 17 Relative abundance for minnow traps and fyke net set at SCW (all years post-restoration).

	SCW	
Year	**Minnow Trap**	**Fyke Net**
2010	15.00	0.00
2011	3.00	74.50
2012	14.40	8.00
2013	12.75	41.00
Total	**45.15**	**123.50**
Average	**15.05**	**61.75**
	n=14	n=6

Table 18 Standard length (SL) average and range for the fish caught at SCW (all years post-restoration) using all fish survey methods.

		SL Average (mm)	SL Range (mm)
Date	**Species**	**SCW**	**SCW**
2010	Nine-spine stickleback	55	55
	Mummichog	41	30 to 50
	Amercian eel		
	Rainbow trout		
	Tom cod		
	Striped bass		
2011	Nine-spine stickleback	50	50
	Mummichog	71	30 to 90
	Amercian eel	218	110 to 450
	Rainbow trout	160	160
	Tom cod	118	90 to 220
	Striped bass	85	50 to 150

2012	Nine-spine stickleback		
	Mummichog	68	35 to 105
	Amercian eel		
	Rainbow trout		
	Tom cod	138	130 to 145
	Striped bass	73	65 to 95
2013	Nine-spine stickleback		
	Mummichog	73	30 to 100
	Amercian eel	205	150 to 500
	Rainbow trout		
	Tom cod	137	150 to 200
	Striped bass	143	70 to 220

4.6 Benthic and Other Aquatic Invertebrates

Benthic Invertebrates

There have been 16 species of invertebrates found in the SCW and SCR samples during the pre- and post-restoration monitoring program data collection. Similar to 2012, the species found most in the samples were species of the sub-class Oligochaetes and Diptera. At Sweet's Corner (the downstream samples), six different species of invertebrates were found in the samples with the species of the sub-class Oligochaetes found most in the samples in 2013. In 2012, *Corophium volutator* was found in the Sweet's Corner samples, but not at SCW or SCR. In 2013, *Corophium volutator* was found at each site. The mean abundances can be found in Figure 40.

An analysis was completed to determine how statistically different the samples from each location (SCW, Sweet's Corner, SCR) were from each other by examining the variation in abundances by sites. It was found that there was not difference in variability between sites when comparing Sweet's Corner with SCW (ANOVA = 0.31, df = 10, F = 1.17). There was no difference in terms of samples or year for variability between Sweet's Corner and SCR (ANOVA = 0.45, DF = 5, F = 0.95). Finally, there was no difference in terms of samples or year for variability between SCW and SCR (ANOVA = 0.29, DF = 5, F = 1.12).

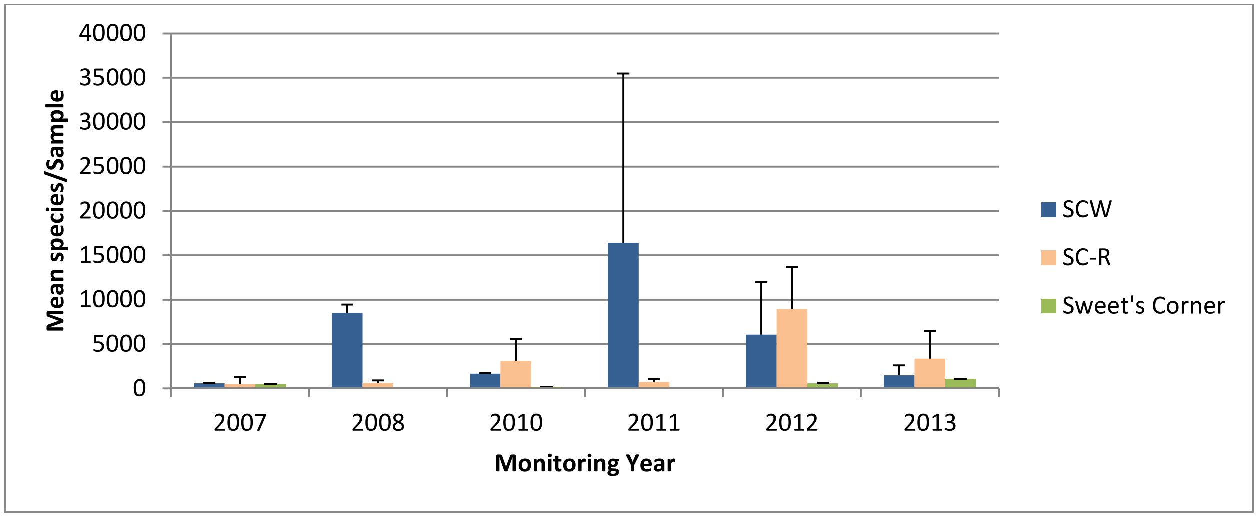


Figure 40 Mean species abundance for the Ekman samples taken from the creek edge at SCW, Sweet's Corner and SCR for all years (2 years pre- and 4 years post-restoration).

Aquatic Invertebrates

There were over 60 species found at the three sampling locations (SCW, SCP_Pond and SCP_Channel) during the post-restoration monitoring program data collection. Of note was the presence of juvenile American eel (*Anguilla rostrata*; elvers) in the IAT samples from the ponds at SCW. SCW also saw the presence of species from the class Gastropoda and a few terrestrial insects that were not present the previous three years of post-restoration monitoring. At SCP_Pond there was an individual *Neomysis americana* and a *Gyraulus* sp. found in the samples that were not found in previous years of the monitoring program. No new species were present in the SCP_Channel IAT samples.

At SCW, the dominant species in the IAT samples were from the sub-class Copepoda and the order Diptera. At four years post-restoration, the dominant species in the IAT samples were from the sub-class Copepoda and Ostracoda. In 2012, species from the sub-class Copepoda had an abundance of 760 within the sample and in 2013, the abundance in the SCW IAT samples for species from the sub-Class Copepoda was 40. The mean species abundance decreased for all samples in 2013 (Figure 41 and Figure 42). The SCP_Channel (front portion of SCP) samples had very low abundance, but the dominant species in the samples for 2013 were from class Gastropoda. For the IAT samples from SCP_Pond (back portion of SCP; cattail marsh), the dominant species for 2013 came from the sub-class Copepoda, similar to 2012. Figure 43 shows the species richness of the IAT samples during the post-restoration program for SCW, SCP_Channel and SCP_Pond.

Similar to 2012 results, the 2013 analysis showed that there was no statistical difference in mean abundance between SCW and SCP over time (ANOVA = 0.59, F = 0.81, df = 7); therefore, SCW and SCP had similar abundance distribution since restoration. However, when mean abundance differences between sample locations were examined for 2013, the results differed from those founded in 2012. In 2013, SCW was statistically different from SCP_Channel (p = 0. 02, df = 7, t = 2.95) and from SCP_Pond (p = 0.02, df = 7, t = 2.95). In 2012 the results showed that SCW and SCP_Channel were not statistically different (Bowron et al. 2013c). Similar to 2012, it was found in 2013 that SCP_Channel was not statistically different from SCP_Pond (p = 0.11, df = 7, t = 1.803). Similar results were found when examining how diverse the sample locations were in terms of the number of different individuals (richness) found in the samples. Richness for SCW was statistically different from SCP_Channel (p = 0.01, df = 7, t = 5.085), which was opposite to 2012 findings, and SCW was statistically different from SCP_Pond (p <0.001, df = 7, t = 7.948). There was enough separation between the two sample locations at SCP to consider them different in terms of richness (p = 0.01, df = 7, t = 5.085).

The pond habitat at SCW has changed considerably over the four years since they were constructed. Sediment deposition and colonization by vegetation has significantly reduced the size and depth of the ponds, thereby reducing the quantity and quality of the open water habitat for invertebrates, fish, etc. (Figure 4). Another year of IAT sampling at SCW and SCP may provide insight into whether the ponds at SCW and the SCP_Channel are becoming different in the species captured or if this was potential natural variability. Although it cannot be stated with certainty, the reduction in habitat of the ponds at SCW has corresponded with a decline in species and abundance of these samples, and could be cause for the significant difference between the SCW ponds and SCP_Channel in 2013.

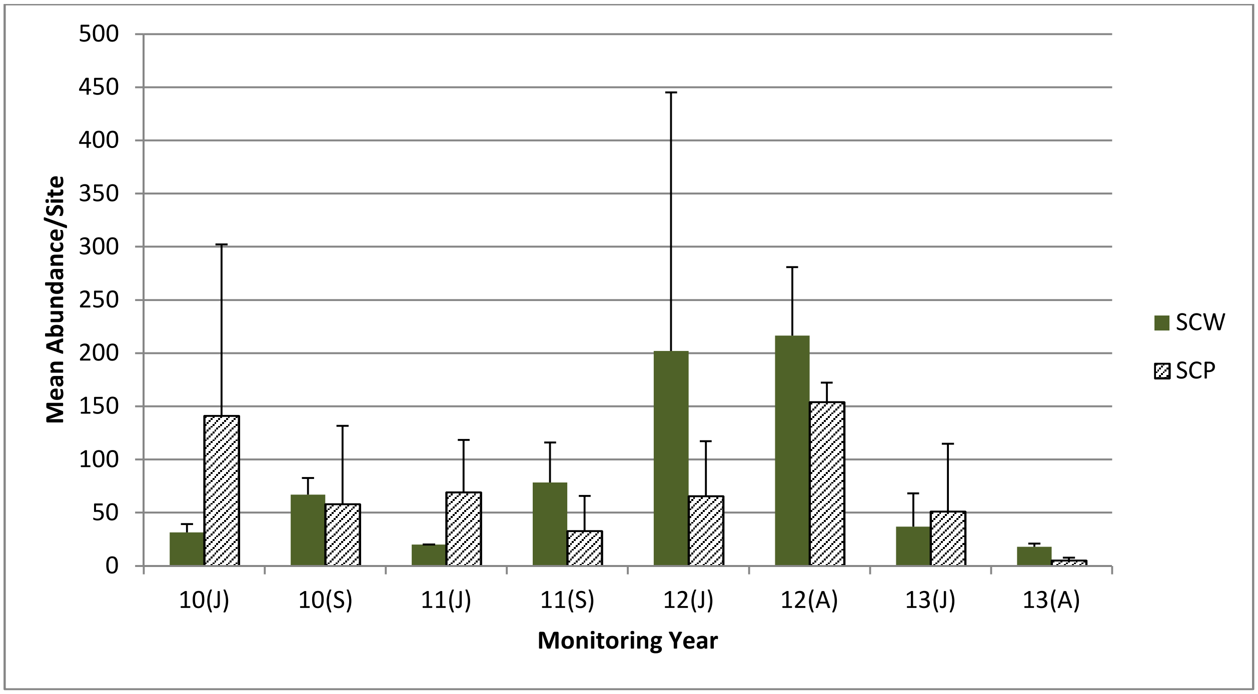


Figure 41 Mean species abundance of IAT samples at SCW and SCP for Years 1 through 4 post-restoration.

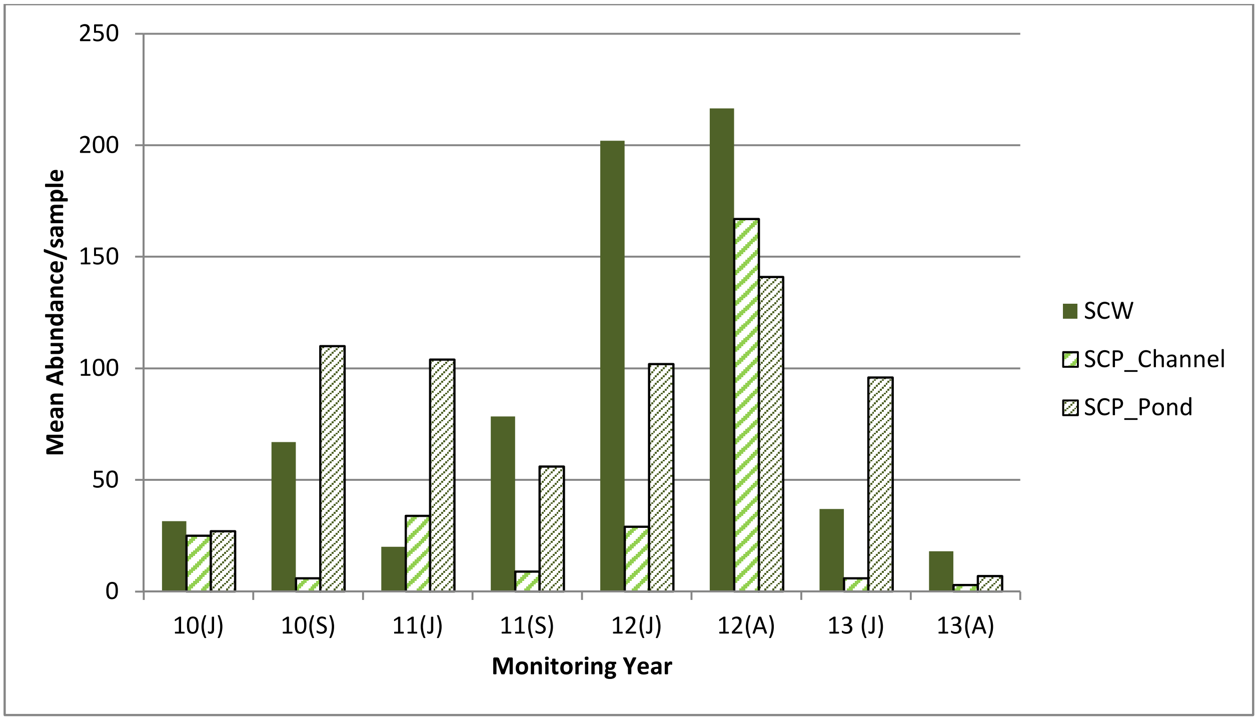


Figure 42 Mean species abundance per sample location for the IAT samples from SCW and SCP (pond and channel) for Years 1 through 4 post-restoration.

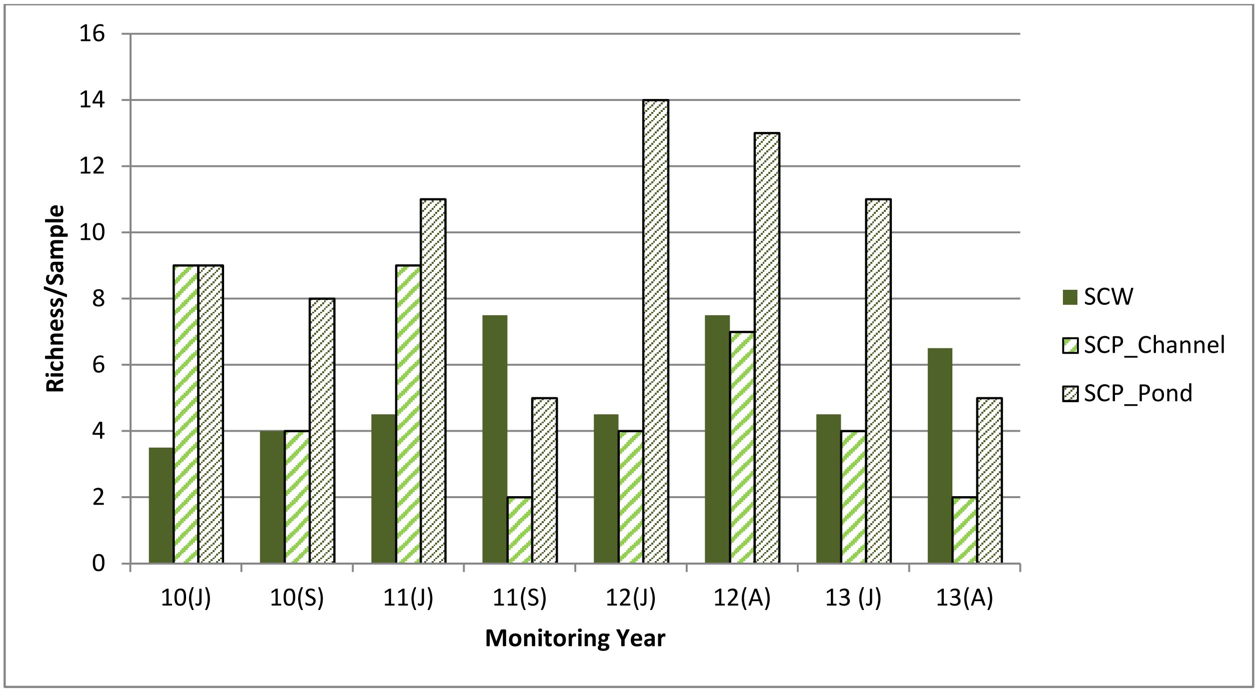


Figure 43 Richness for the IAT samples collected in Years 1 through 4 post-restoration at SCW and SCP (pond and channel).

4.7 Structured Winter Site Walk

There were numerous snow fall events during the winter of 2013/2014 resulting in the SC restoration sites being snow covered at the end of February. There were no major ice deposits on the marsh surface at any of the restoration sites. SCW had a few ice blocks on the fringe of the site and on the marsh surface near Line 1. Creeks 2 and 3 at SCW were ice covered, but Creek 4 and the aboiteau channel, which flood on a higher frequency, were not (Figure 44; Figure 45). There were no areas of erosion in the excavated channels at the SC restoration sites, although the aboiteau channel at SCW continues to erode further back into the site (Figure 44). At SCP, a small beaver dam had water backed up into the cattail portion of the site, although it was not large enough to contain the water and there was water flowing from this portion of the site to the front, filling the borrow pit (Figure 48). SCR was also snow covered with no ice blocks on the marsh surface. There were no changes over the winter months at this site. Appendix D has a selection of photographs from the 2014 winter walk.

Figure 44 Main channel at SCW showing a) mouth of channel; b) old aboiteau structure; c) the scour and erosion along the right of the channel facing the River; and c) channel towards upstream; d) scour erosion and area where channel is now, continuing to erode back and deepen. Photographs by CBWES Inc., 21 February 2014.

Figure 45 Channels at SCW in 2013 (left) and 2014 (right) starting with the creek closest to the aboiteau channel (A/B) and working to back of the site (E/F). Photographs by CBWES Inc., 21 February 2014.

Figure 46 Mouth of excavated channel at SCE, 21 February 2014.

Figure 47 Excavated channel at SCE, 21 February 2014.

Figure 48 Small beaver dam at SCP that flooded the old access road and into the back portion of the site in A) 6 March 2013 and B) 21 February 2014.

5.0 St. Croix River Year-Four Project Summary

The results of the fourth year of post-restoration (2013) monitoring of the St. Croix River restoration project were presented in this report. The goal of the monitoring program was to provide a scientific record of habitat conditions at both the restoration and reference sites, to document the change in physical and biological conditions in response to manipulation and to facilitate adaptive management if warranted.

Prior to restoration the SC restoration sites were fallow agricultural lands, with only one of the four sites (SCW) used intermittently as marginal grazing land for a small number of cattle. The restoration of these sites, which included dyke breaching and channel excavation, re-established tidal flooding of the former dykelands upon completion of restoration activities. The result was a more natural hydrological regime; a rapid influx of sediment (increase in marsh surface elevation); a shift in vegetation community assemblage (decrease in pasture weeds and increase in fresh, brackish and halophyte species); an increase in soil water content and salinity levels; creation of new habitat for birds and waterfowl; restored fish access and an increase in fish habitat.

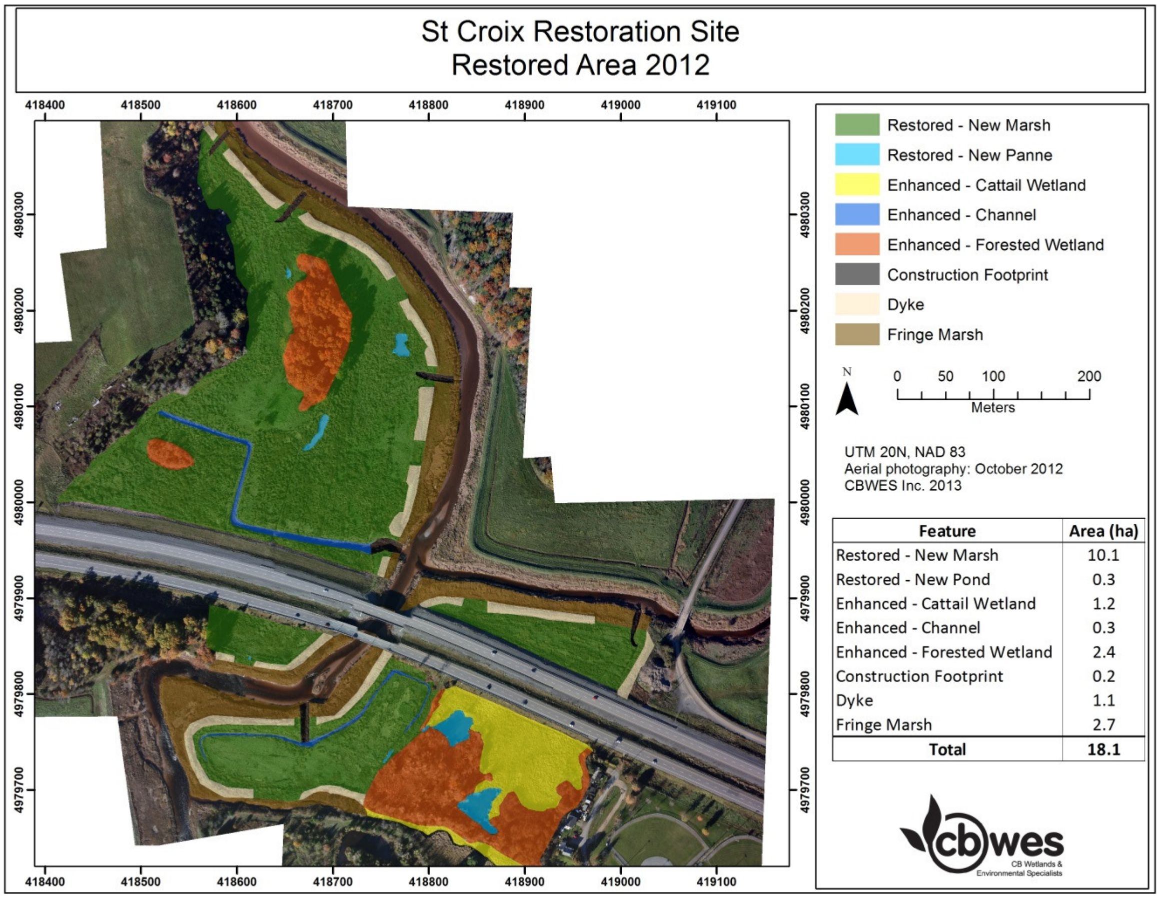
The vegetation at SCW has not yet reached equilibrium at year four, with individual plots still experiencing change in vegetation type year to year. In addition, with the continued sediment deposition, there is continued disturbance potential at the site, which can allow for vegetation colonization of differing species at certain areas. With the initial high sediment deposition at SCW there was concern that the agricultural layer would decay, creating an anoxic layer with a subsequent vegetation die-back. Soil chemistry readings taken in year four revealed that this was not occurring at the present time. The redox potential values indicated that anaerobic respiration was present, but that sulfate reduction was not the dominant redox reaction; therefore, sulfide, a known phytotoxin, was not accumulating in the soils. SCW differs from the other three SC restoration sites as it receives flooding on a greater number of tides due to its location within the estuary and within the apparent upstream extent of the tidally driven salt wedge. SCW's position within the turbidity maximum results in significantly higher rates of sediment deposition than experienced by the other three sites (i.e. SCP). SCP differs from SCW in most parameters and is the most similar to the reference site, four years post-restoration, of the four SC restoration sites. There have been little to no changes at the reference site over the duration of the monitoring program.

Given the location of the SC restoration sites in the estuary, these sites are not similar to the other dykeland restoration projects in the region e.g. Walton River and Cogmagun River (Neatt et al. 2013; Bowron et al. 2014a). The Walton and Cogmagun restoration projects have developed into salt marsh habitat, whereas the SC restoration sites have thus far developed into brackish marsh habitat, as anticipated. The design of the SC restoration sites was based on the experience of the Walton River project (Neatt et al. 2013), which did not have a full creek excavation during earthworks. A central tidal creek developed at the Walton River restoration site, beginning the first winter following restoration. For this reason creek excavations were completed at the SC restoration sites as part of the restoration design, with the exception of SCS. This allowed tidal waters to reach the sites with the first spring tides and allowed tidal waters and species to reach the ditch/channels and marsh surfaces within the sites immediately and across a broader range of tide levels. The re-establishment of tidal flow to the SC restoration sites has led to the activation of a hybrid creek network and the re-establishment of tidal wetland habitat conditions at each of the restoration sites.

Four years of post-restoration monitoring indicates that the St. Croix River High Salt Marsh & Tidal Wetland Restoration project is on an acceptable restoration trajectory, having restored tidal wetland physical and biological conditions from fallow agricultural sites, without the need for additional manipulations beyond the original restoration activities. The St. Croix restoration sites are continuing to change, as differences still persist between the sites; therefore, it may be a number of years before maturation (steady state) of the sites occurs. The year four data will be built upon with a more comprehensive year five of post-restoration monitoring. In year five (2014), data will be collected for all parameters including geospatial attributes, hydrology, soils and sediment, nekton and vegetation, giving a more complete picture of the changes that have and are occurring at the SC restoration sites.

Restored Area

Prior to highway construction the total area of the SC restoration sites was calculated to be 22.61 ha. This value was refined in 2010, by removing the highway footprint from the SCE and SCW sites, using low-altitude aerial photography, giving a total area value of 19.29 ha. In 2012, with the addition of aerial photography for all four SC restoration sites the total area was deemed to be 18.13 ha. Using the 2012 aerial imagery, vegetation, habitat and hydroperiod data, the restored wetland area was determined to be 18.1 ha (Figure 49).



Feature	Area (ha)
Restored - New Marsh	10.1
Restored - New Pond	0.3
Enhanced - Cattail Wetland	1.2
Enhanced - Channel	0.3
Enhanced - Forested Wetland	2.4
Construction Footprint	0.2
Dyke	1.1
Fringe Marsh	2.7
Total	**18.1**

Figure 49 Restored area at the SC restoration sites.

6.0 Recommendations for Post-Restoration Monitoring

Pre- and post-restoration monitoring is an essential component of any habitat restoration project. Monitoring measures the effectiveness of the restoration effort; provides valuable information on the ecological condition of the restoration and reference sites; and provides information on the response of physical and biological elements, as well as, the overall system to the restoration treatment. In this way, a well-developed and implemented monitoring program can inform and support the management of a specific restoration project, identify the need for additional intervention (adaptive management), and help guide future management and restoration efforts throughout the region.

Annual monitoring during the first three years following restoration is critical because it is during these initial years that the greatest and most rapid changes occur. Monitoring beyond the first three years following restoration allow a greater period of time for change to occur and for the documentation of the longer term, often more gradual, changes in response to restoration (Able et al. 2008; Burden et al. 2013; Garbutt and Wolters 2008; Mitsch et al. 2012; Neatt et al. 2013). It may also be necessary, as has been observed with the Walton River Restoration Project, that monitoring activities be required beyond the five year post-restoration point, as these types of habitats often require longer periods of time to mature.

The fifth and final year of post-restoration monitoring of the St. Croix River Restoration Project is scheduled to begin spring 2014. This will enable the continued documentation of the ecological changes and habitat/species responses to restoration and the determination of project success. The results of the fourth year of post-restoration monitoring, as discussed in this report, indicate that the system has continued to respond in a positive and acceptable manner to the original intervention. Based on this, the sampling activities outlined in the monitoring program (Table 1; Chapter 3) for the fifth year of post-restoration monitoring are recommended for 2014.

Additionally:
SC Specific Recommendations:

- The presence of *Phragmities australis* and *Lythrum salicaria* within the restoration site is of great concern. It is recommended that if additional individuals are found on any of the SC restoration sites then they should be removed. Samples of *Phragmities australis*, if found again, should have the necessary laboratory testing be undertaken in order to determine its native or non-native identity.

- It is recommended that soil chemistry (redox potential) continue to be monitored at the SC Restoration and Reference sites during the final year of the monitoring program.

- Detailed mapping of the morphological changes at the excavated channels at SCW, SCE, and SCP was conducted on a monthly basis between June and November 2010 and 2011 as part of a graduate level research project (Appendix A). It is recommended that detailed mapping of the tidal channel be conducted during year five of the monitoring program for comparison.

Tidal Wetland Restoration Monitoring Recommendations:

- Depending on the amount and type of vegetation dominating a site prior to restoration, it may be advisable to remove the vegetation entirely or partially from the site to ensure fast recovery of vegetation and soil conditions post-restoration. The removal is especially important on sites where appropriate hydrology is not going to be restored to the site (i.e. Cogmagun). Without appropriate hydrology, a site may not be able to flush the plant debris off of the site and this can lead to mats forming on the marsh surface. The mat creates a barrier to new vegetation growth and can also impede oxygen getting into the soil to assist in the decomposition. Decrease of oxygen and inadequate flushing of the sediments can also lead to high levels of phytotoxins to accumulate (i.e. hydrogen sulfide) that negatively affect the growth of plants and thus the rate of recovery of the site (Koch and Mendelsshn 1989).

- Our paper (Porter et al. submitted) classifies tidal wetland habitats based on reference sites, primarily in the Bay of Fundy. With the increasing number of tidal wetland restoration projects and expansion into new regions (e.g. SW Nova Scotia, eastern shore), there is a need for a more comprehensive characterization of reference site vegetation across the province, coupled with quantification of key environmental gradients (salinity, tidal regime etc.). This would allow for a more robust vegetation classification that could be used to set restoration targets, and monitor restoration success using a multiple reference site approach. This would be similar to the Reference Condition Approach (RCA) used for monitoring benthic invertebrate community assemblages as part of the Cheverie Creek and Walton River Salt Marsh Restoration Projects (Armanini et al. 2012; Bowron et al. 2011a; Reynoldson 2005; Reynoldson et al. 1997; van Proosdij et al. 2010; Westhead 2005). If this were undertaken, a further innovation would be to develop a key to allow assignment of any quantitative tidal marsh vegetation sample to a community type.

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Appendix A – Summary of CBWES Supported Student Research

In addition to the undergraduate and graduate research projects described below, CBWES routinely collaborates with universities, community colleges, and local elementary schools to use the restoration sites as outdoor classrooms, provide student volunteers with valuable field experience, and supports student projects by providing research project ideas and access to data, information, expertise and supervision. CBWES has been a recognized NSERC Industrial Partner and multiple NSERC grant recipient since 2009. Through programs such as these, we are able to provide valuable internship opportunities to highly qualified undergraduate and graduate co-operative education students.

Current Projects:

Masters of Applied Science

Department of Environmental Science
Saint Mary's University
Christa Skinner
2013-2015

Temporal and Spatial Patterns of Soil Chemistry and Primary Productivity in a Restored Salt Marsh

Salt marshes are highly productive ecosystems that provide a variety of ecosystem services. These ecosystems have been hindered by human alteration for hundreds of years and now provide opportunities for restoration. Salt marsh restoration of a previously tide-restricted site creates alteration to biogeochemical cycles within the sediment that have implications for vegetation recolonization and expected timeline for marsh development. Restoring appropriate hydrology to the previously tide-restricted site is extremely important to ensure proper drainage and minimize pooling of water on the marsh surface. Biogeochemistry is the study of the exchange of materials between living and nonliving components of the biosphere. Tidal water brings large amounts of salt and sulfate into coastal systems that can influence the productivity of vegetation. The sulfur cycle has been found to be the dominant oxidation-reduction cycle within coastal systems due to the large volume of sulfate available. Sulfate is used as an electron acceptor when conditions are favorable to assist in the oxidation of organic matter and subsequent production of sulfide. High levels of sulfide and salinity have been found to influence the productivity of vegetation within salt marshes and is influenced by the hydrologic network of the site. This study strives to determine the temporal and spatial pattern of sulfide, salinity and redox potential and related primary productivity and hydrology. It is hypothesized that the highest concentrations of sulfide and salinity will be found in areas of poor drainage during neap tides. An understanding of the temporal and spatial patterns of biogeochemical factors within a macro-tidal salt marsh will assist in the development and planning of future restoration projects.

Directed Study

Environmental Science
Saint Mary's University
Carly Wrathall
2014

Identification of the Challenges and Opportunities of Salt Marsh Creation as part of Shoreline Management Strategy

The purpose of this directed studies course is to develop a proof of concept for the use of a created (engineered) salt marsh to reduce erosion along the Lawrencetown Lake section of the Trans Canada Trail. Project will include a thorough review of the scientific and technical literature on the use of engineered salt marshes (living shorelines) to control erosion; the development of a rationale for the use of this technique as part of a shoreline management strategy for Lawrencetown Lake salt marsh restoration project and trail system; a site design proposal (techniques, materials, timelines, cost estimates, etc.); and the presentation of this "proof of concept" to provincial and federal regulatory agencies in order to identify regulatory requirements and obstacles. This course will involve literature review; consultation with restoration practitioners, material supply companies, and provincial & federal regulatory agencies; development of a project design using a geographical information system.

Completed Projects:

Directed Study

Environmental Science
Saint Mary's University
Carly Wrathall
2013

Vegetation Patterns and Primary Productivity of Natural and Restored Bay of Fundy Salt Marshes.

The purpose of this directed studies course is to examine above and below ground productivity of salt marshes in Nova Scotia's Bay of Fundy macro-tidal environment, and and the potential for carbon sequestration. This will include examining the physiological, chemical, sedimentological, environmental and anthropogenic factors that could be potentially be influencing productivity. Along with field research and data collection, this course will also include a major research project including statistical analysis of field samples and geospatial analysis using a geographical information system.

Peer-review Publication

Caitlin Porter, Jeremy Lundholm, Danika van Proosdij, Tony Bowron, Nancy Neatt, Jennie Graham, Ben Lemieux
Saint Mary's University & CBWES Inc.
2013

Classification and environmental correlates of tidal marsh vegetation in Nova Scotia, Canada.

Vegetation in tidal marshes of eastern North America shows conspicuous zonation attributable to biotic interactions between plant species and differential tolerance of salinity and flooding. Tidal marshes are a conspicuous feature of the coastline in Nova Scotia, and previous descriptions suggest that many of the plant communities are similar to those found in New England, which have been extensively studied. The goal of this study was to perform a numerical classification of tidal marsh vegetation in Nova Scotia, and to determine the relationships between variation in plant species composition and environmental factors. We sampled tidal marsh vegetation in six sites designated as reference (intact) sites for salt marsh restoration projects. Cluster analysis revealed seven distinct plant communities related to gradients of inundation duration and salinity. Plant community types were usually dominated by a single graminoid species. Communities detected are similar to those found farther south in Maine and New England, but we also describe three brackish communities of which the *Juncus balticus/Festuca rub*ra and *Spartina pectinata* communities have not been previously described. Redundancy analysis shows continuous variation among these community types and highlights key environmental variables related to plant community patterns. These analyses provide a baseline for further restoration work and identify environmental correlates of plant communities, allowing for better predictions of ecological restoration trajectories in tidal marshes.

Undergraduate Honours

Environmental Science
Saint Mary's University
Carly Wrathall
2013-2014

The restoration of tidal wetlands (salt marshes) in Nova Scotia (NS) has been identified as an important step in enhancing the quality of the natural environment. Salt marshes in NS are important wildlife habitats, are highly productive ecosystems, and play an important role in shoreline protection and carbon storage in the face of climate change and rising sea levels. The collaborative team of CBWES, Intertidal Coastal Sediment Transport (InCoaST) Research Unit at Saint Mary's University (SMU) and Dr. Jeremy Lundholm (SMU) are at the forefront of salt marsh restoration in NS, having initiated and monitored the success of nine large-scale restoration projects, most in the Bay of Fundy (BoF) area. Many of the challenges to restoration in BoF marshes are unique, with macro-tidal conditions, high sediment loads and significant ice disturbance in winter; as a result, ecological knowledge and restoration practices cannot be simply imported from other regions where conditions are more benign. Restoration monitoring by CBWES has indicated that these BoF restoration sites do develop some form of salt marsh vegetation community structure within a few years. This salt marsh vegetation recovery monitoring has never included comprehensive quantitative analysis of primary productivity (as measured by above- and below- ground biomass) of natural and restored marshes. The student will work with CBWES to collect and analyze ecological data on a series of salt marsh restoration projects. The student will be responsible for an independent project comparing the vegetation community patterns and primary productivity of a series of restored and natural salt marshes in the BoF's Minas Basin. This project will greatly enhance our understanding of the form and function of salt marshes in the BoF, evaluate the success of restoration efforts, and our ability to design future restoration projects.

Masters of Applied Science

Department of Geography
Saint Mary’s University
Ben Lemieux
NSERC Industrial Postgraduate Scholarship
2010-2012

The influence of drainage network and morphological features on the vegetation recovery pattern of a macro-tidal wetland restoration project.

Almost all life on earth depends on plants for their existence. Plants form the base of most food webs, but they also serve as habitat for many invertebrate, fish, birds and other species. Therefore, any attempt to restore a habitat should primarily aim at restoring vegetation structure. However, in Atlantic Canada there are few salt marsh restoration models or projects for managers to draw upon. This project aims to study the dynamics controlling vegetation community structure, so that a greater understanding of plant propagation patterns can be understood and modeled. The goal is to examine how surface morphology contributes to vegetative re-colonization. Low altitude photometric approaches, such as the use of a helium filled blimp, to document vegetation re-colonization patterns will be used. The contribution that surface features, such as the ponds created at the St. Croix River High Salt Marsh and Floodplain restoration site as well as internal creek structures of the Cogmagun River Salt Marsh restoration site, have on salt marsh propagation will be examined so that a vegetative propagation model can be created. Understanding how marsh morphology changes in time and the response of vegetation to those changes will serve to improve our understanding how habitat restoration is progressing and will further contribute to the continued progression of salt marsh restoration science.

Masters of Applied Science

Department of Geography
Saint Mary’s University
Jennie M. Graham
NSERC Industrial Postgraduate Scholarship
2010-2012

Tidal Creek Hydraulic Geometry for Salt Marsh Restoration in the Upper Bay of Fundy

CBWES Inc. has been engaged in tidal wetland restoration and monitoring projects in Nova Scotia since 2005. In 2009, CBWES Inc. developed the project design and undertook restoration at two former tidal wetland systems in the Bay of Fundy; a 8 ha site on the Cogmagun River (COG) and a 19 ha site on the St. Croix River (SC). Both projects involved the breaching of an existing dyke in one or more locations and the excavation and recreation of historical tidal channel networks. The restoration designs put forward the problem of identifying appropriate locations for dyke breaches and excavated tidal channels in order to restore a more natural

hydrological regime to the systems including the re-activation of relict creek systems while avoiding excessive erosion. During the restoration design phase of the SC project (Graham et al. 2008) a set of preliminary hydraulic equations were established for the Bay of Fundy region using the methods laid out by Williams et al. (2002). These equations were used to determine width and depth of excavated creeks and were further tested and refined through observations and application to a previously restored salt marsh (Walton River; van Proosdij et al. 2010).
The results of this preliminary work brought up several questions which would be addressed in this research project by:

- Ground-truthing reference marsh systems (i.e. creek widths and depths) to improve the quality of the data set.
- Improving the correlation of hydraulic geometry relationships through the refinement of the existing dataset and the addition of other marsh systems in the region, particularly large pristine marshes.
- Further analyzing the function of channelized versus free flow conditions on creek network development and maintenance and incorporating an analysis of flow velocity within channels using.
- Addressing the importance of additional variables such as location in the tidal frame and depth/width characteristics of the water body that the constructed creek network is entering.
- If possible, examining the impact of large (or multiple) storm events, freshwater runoff, and ice movement on newly constructed creeks which are particularly vulnerable to erosion.

The overall goal for this thesis project will be to produce a GIS-based model and protocol for future use in the design of marsh restoration projects in macrotidal environments.

References

Bowron, T.M., N.C. Neatt, J.M. Graham, J. Lundholm and D. van Proosdij. 2009. Post-Construction Monitoring (Year 3) of the Walton River Salt Marsh Restoration Project. Report Prepared for Nova Scotia Department of Transportation and Infrastructure Renewal. CBWES Inc. Publication No.12

Graham, J.M., D. van Proosdij, N.C. Neatt & T.M. Bowron. 2008. Restoration Design Proposal for the St. Croix River High Salt Marsh and Floodplain Wetland Restoration Project Report Prepared for Nova Scotia Department of Transportation and Infrastructure Renewal. CBWES Inc. Report No.4.

Williams, P.B; Orr, M.K. and N.J. Garrity. 2002. Hydraulic geometry: a geomorphic design tool for tidal marsh channel evolution in wetland restoration projects. Restoration Ecology 10(3): 577-590.

Undergraduate Honours

Environmental Science
Saint Mary's University
Christa Skinner
2012-2013

Analysis of the Relationship Between Vegetative Community Structure and Geodetic Elevation for Salt Marsh Restoration in Hypertidal Systems

Monitoring of salt marsh restoration sites is critical to the success of current and future projects but may also lead to costly projects. The distribution of vegetation across the marsh surface is highly influenced by soil salinity, duration of tidal flooding and competition between plant species. Focus has been placed on vegetation regeneration in post restoration activities and the role vegetation plays in sediment deposition within the Bay of Fundy. The influence that geodetic elevation has on the distribution of vegetation across the marsh has not been studied within restoration salt marshes in the Bay of Fundy. This study analyzes the relationship between vegetation community structure and geodetic elevation within restoration and reference macrotidal salt marshes in the Bay of Fundy.

This reseach was conducted within three newly restored salt marshes (and associated reference site(s)) in the upper Bay of Fundy currently being monitored as a compensation project. Dominant vegetation and geodetic elevation was determined at sampling stations arranged in transects running from the main tidal creek to the upland for each of the study sites in 2010. Five similar salt marsh species were found in both the reference and restoration sites. These include *Carex paleacea, Juncus gerardii, Spartina patens, Spartina pectinata*, and *Spartina alterniflora*. Of these five species, *Juncus gerardii, Spartina pectinata,* and *Spartina alterniflora* were found to have significantly different means and ranges of elevation within the restoration sites as compared to the reference sites. This is due to soil salinity, frequency and duration of inundation, and competition. All of these factors are influenced by geodetic elevation and time since beginning of restoration.

Undergraduate Honours

Environmental Science
Saint Mary's University
Alisha Glogowski
2012-2013

Information From the Wrack: Viability of Halophytic Vegetation within Tidal Wetland Wrack Mats

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.

Undergraduate Honours

Environmental Science
Saint Mary's University

Alison Bijman
NSERC Industrial Undergraduate Student Research Awards
2011-2012

The Influence of Tidal Creek Networks on Wetland Vegetation Colonization in a Macro-tidal System

Six years of research and experience with restoring Bay of Fundy (Nova Scotia) salt marshes has shown that salt marsh plant species can colonize readily without planting, if the barriers to tidal flow are removed and suitable abiotic conditions (i.e. elevation) are present. Reactivated hybrid creek networks are potentially highly important to the restoration process, as they may represent the primary transport mechanism for seeds and vegetative material for re-colonization. It is unknown how important creeks are for the actual colonization of target species (*Spartina alterniflora; S. patens; Salicornia europaea; Suaeda maritima; Atriplex spp.*). Utilizing the Cogmagun River salt marsh restoration site (Hants County), which was restored in 2009, this research aims to examine if there is a relationship between proximity to creek and colonization rates of common salt marsh species, as well as if seedling coverage of *Suaeda maritima* in the previous year had a relationship with colonization rates of the following year. Colonization rates were positively related to proximity to the main tidal creek for four out of five target species (*S. alterniflora, S. europaea, S. maritima, and Atriplex spp),* and the presence of *S. maritima* in the previous year did increase the colonization rates of newly established communities. These results provide a fine-scale complement to existing and ongoing macro-scale studies and further clarify the relationships between abiotic properties of a recently restored tidal wetland and colonization.

Undergraduate Class Research Project

Department of Biology
Saint Mary's University
by Shawn Adderley, Alison Bijman, Lydia Ephraim, Kristen Gallant, Robert Hicks, Sebastien Letourneau-Paci, Lori Miller, Chantal Pye, Benjamin Royal-Preyra, Shayna Weeks

Edited by Dr. Jeremy Lundholm, Department of Biology/Environmental Science, Saint Mary's University

Phragmites australis at Cogmagun Restoration Site

A population of *Phragmites australis* was discovered at the salt marsh restoration site at Cogmagun Creek in summer 2011. As this species includes native and invasive subspecies, we undertook several analyses to determine a) the extent of colonization at the site; b) whether other nearby sites have also been colonized by *Phragmites*; c) environmental and vegetation characteristics of colonized areas. We found that *Phragmites* has colonized an area of 885 m^2 and has been present for at least two growing seasons (CBWES pers. comm 2011). However, there was no evidence of the species further upstream at the restoration and reference sites, nor on any adjacent marshes.

This population has morphological characteristics suggesting that it belongs to the native subspecies, but several of the measurements overlap with those from other populations from central Nova Scotia known to be non-native. Existing *Phragmites* stands contain a mixture of other species, mostly natives. The presence of many species coexisting within *Phragmites* stands provides more evidence to suggest that the plants at Cogmagun are representatives of the native strain of *Phragmites*, which is known to grow in less dense stands and to coexist with other native species. The elevation range of current populations suggests that much of the restoration site and upstream coastal marshes have similar elevation ranges to the area occupied by current populations, however, soil salinity values suggest that much of the site cannot be colonized by the native subspecies of *Phragmites*. We recommend that the most important next step in assessing the site would include a genetic analysis of the *Phragmites* populations to obtain a definitive genetic identity and to better estimate potential spread on the site.

Based on experiments conducted in other parts of North America, appropriate control measures for non-native *Phragmites* at Cogmagun could include mechanical and/or chemical control.

Undergraduate Honours

Department of Environmental Science
Dalhousie University
Rachel Deloughery
2010

Contribution of seed hydrochory to re-colonization of vegetation in macro-tidal Bay of Fundy salt marsh restoration projects

This project examines the role of seed dispersal *via* water, or hydrochory, in the re-colonization of restored salt marsh vegetation communities. The chosen study sites were macro-tidal coastal wetlands on the Bay of Fundy in Nova Scotia, Canada where CB Wetland and Environmental Specialists have undertaken restoration projects. Actively returning salt water marshes to more natural hydrological regimes through designed and monitored projects is a relatively new practice in Atlantic Canada, but one that is increasingly seen. Research exploring the patterns and mechanisms of initial stages of re-vegetation is limited. This study examined the degree to which hydrochory was occurring, and its contribution to re-colonization by target salt marsh species, on the study sites where tidal flooding was enhanced through construction of breaches in 2009. Using artificial turf traps and seed extraction of collected material, rates and richness of seed dispersal in flooding were assessed. Vegetation surveys measured richness and abundance of emergent vegetation on the sites in August 2010, approximately one-year following restorations. The turf trap and survey data were analysed for overlap of species, relative contributions to target species pool, and similarities in relative abundance at corresponding sample points. Results indicate that hydrochory was contributing to availability of propagules at both sites. Proportions of target species seeds in the turf traps were small or undetected, but this does not necessarily signify a minor effect on above-ground community. Rates and patterns of seed hydrochory, and its relationship to emergent vegetation, are site-specific. Differences in environmental histories, relative locations within the estuary, natural flooding regime dynamics, existing vegetation communities and salinity levels are all possible contributors to the discrepancies seen here.

Undergraduate Honours

Department of Biology
Saint Mary's University
Ben Lemieux
NSERC Industrial Undergraduate Student Research Awards
2009

The influence of soil seed bank on the colonization and restoration of a macro-tidal marsh

The aim of this project was to determine if hydrochory (seed transport by water) was a more likely source of early colonists than the soil seed banks of newly restored salt marshes. The project had two sample sites, St. Croix River and Cogmagun River salt marsh restoration sites. Soil seed banks in this study were defined as viable seeds based in the first 10 cm of soil on the surface of the restoration site. The project aimed to determine the relative contribution of the soil seed bank prior to breaching of the dyke and hydrochory post dyke breach to salt marsh vegetation re-colonization. The soil seed banks of the Cogmagun site and the St. Croix site were both sampled prior to the breaching of the dyke. The soil seed bank was sampled by placing quadrats at pre-determined sample points and sampling the soil using soil cores. This soil was then taken to a greenhouse, allowing any seeds present to grow, and then species and relative seed abundance was determined. The hydrochory traps for the St. Croix site were sampled by placing artificial turf traps at the same locations as the soil seed bank samples post breaching of the dyke. For the Cogmagun traps, due to time constraints with the thesis requirements, artificial turf traps were deployed prior to the dyke breach on an adjacent marsh. This would give a good indication of the potential for seed transport via tidal waters. The traps were deployed for the first spring tide period following the breaching of the dykes, during which time Hurricane Bill passed over Nova Scotia. The storm surge most likely washed away many of the seeds and sediment from the artificial turf traps. The traps were then collected, cold stabilized, and washed on a sieve to collect seeds and sediment which was then sent to the greenhouse for germination.

Preliminary results showed that the dominant plants found in the both the St. Croix artificial turf traps and hydrochory traps were mostly of the *Poacaea* genus. The samples from the Cogmagun soil seed bank were dominated by cattails (*Typha sp.)*. These findings point to the soil seed banks being reflective of the above ground vegetation. The hydrochory traps point to the localized seed transport as species from the St. Croix soil seed bank were dominated by grasses (*Poacaea*). Species for the Cogmagun site are still growing in the greenhouse as they need to flower so that their identification can be complete.

Undergraduate Honours

Department of Biology
Saint Mary's University
Emile Colpron
2008

The avian fauna of restored and natural salt marshes Minas Basin, Bay of Fundy, Nova Scotia

This study focused on the avian fauna of four salt marshes found in the upper Bay of Fundy, on the Minas Basin. The Bay of Fundy salt marshes are important coastal ecosystems for many avian species. They provide breeding and foraging habitat for numerous species of shorebirds, passerines and waterfowl. Many species which breed in the Arctic make use of tidal marshes as well, either for over-wintering, or as stop-over areas to rest and feed during annual migrations (Brawley et al. 1998). Despite the importance of salt-water marshes for biodiversity conservation, the avian responses to alterations are poorly understood (Benoit and Askins 2002, Shriver et al. 2004, Hanson and Shriver 2006). The loss of salt marshes is especially a threat to salt-marsh specialist species such as the Nelson's sharp-tailed sparrow (*Ammodramus nelsoni*) and the willet (*Tringa semipalmata*). Both Nelson's sharp-tailed sparrow and the willet have been listed as a species at risk by COSEWIC (Committee On the Status of Endangered Wildlife In Canada) in the past due to population declines.

The objectives of this study were to (1) compare the species richness and abundance of avian fauna in restored and natural salt marshes, and (2) to determine the use of restored and natural salt marshes by avian salt marsh specialists.

References:
Benoit, L.K. and R.A. Askins. 2002. Relationship between habitat area and the distribution of tidal marsh birds. *The Wilson Bulletin*. 114(3):314-323.

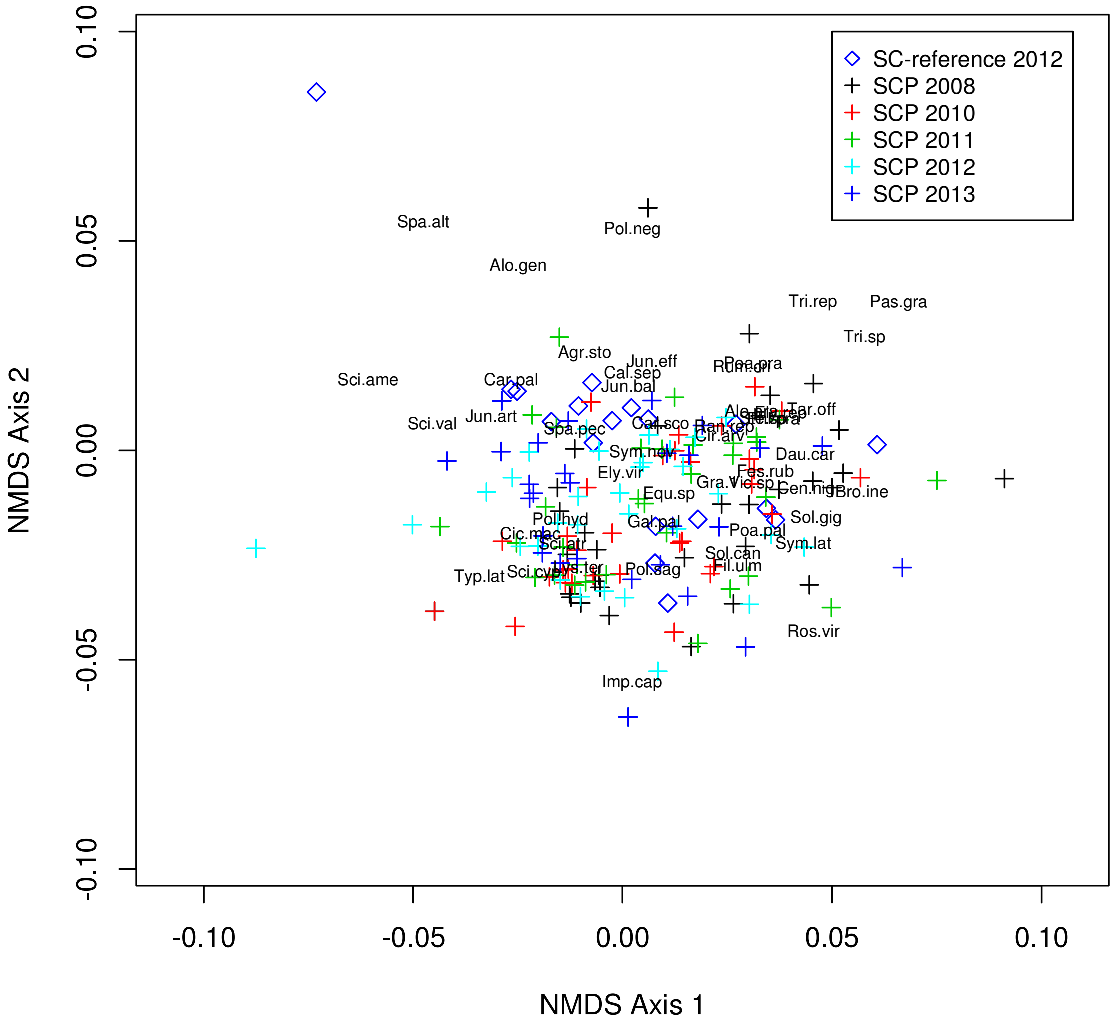
Brawley, A.H., R.S. Warren and R.A. Askins. 1998. Bird use of restoration and reference marshes within Barn Island Wildlife Management Area, Stonington, Connecticut, USA. *Environmental Management*. 22(4):625-633

Hanson, A.R. and W.G. Shriver. 2006. Breeding birds of Northeast saltmarshes: habitat use and conservation. *Studies in Avian Biology*. 32:141-154.

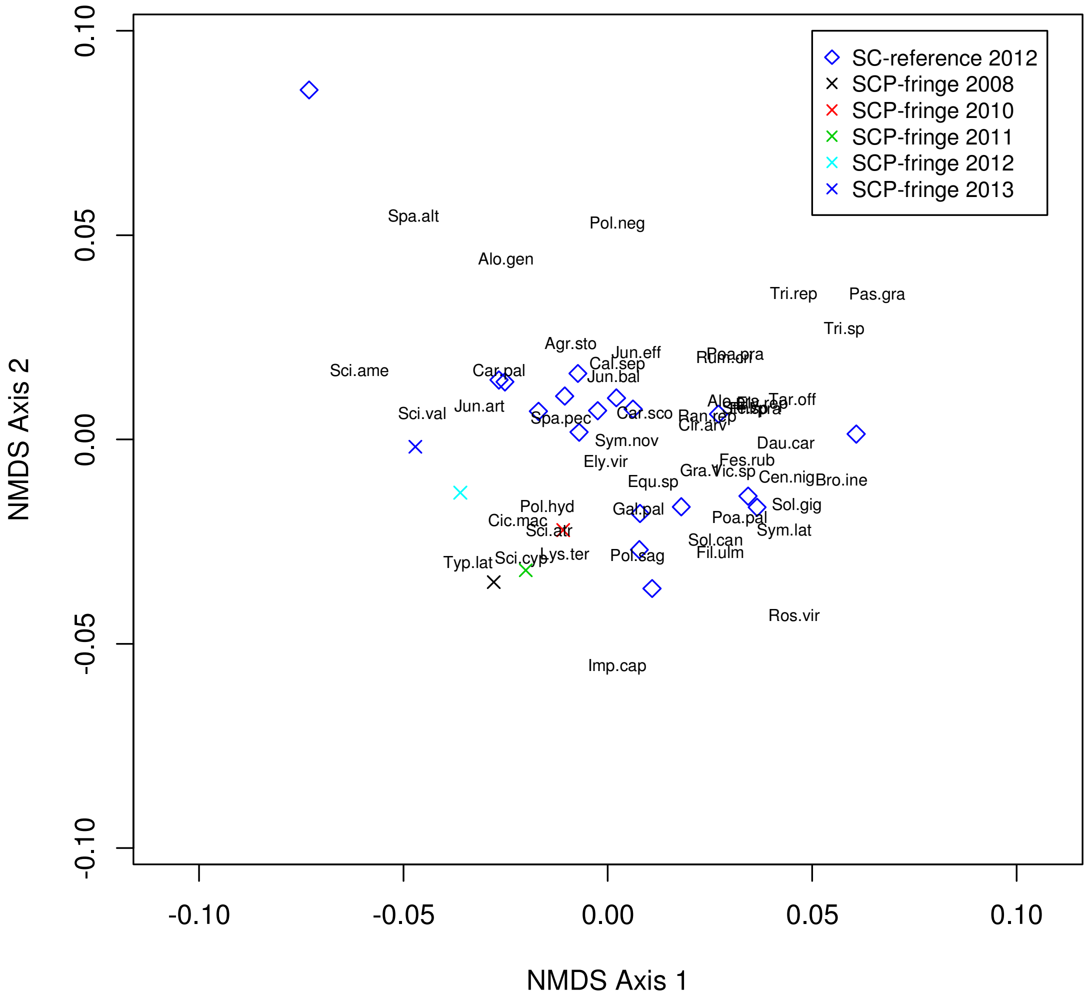
Shriver, W.G., T.P. Hodgman, J.P. Gibbs and P.D. Vickery. 2004. Landscape context influences salt marsh bird diversity and area requirements in New England. *Biological Conservation*. 119:545-553.

Appendix B – NMDS Ordination Diagrams

B1 SCP



B1 SCP-Fringe



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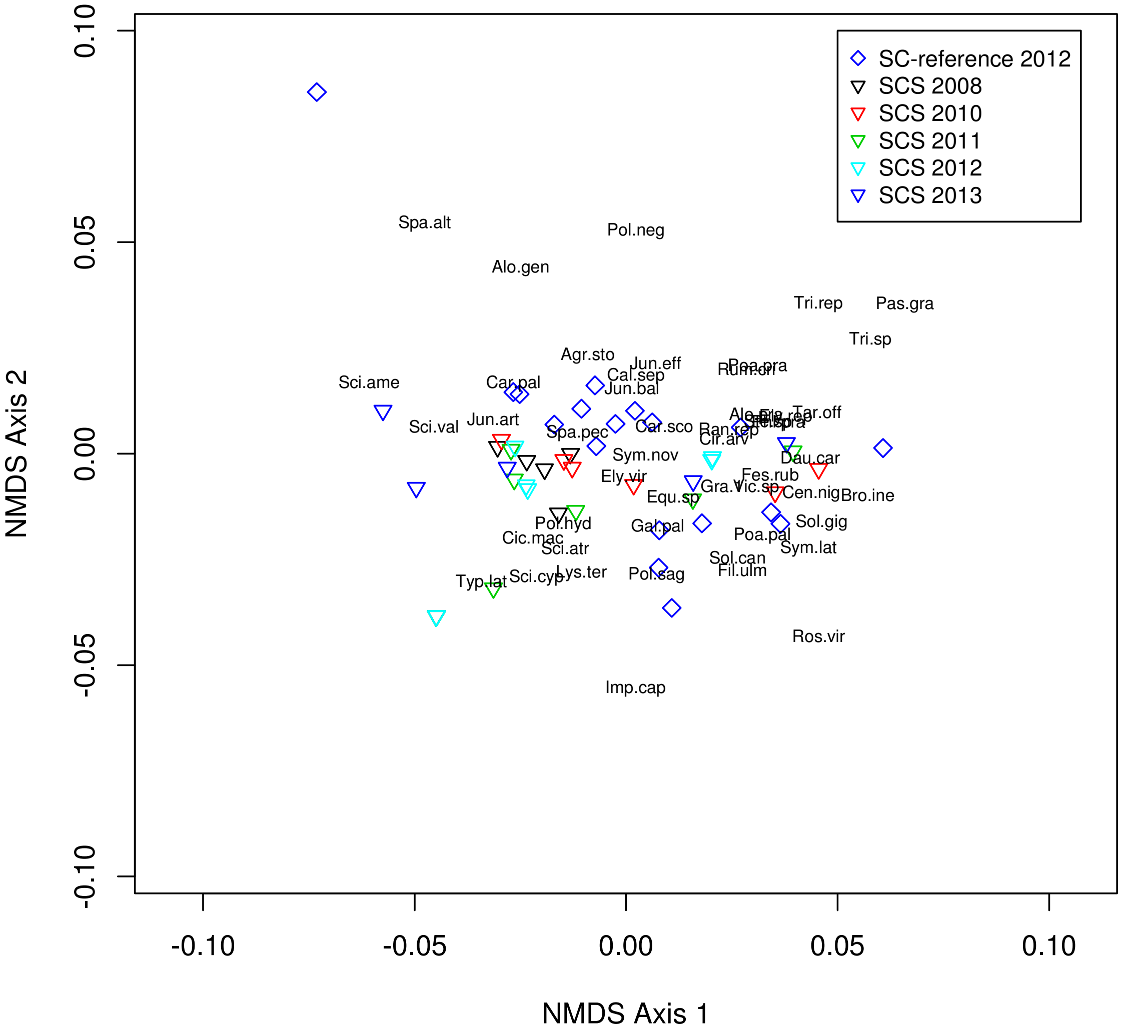
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SCS 2008
SCS 2010
SCS 2011
SCS 2012
SCS 2013
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Pol.neg
Alo.gen
Tri.rep
Pas.gra
Tri.sp
Agr.sto
Jun.eff
Cal.sep
Jun.bal
Rum.cri
Poa.pra
Sci.ame
Car.pal
Jun.art
Sci.val
Spa.pec
Car.sco
Ran.rep
Cir.arv
Ely.rep
Tar.off
Sym.nov
Dau.car
Ely.vir
Fes.rub
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Bro.ine
Equ.sp
Pol.hyd
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Sol.can
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Lys.ter
Pol.sag
Ros.vir
Imp.cap
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0.05
0.00
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NMDS Axis 2
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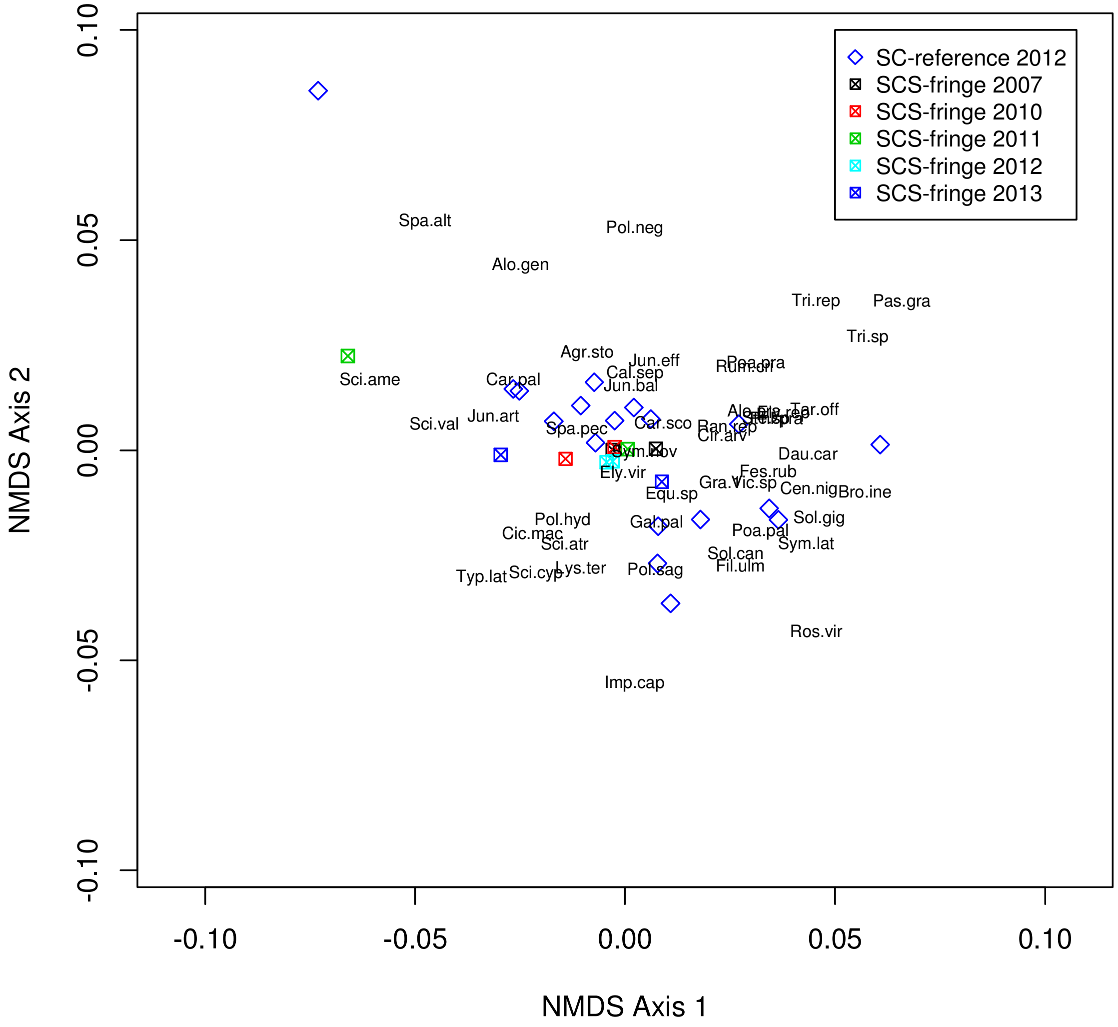
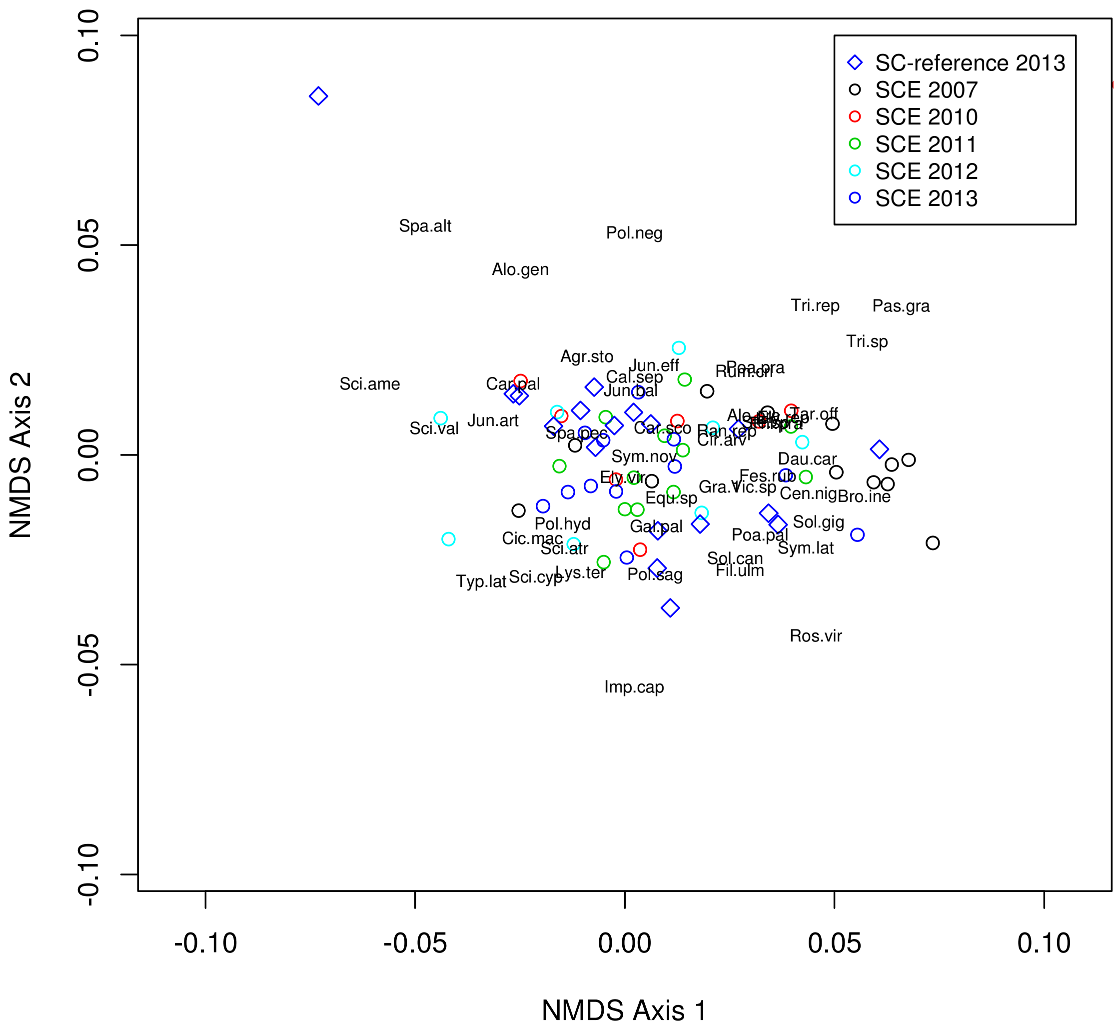
NMDS Axis 1

B2 SCS-Fringe



B3 SCE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SCE 2010
SCE 2011
SCE 2012
SCE 2013
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NMDS Axis 1
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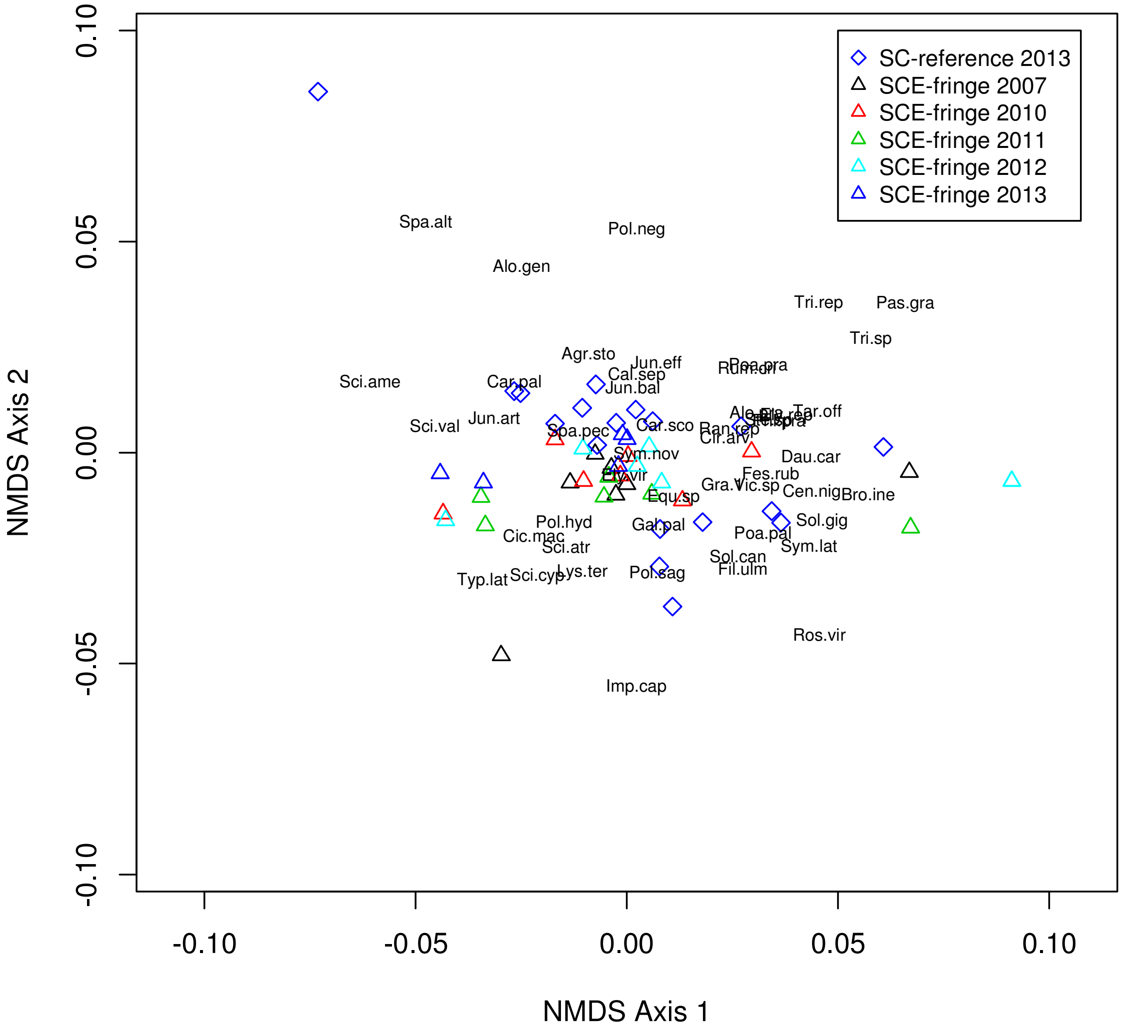
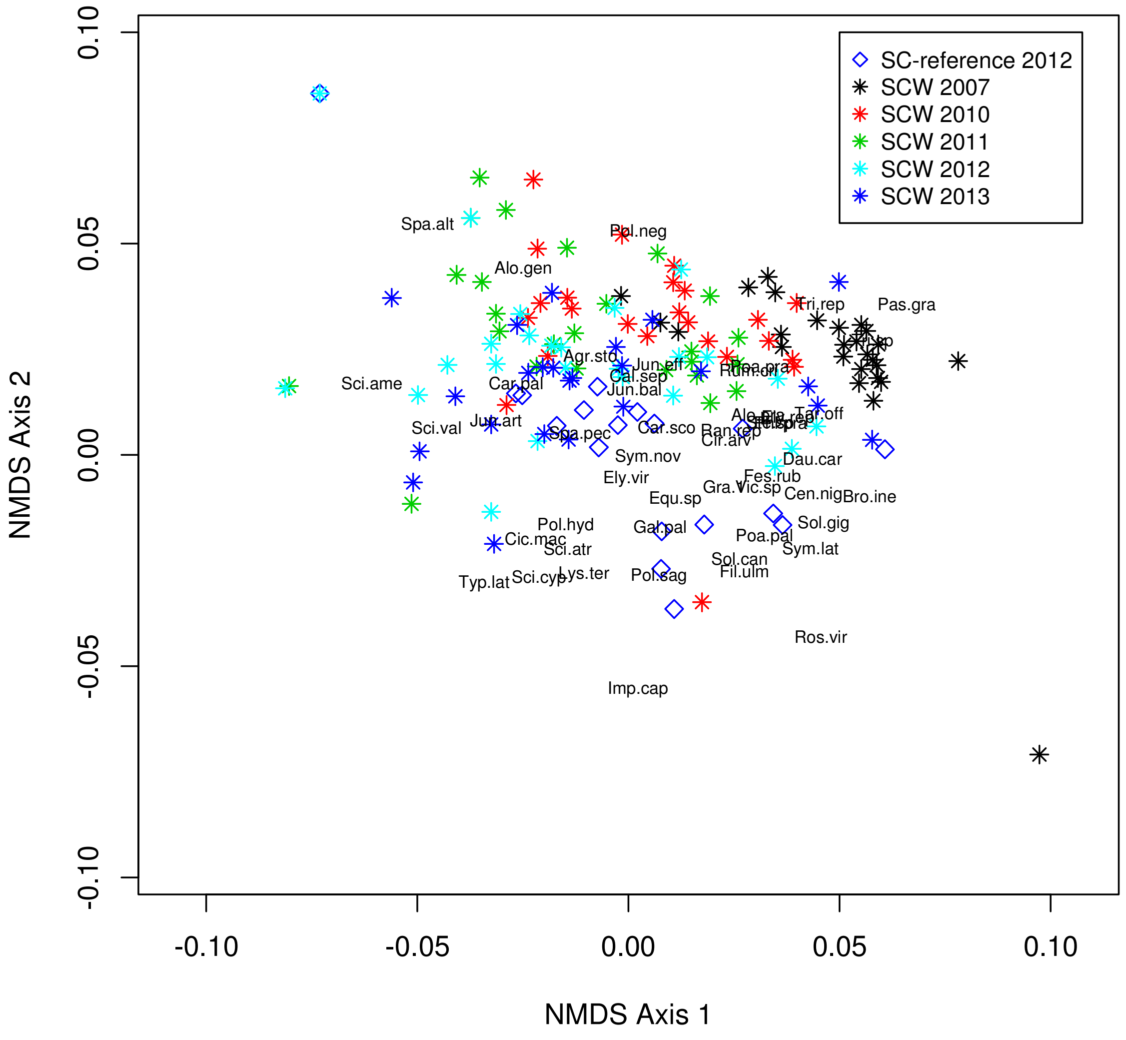
B3 SCE-Fringe



B4 SCW


SC-reference 2012
SCW 2007
SCW 2010
SCW 2011
SCW 2012
SCW 2013
NMDS Axis 1
NMDS Axis 2
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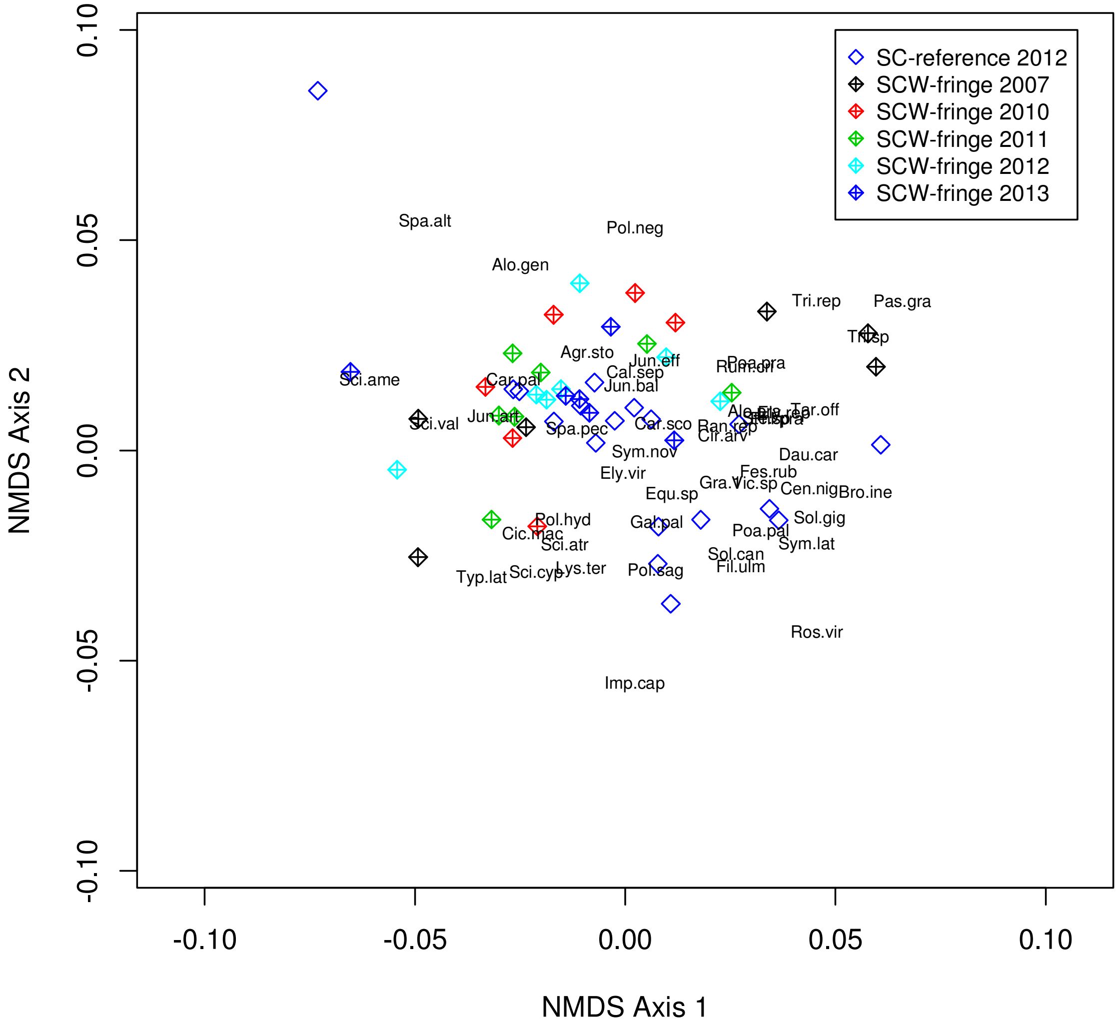
B4 SCW-Fringe



Appendix C – Vegetation Analysis: Mean Plot Abundance and Frequency (f) Tables for Regular and Fringe Plots for all sites (SCR, SCW, SCE, SCS, and SCP)

C1	SCR 08	SCR 08f	SCR 10	SCR 10f	SCR 11	SCR 11f	SCR 12	SCR 12f	SCR 13	SCR 13f
Agr.sto	4.329	10	6.737	8	8.526	10	4.333	8	4.105	8
Alo.gen	0	0	0	0	0.105	1	0	0	0	0
Ast.sp	0	0	0	0	0.526	2	0	0	0	0
Atr.gla	0.053	1	0.263	3	0.105	1	0	0	0.053	1
Bro.ine	0	0	0.211	1	2.632	2	0	0	0	0
Cak.edt	0	0	0	0	0	0	0.014	1	0	0
Cal.can	0	0	0.421	1	0	0	2.778	2	0.961	2
Cal.sep	0.737	2	1.105	4	2.526	5	3.944	4	2.421	4
Car.atl	0	0	0	0	0	0	0.889	1	0	0
Car.cra	0	0	0	0	0.842	1	0	0	0.053	1
Car.cri	0	0	0	0	0	0	0	0	2.211	2
Car.gyn	0	0	0	0	0	0	0.889	1	0	0
Car.lac	0	0	0	0	0.013	1	0	0	0	0
Car.len	0	0	0	0	0	0	0.014	1	2.105	3
Car.nig	0	0	0	0	0	0	1.389	1	0	0
Car.pal	2.474	4	2	4	4.211	4	3.222	3	0.684	2
Car.sco	0	0	0.105	1	0	0	0.056	1	0	0
Car.sti	0	0	0	0	0	0	0	0	0.053	1
Car.str	0	0	2.263	2	1.158	2	0	0	0	0
Car.tri	0	0	0	0	0	0	0	0	0.053	1
Cen.nig	2.842	5	1.316	3	1.789	4	1.736	3	1.329	4
Cic.mac	0	0	0	0	0.013	1	0	0	0	0
Cir.arv	0.263	2	0.737	3	0.803	6	0.069	2	0	0
Cir.vul	0.263	1	0	0	0	0	0	0	0	0
Tri.sp	0	0	0	0	0	0	0.014	1	0	0
Tar.off	2.026	8	1.487	9	2.211	7	2.514	9	1.329	5
Dau.car	0	0	0	0	0.158	1	0	0	0	0
Doe.umb	0.158	2	0.211	1	0	0	0.556	1	0.526	1
Ely.rep	0.053	1	0.105	1	0.539	3	0.014	1	0.013	1
Ely.vir	0	0	0	0	0	0	0.069	2	0	0
Epi.cil	0	0	0.474	2	0.053	1	0.167	2	0.053	1
Epi.pal	0	0	0.105	1	0.053	1	0	0	0	0
Equ.sp	0.013	1	0.342	4	3.224	6	0.292	4	0.053	1

C1	SCR 08	SCR 08f	SCR 10	SCR 10f	SCR 11	SCR 11f	SCR 12	SCR 12f	SCR 13	SCR 13f
Eup.mac	0	0	0.211	1	0.053	1	0	0	0	0
Eut.gra	0	0	0.211	2	0	0	0	0	0	0
Fes.rub	0	0	1.421	3	0	0	6.556	7	3.487	7
Fil.ulm	1.526	2	1.316	2	2.684	3	1.667	3	2.474	3
Gal.asp	0	0	0.316	1	1.368	2	0	0	0.895	1
Gal.mol	0.316	1	0.263	1	0	0	0	0	0	0
Gal.pal	2.539	10	5.789	11	5.013	13	2.417	11	1.816	9
Gla.mar	0	0	0	0	0	0	0.167	1	0	0
Hie.sp	0	0	0	0	0	0	0	0	0.263	1
Imp.cap	0.947	3	1.737	3	1.5	7	0	0	0.013	1
Iri.ver	0	0	0	0	0.105	1	0	0	0	0
Jun.bal	4.105	4	3.947	3	3.789	3	4.167	3	3.105	3
Jun.bre	0.316	2	0.053	1	0	0	0	0	1.211	2
Jun.eff	0	0	0	0	0	0	0.444	1	0.053	1
Jun.ger	0.263	2	0	0	0.632	3	0.167	1	0.079	3
Lot.cor	0	0	0.053	1	0	0	0	0	0	0
Lyc.ame	0.053	1	0	0	0	0	0	0	0	0
Lyc.uni	0	0	0	0	0.053	1	0	0	0	0
Lys.ter	0	0	0.211	1	0	0	0	0	0	0
Men.arv	0	0	0.316	1	0.684	3	0.167	1	0.105	1
Ono.sen	0	0	0	0	0.105	2	0.278	1	0.316	1
Oxa.sp	0.066	2	0	0	0	0	0	0	0	0
Pha.aru	0.632	1	1.316	1	1.316	1	1.389	1	1.316	1
Poa.pal	0	0	2.895	4	1.789	2	2.778	4	2.526	6
Poa.pra	0	0	1.842	3	6.579	9	1.278	1	0.316	2
Pol.hyd	0	0	0	0	0	0	0.056	1	0	0
Pol.sag	0.684	3	1.158	3	0.947	3	0.056	1	0	0
Pot.sim	0	0	0	0	0.895	1	0	0	0	0
Ran.acr	0	0	0	0	0.158	1	0	0	0	0
Ran.cym	0	0	0	0	0.211	1	0	0	0	0
Ran.rep	0	0	0	0	1.421	3	0.625	4	0.421	2
Ros.vir	0	0	0	0	0.158	1	0.056	1	0.013	1
Rub.all	0	0	1.158	1	0.947	1	1.333	1	1.263	1
Rub.pub	0	0	0	0	0	0	0	0	0.158	1
Rub.str	1.263	1	0	0	0	0	0	0	0	0
Rum.cri	0.316	1	0	0	0	0	0	0	0	0
Gra.1	9.789	11	4.053	5	0.158	1	0	0	0	0
Sci.atr	0	0	1.263	1	1.421	2	1.222	1	1.737	3
Sci.cyp	0.789	2	0	0	0	0	0	0	0	0

C1	SCR 08	SCR 08f	SCR 10	SCR 10f	SCR 11	SCR 11f	SCR 12	SCR 12f	SCR 13	SCR 13f
Sci.val	0	0	0.053	1	0	0	0.056	1	0	0
Car.2	0.632	2	0	0	0	0	0	0	0	0
Car.3	1.947	2	0	0	0	0	0	0	0	0
Sp.4	0	0	0	0	0	0	0.333	1	0	0
Gra.4	0.211	1	0	0	0	0	0	0	0	0
Sp.5	0	0	0	0	0	0	0.111	1	0	0
Sol.jun	0	0	0	0	1.421	4	0.111	1	0.474	1
Sol.alt	0	0	0.171	2	1.276	3	0.014	1	0	0
Sol.can	2.053	5	2.789	8	4.316	6	1.333	7	1.171	5
Sol.gig	1.368	5	1.053	4	0	0	0.889	4	0.842	3
Sol.rug	0.224	2	0.053	1	0.105	2	0	0	0.421	3
Sol.ten	0	0	0	0	0.053	1	0.625	4	0.474	3
Son.arv	0	0	0	0	0	0	0	0	0.895	1
Spa.alt	1.368	2	2.632	2	0	0	0.389	1	1.263	1
Spa.pec	4.579	6	2.947	5	4.842	7	5.167	7	7.053	8
Spe.can	0	0	0	0	0	0	0	0	0.053	1
Ste.sp	0	0	0	0	0.013	1	0	0	0	0
Sym.lan	0	0	0	0	0.263	1	1	4	0	0
Sym.nov	4.711	10	5.421	9	2	4	4.125	9	4.382	10
Sym.lat	0.895	3	0.632	1	1.053	2	0.944	2	0.842	2
Sym.nag	0	0	0	0	1.579	4	0	0	0	0
Tri.rep	0	0	0.211	1	0.263	1	0	0	0	0
Typ.lat	0.855	2	0.368	1	0.526	1	0.333	1	0.474	2
Vic.sp	0.013	1	0.158	3	0.368	1	0.458	3	0.105	1

C2	SCP 08	SCP 08f	SCP 10	SCP 10f	SCP 11	SCP 11f	SCP 12	SCP 12f	SCP 13	SCP 13f
Ace.rub	0	0	0.514	1	0	0	0	0	0	0
Ach.mil	0.162	3	0.171	1	0.057	1	0.007	1	0	0
Agr.gig	0	0	0	0	0	0	0.429	2	0.294	3
Agr.per	0	0	0	0	0.2	1	0	0	0.176	1
Agr.sto	0.147	1	0.086	1	0.743	2	1.129	7	0.676	5
Aln.sp	1.471	2	0.343	1	0.007	1	0.057	1	0.235	1
Algae	0	0	0	0	0	0	0	0	0.176	1
Ali.tri	0	0	0	0	0.029	1	0.036	2	0.176	2
Alo.gen	0	0	0	0	0.686	1	0.007	1	0	0
Alo.pra	0	0	3.829	13	4.55	12	1.064	7	1.978	5
Amp.bra	0	0	0	0	0	0	0.086	1	0	0
Ast.sp	0	0	0.086	1	0.236	4	0	0	0	0

C2	SCP 08	SCP 08f	SCP 10	SCP 10f	SCP 11	SCP 11f	SCP 12	SCP 12f	SCP 13	SCP 13f
Atr.has	0	0	0	0	0.286	1	0	0	0	0
Atr.sp	0	0	0	0	0	0	0	0	0.007	1
Bet.sp	0.735	1	0	0	0	0	0	0	0.735	1
Bid.cern	0.051	4	0	0	0	0	0	0	0.088	1
Bro.ine	0.971	2	0.807	3	0.914	2	0.371	1	1.324	2
Cal.can	0.265	1	0.629	1	0.571	2	0.6	1	0.735	1
Cal.sep	0	0	0	0	0.057	1	0.143	1	0	0
Car.cri	0	0	0	0	0.971	4	0.286	3	0.235	1
Car.gyn	0	0	0.064	2	0.371	1	0.264	2	0.441	2
Car.lac	0	0	0	0	0.714	1	0.921	3	0.735	1
Car.lur	0	0	0	0	0	0	0.057	1	0	0
Car.pal	0	0	0.4	2	0	0	0	0	0	0
Car.pro	0.118	1	0.029	1	0	0	0	0	0.147	2
Car.pse	1.706	6	0.514	1	0	0	0	0	0	0
Car.sco	0.176	2	0.757	8	0.664	4	0.8	5	0.559	4
Car.sp	0	0	0.029	1	0.007	1	0.521	3	0	0
Car.sti	0	0	0	0	0.007	1	0.029	1	0	0
Car.str	0	0	0.629	1	0.486	1	0	0	0	0
Car.tri	0	0	0	0	0.029	1	0.314	2	0	0
Cen.nig	1.5	5	0.743	4	0.543	2	0.286	2	0.272	3
Cer.vul	0	0	0	0	0	0	0.057	1	0	0
Che.gla	0	0	0	0	0	0	0.029	1	0	0
Pru.vir	1.471	2	0	0	0.714	1	0.157	4	1.471	2
Cic.bul	0	0	0.071	3	0.014	2	0.086	3	0.096	3
Cic.mac	0	0	0.029	1	0	0	0.086	1	0.213	3
Cir.arv	0	0	0	0	0.114	1	0.064	2	0.059	1
Cir.vul	0.029	1	0	0	0	0	0	0	0	0
Tri.sp	0.015	2	0	0	0.371	2	0.086	1	0.301	2
Mal.syl	0	0	0	0	0	0	0	0	0.706	1
Dal.rep	0	0	0.029	1	0	0	0	0	0	0
Tar.off	0.949	5	0.436	5	0.464	6	0.464	5	0.397	5
Dau.car	0.478	5	0.057	2	0.179	2	0.014	2	0.059	1
Lem.min	0.471	1	0.257	2	0	0	0	0	0.029	1
Ely.rep	6.147	10	4.714	7	0.371	2	0.143	4	0.044	3
Ely.tra	0	0	0	0	0.686	1	0	0	0	0
Epi.cil	0.147	2	0	0	0	0	0	0	0	0
Epi.pal	0.147	3	0.086	3	0.036	2	0	0	0.176	1
Equ.sp	0	0	0.571	2	1.4	3	0.143	1	0.007	1
Eup.mac	0	0	0	0	0.286	1	0.114	1	0	0

C2	SCP 08	SCP 08f	SCP 10	SCP 10f	SCP 11	SCP 11f	SCP 12	SCP 12f	SCP 13	SCP 13f
Eut.gra	0	0	0	0	0.264	3	0	0	0.294	2
Fes.rub	0	0	0	0	0	0	0	0	0.088	1
Gal.tet	0	0	0	0	0.029	1	0	0	0	0
Gal.mol	0	0	0.714	2	0	0	0	0	0	0
Gal.pal	0.603	16	2.936	21	2.6	19	1.829	22	1.206	9
Gle.hed	0.007	1	0	0	0	0	0	0	0	0
Hie.odo	0	0	0	0	0	0	0.143	1	0	0
Imp.cap	1.096	6	1.5	12	1.543	13	0.407	4	0.037	2
Iri.ver	0.007	1	0.171	3	0.543	4	0.179	2	0.147	1
Jun.art	0	0	0	0	0	0	0.229	1	0.147	1
Jun.eff	0.353	3	0.286	3	0.229	4	0.693	5	0.831	4
Jun.ger	0.059	1	0	0	0	0	0	0	0	0
Jun.sp	0	0	0	0	0.2	1	0	0	0	0
Jun.ten	0	0	0	0	0.343	1	0.007	1	0	0
Lap.com	0	0	0	0	0	0	0.114	1	0	0
Leo.aut	0	0	0.114	1	0.029	1	0	0	0	0
Lee.ory	0	0	0	0	0	0	0.457	4	0.853	4
Leu.vul	0	0	0	0	0.007	1	0	0	0	0
Lin.vul	0.088	2	0	0	0	0	0	0	0	0
Lyc.uni	0.088	1	0	0	0	0	0.007	1	0	0
Lys.ter	0.507	5	1.036	9	0.9	6	0.643	9	0.037	2
Moss	0.5	5	0.143	2	0.264	2	0.4	2	0.243	2
Ono.sen	0	0	0.086	1	0.064	2	0	0	0	0
Oxa.sp	0.147	2	0	0	0	0	0	0	0	0
Pha.aru	0	0	0.686	1	0.714	1	0.629	1	0.735	1
Phl.pra	0	0	0.029	1	0	0	0.086	1	0	0
Pic.gla	0.441	1	0.629	1	0.114	1	0.6	1	0.735	1
Pla.maj	0	0	0	0	0	0	0.029	1	0.029	1
Poa.pal	1.088	2	1.571	5	1.771	5	3.064	10	0.596	6
Poa.pra	0.647	1	3.514	9	3.571	9	0.886	3	0.853	3
Pol.hyd	0	0	0.114	2	0.686	8	1.607	9	1.265	8
Pol.lap	0.029	1	0	0	0	0	0	0	0	0
Pol.neg	0	0	0	0	0	0	0	0	0.147	1
Pol.per	0	0	0	0	0.143	2	0.171	2	0	0
Pol.sag	2.449	11	0.464	5	1.114	10	0.721	7	0.426	6
Pop.tre	0	0	0	0	0	0	0.029	1	0	0
Pot.can	0	0	0.114	1	0	0	0	0	0	0
Pot.pal	0	0	0	0	0.007	1	0	0	0	0
Pot.sim	0.037	2	0.114	1	0	0	0.029	1	0	0

C2	SCP 08	SCP 08f	SCP 10	SCP 10f	SCP 11	SCP 11f	SCP 12	SCP 12f	SCP 13	SCP 13f
Pro.pal	0.654	6	0.257	2	0.05	4	0.071	4	0	0
Ran.rep	0	0	0.086	3	0.093	3	0.15	4	0.118	3
Ros.vir	0.066	2	0.543	3	0.857	4	0.693	3	0.868	6
Rub.ida	0.566	2	0.429	1	0.143	1	0.343	1	0.676	1
Rum.cri	0.007	1	0	0	0	0	0.143	1	0.118	1
Sci.atr	2.029	7	4.143	10	3.407	8	4.779	11	4.353	10
Sci.cyp	6.176	10	4.521	10	2.543	8	4.207	13	4.294	10
Sci.val	0.029	1	0	0	0	0	0.371	1	0.654	2
Sp.2	0	0	0	0	0	0	0	0	0.206	1
Sp.3	1.176	5	0	0	0	0	0	0	0	0
Scu.gal	0	0	0	0	0.2	1	0	0	0	0
Sol.dul	0.184	2	0.036	2	0.121	2	0.007	1	0	0
Sol.jun	0	0	0.007	1	0	0	0	0	0	0
Sol.alt	0.412	5	0.2	2	0.086	2	0.343	3	0	0
Sol.can	0.868	9	0.293	5	0.457	3	0.15	4	0.007	1
Sol.gig	0.059	1	0	0	0.057	1	0.029	1	0	0
Sol.rug	0.39	4	0.343	4	0	0	0	0	0	0
Sol.ten	1.118	5	0.229	3	0	0	0.171	2	0	0
Spa.eme	0	0	0	0	0	0	0.4	1	0	0
Spa.pec	2.441	5	4.2	10	5.029	12	6.457	14	7.5	13
Spi.lat	0	0	0	0	0.114	1	0	0	0	0
Spi.alb	0	0	0.121	2	0	0	0	0	0	0
Ste.gra	0	0	0	0	0	0	0.029	1	0.059	1
Ste.sp	0.331	3	0.343	1	0.064	2	0	0	0	0
Sym.lan	0	0	0	0	0.029	1	0.229	3	0	0
Sym.nov	0.272	3	0.893	5	0.464	4	1.543	5	2.301	12
Sym.lat	0	0	0.036	2	0.121	3	0.293	4	0.353	3
Sym.nag	0	0	0	0	0.714	3	0	0	0.088	1
Tha.pub	0	0	0.007	1	0.064	3	0.036	2	0.066	2
Tor.pal	0	0	0	0	0.007	1	0	0	0	0
Tra.pra	0	0	0.029	1	0	0	0	0	0	0
Tri.fra	0.037	2	0	0	0	0	0	0	0	0
Tri.pra	0	0	0.064	3	0.057	1	0	0	0	0
Tri.rep	0	0	0.143	1	0.264	4	0	0	0	0
Typ.Ang	0	0	0	0	0.007	1	1.571	3	1.507	4
Typ.lat	2.118	9	4.114	8	3.114	8	1.829	7	1.971	6
Vic.sp	0.618	11	1.1	13	1.3	10	0.45	10	0.176	2

C2	SCPF 08	SCPF 08f	SCPF 10	SCPF 10f	SCPF 11	SCPF 11f	SCPF 12	SCPF 12f	SCPF 13	SCPF 13f
Car.gyn	0	0	0	0	0	0	0	0	8	1
Car.lac	0	0	0	0	0	0	1	1	0	0
Cic.mac	0	0	1	1	0	0	0	0	0	0
Equ.sp	0	0	2	1	1	1	0.25	1	0	0
Eup.mac	14	1	8	1	13	1	6	1	3	1
Gal.pal	0	0	1	1	0	0	0.25	1	0	0
Imp.cap	1	1	5	1	1	1	0	0	0	0
Lys.ter	0	0	0	0	1	1	0	0	0	0
Pol.sag	0	0	1	1	0	0	1	1	0	0
Sci.atr	2	1	11	1	18	1	3	1	0	0
Spa.pec	0	0	2	1	0	0	2	1	3	1
Sym.nov	0	0	0	0	0	0	0	0	2	1
Typ.Ang	0	0	0	0	0	0	23	1	25	1
Typ.lat	22	1	22	1	25	1	0	0	0	0

C3	SCS 08	SCS 08f	SCS 10	SCS 10f	SCS 11	SCS 11f	SCS 12	SCS 12f	SCS 13	SCS 13f
Ach.mil	0	0	0	0	0	0	0.75	2	0	0
Agr.per	0	0	0	0	0.125	1	0	0	0	0
Agr.sto	9	5	6.5	3	2.25	1	5.031	4	1.531	3
Ali.tri	0	0	0	0	0.031	1	0	0	0.25	1
Alo.pra	0	0	0	0	3	2	0.25	1	2.5	1
Ast.sp	0	0	0	0	0.031	1	0	0	0	0
Bid.cern	0	0	0	0	0	0	0.063	2	0.031	1
Bro.ine	0	0	4.125	2	5	2	0	0	2.5	2
Car.lur	0.042	1	0	0	0	0	0	0	0.5	1
Car.pse	0.333	1	0	0	0	0	0	0	0	0
Car.sco	3.833	1	0	0	0	0	0	0	0.625	1
Car.sp	0	0	0	0	1.125	1	0	0	0	0
Car.sti	0	0	0.25	1	0	0	0	0	0	0
Car.str	0	0	2.75	1	0	0	0	0	0	0
Cir.arv	0	0	0	0	0.125	1	1.125	2	0.031	1
Cir.vul	0	0	1.5	2	0	0	0	0	0	0
Tri.sp	0	0	0	0	0	0	0.125	1	0	0
Tar.off	0	0	2.75	3	2.875	1	2.625	2	1.75	2
Dau.car	0	0	0.25	1	0	0	0	0	0.375	1
Ele.obt	0	0	0	0	0	0	0	0	0.125	1
Ely.rep	0	0	0.281	2	0	0	0.25	1	0	0
Epi.cil	0.167	1	0	0	0	0	0	0	0	0

C3	SCS 08	SCS 08f	SCS 10	SCS 10f	SCS 11	SCS 11f	SCS 12	SCS 12f	SCS 13	SCS 13f
Equ.sp	0	0	2.5	2	1.75	1	1	2	1.625	1
Gal.tet	0	0	0	0	0.625	2	0	0	0	0
Gal.pal	0	0	0.031	1	0.156	2	0.25	1	1.75	1
Imp.cap	3	1	0.031	1	0	0	0	0	0	0
Iri.ver	0	0	0	0	0	0	0	0	0.031	1
Jun.art	0	0	0	0	0	0	0.031	1	0.625	1
Jun.bre	0	0	0	0	0	0	0.25	1	0.031	1
Jun.eff	0	0	0.75	1	0	0	0	0	0	0
Lin.vul	0	0	0.25	1	0	0	0	0	0	0
Lol.per	0	0	0.125	1	0	0	0	0	0	0
Lyc.ame	0	0	0	0	0	0	0	0	0.031	1
Lyc.uni	0	0	0.125	1	0	0	0.375	1	0	0
Lys.ter	0	0	0	0	0	0	0.25	2	0	0
Pla.maj	0	0	0.031	1	0	0	0.75	1	0.25	1
Poa.pal	0	0	1	1	0	0	2.5	2	1.5	1
Poa.pra	0	0	0	0	0.5	1	0	0	0.375	1
Pol.hyd	0	0	0	0	0.031	1	0.656	2	0.375	1
Pol.neg	0	0	0	0	0.031	1	0	0	0	0
Pol.sag	0.167	1	0	0	0.25	1	0	0	0.375	1
Ran.rep	0	0	0	0	0	0	2.625	2	0.75	2
Ros.vir	0	0	0.75	1	0.656	2	0	0	0.156	2
Sag.lat	0	0	0	0	0	0	0	0	0.031	1
Car.1	0.042	1	0	0	0	0	0	0	0	0
Sci.acu	1.167	1	0	0	0	0	0	0	0	0
Sci.atr	0	0	5	3	3.281	3	3.75	2	0.531	2
Sci.cyp	1.333	1	0	0	0	0	0	0	0	0
Sci.val	0	0	1	1	0.375	1	0	0	0.375	1
Sol.dul	3	1	0.5	2	1.531	2	0	0	0.375	2
Sol.can	0.833	1	0	0	0	0	0.75	1	0.75	1
Sol.gig	0	0	0	0	0.375	1	0.375	1	0	0
Spa.pec	3.333	2	4.5	2	3.375	3	2.906	2	0.156	2
Ste.sp	1	2	0	0	0	0	0	0	0	0
Sym.nov	0.333	1	0.75	2	0	0	1.125	2	1	1
Tri.rep	0	0	0.75	1	0	0	0	0	0	0
Typ.Ang	0	0	0	0	0	0	0	0	11.63	4
Typ.lat	16.33	6	13.38	6	14.5	6	14.75	6	3	1
Vic.sp	0	0	0.125	1	0.125	1	0	0	0.125	1

C3	SCSF 08	SCSF 08f	SCSF 10	SCSF 10f	SCSF 11	SCSF 11f	SCSF 12	SCSF 12f	SCSF 13	SCSF 13f
Agr.sto	3	1	2	2	2.5	1	6	2	4	2
Car.cri	0	0	0	0	2.5	1	0	0	0	0
Car.gyn	0	0	0	0	0	0	4	2	1	1
Car.pal	0	0	7.5	2	0	0	0	0	0	0
Car.sco	0	0	1.5	1	1.5	1	0	0	0	0
Car.sp	0	0	0	0	0	0	0	0	2	1
Car.sti	0	0	0	0	3.5	1	1	1	0	0
Car.vul	0	0	1	1	3	1	0	0	2	1
Cic.bul	1	1	0	0	0	0	0	0	0	0
Cic.mac	0.5	1	0	0	0	0	0.5	1	0	0
Cir.arv	0.125	1	0	0	0	0	0	0	0	0
Tri.sp	0	0	0	0	1	1	1.5	1	0	0
Ely.vir	0	0	0.5	1	0	0	2	2	2.5	1
Equ.sp	6.5	1	4	1	9	1	6	2	5.5	1
Fes.rub	0.125	1	0	0	0	0	0	0	0	0
Gal.pal	0	0	1.5	2	6.5	1	8.5	2	7	2
Jun.art	2.5	2	1	1	5	1	5	2	1.5	1
Jun.bre	0	0	0	0	0	0	6	1	2.5	2
Jun.ger	6	1	0	0	7.5	1	0	0	0	0
Lyc.ame	0	0	0.5	1	0	0	0	0	0	0
Lyc.uni	0	0	0	0	0	0	0.125	1	0	0
Lys.ter	0	0	2	1	0.5	1	2	1	0	0
Men.arv	0.125	1	1	1	0	0	0	0	0	0
Pha.aru	2	1	0	0	0	0	0	0	1	1
Poa.pal	0	0	0.5	1	0	0	5.5	1	3.5	1
Pol.hyd	0	0	0	0	0	0	0.5	1	0.125	1
Pol.sag	1	1	0	0	0	0	0	0	0.125	1
Pot.pal	0	0	0.125	1	0	0	0	0	0	0
Ran.rep	0	0	0	0	0.125	1	0	0	0	0
Sci.acu	2	1	0	0	0	0	0	0	0	0
Sci.ame	13	2	6.5	2	14.5	2	10	2	11	2
Sci.atr	0	0	4	2	1.5	1	8	2	3	2
Sci.val	0	0	0	0	2.5	1	0	0	0.5	1
Scu.gal	0	0	0	0	0	0	0.125	1	0.5	1
Spa.pec	19	2	22	2	11	1	22	2	24	2
Ste.sp	5.5	2	0	0	0	0	0	0	0	0
Sym.lan	0	0	0	0	8	1	0	0	0	0
Sym.nov	4	2	4	1	0	0	4	1	7.5	2
Typ.Ang	0	0	0	0	0	0	0	0	4	1

C3	SCSF 08	SCSF 08f	SCSF 10	SCSF 10f	SCSF 11	SCSF 11f	SCSF 12	SCSF 12f	SCSF 13	SCSF 13f
Typ.lat	0	0	1	1	0	0	1	1	0	0
Vic.sp	0.5	1	0.125	1	0	0	0	0	0	0

C4	SCE 08	SCE 08f	SCE 10	SCE 10f	SCE 11	SCE 11f	SCE 12	SCE 12f	SCE 13	SCE 13f
Ach.mil	0	0	0	0	0	0	0.625	1	0	0
Agr.sto	1.625	3	5	3	3.5	3	3.75	3	0.417	3
Ali.tri	0	0	0.5	1	0	0	0	0	0	0
Alo.gen	0	0	2.5	2	1.75	2	0	0	0	0
Alo.pra	0	0	9.5	6	6.771	8	4.5	3	0.104	2
Bro.ine	3.417	2	1.375	2	2.75	3	0.75	1	7.583	4
Car.ech	0	0	0	0	0.167	1	0	0	0	0
Car.hor	0	0	0	0	1.167	3	0	0	0	0
Car.lur	0	0	0.375	1	0	0	0.125	1	0	0
Car.pal	0	0	0	0	0	0	0	0	0.021	1
Car.sco	0	0	2.156	3	2.333	5	2	2	3.917	5
Car.spi	0	0	0.125	1	0	0	0	0	0	0
Car.sti	0	0	0	0	0.917	2	0.875	1	0	0
Cer.vul	0	0	0	0	0	0	0.375	1	0	0
Cic.mac	0	0	0.375	2	0.271	3	0.125	1	0.021	1
Cir.arv	0	0	0	0	0.271	2	0	0	0.542	5
Cir.mut	0	0	0	0	0	0	0.031	1	0	0
Tri.sp	1.625	6	0	0	0.021	1	1.625	1	0.167	1
Tar.off	5.583	8	0.406	3	0.104	2	0.375	1	0.021	1
Dau.car	0.25	1	0	0	0.271	2	0	0	0	0
Ely.rep	0	0	3.125	3	1.417	4	1.125	1	1.5	1
Ely.vir	0	0	0	0	2.417	2	0	0	0.833	2
Epi.pal	0	0	0.125	1	0	0	0	0	0	0
Equ.sp	0	0	0	0	3.5	6	0.5	4	1.75	5
Eut.gra	0	0	0	0	0.25	1	0	0	0.417	1
Fes.rub	7.917	5	0	0	0	0	0	0	0	0
Fil.ulm	0.208	3	0	0	0	0	0	0	0	0
Gal.mol	0.833	2	2.375	1	0.833	2	3.5	5	0	0
Gal.pal	0.25	1	2.75	3	1.771	4	0	0	0.25	3
Hie.odo	0	0	0	0	0	0	1	1	0.021	1
Imp.cap	0	0	0	0	2.438	5	0.25	1	0.458	4
Jun.art	0	0	0.031	1	0.25	1	0	0	0	0
Jun.bre	0	0	0	0	1.354	2	0	0	0.25	2
Jun.eff	0	0	1.5	2	1.917	4	1.938	3	1.854	4

C4	SCE 08	SCE 08f	SCE 10	SCE 10f	SCE 11	SCE 11f	SCE 12	SCE 12f	SCE 13	SCE 13f
Jun.ten	0.021	1	0.125	1	0	0	0	0	0	0
Leo.aut	0	0	0	0	0.667	1	0	0	0	0
Lee.ory	0	0	0	0	0	0	0	0	0.417	1
Lol.per	0	0	1.75	1	0	0	0	0	0	0
Lyc.uni	0	0	0	0	0.25	2	0	0	0.083	1
Lyt.sal	0	0	0	0	0.083	1	0	0	0	0
Pha.aru	8.438	7	0	0	0	0	0	0	0.25	1
Phl.pra	0	0	3.375	4	1.583	2	1.813	3	1.5	1
Pla.maj	1.25	3	0	0	0.5	2	0	0	0	0
Poa.pal	0	0	4.375	2	4.354	7	6.625	3	0	0
Poa.pra	0	0	3	2	1.25	2	1	2	0.583	1
Pol.hyd	0	0	0.25	1	0	0	0.125	1	0.25	1
Pol.lap	0	0	0.375	1	0	0	0.406	2	0	0
Pol.per	0	0	0.125	1	0	0	0	0	0	0
Pol.pun	0	0	0.031	1	0	0	0	0	0	0
Pol.sag	0	0	0	0	1.542	7	0.906	3	0.354	3
Ran.rep	0.771	4	0.5	3	0.354	4	1.875	1	0	0
Ror.pal	0	0	0.031	1	0	0	0	0	0	0
Rum.cri	0.083	1	0	0	0	0	0	0	0	0
Gra.1	5.417	4	0	0	0	0	0	0	0	0
Gra.2	0.188	2	0	0	0	0	0	0	0	0
Gra.3	0	0	0	0	0.75	1	0	0	0	0
Sp.1	0	0	0	0	0	0	0	0	0.083	1
Sci.acu	0	0	1.5	2	0	0	0	0	0	0
Sci.atr	0	0	0	0	0	0	0	0	0.021	1
Sci.cyp	0.167	1	3.375	3	2.583	2	3.25	2	4.771	5
Sci.val	0	0	0	0	0.917	1	2.125	2	1.333	2
Sol.can	0	0	0	0	0	0	0	0	1.583	1
Sol.ten	0	0	0.125	1	0	0	0	0	0	0
Son.arv	0	0	0	0	0	0	0	0	0.083	1
Spa.pec	3.5	3	4.75	3	12	7	3.25	2	14	10
Ste.sp	0.167	1	1.75	3	0.417	2	1.75	1	0.417	1
Sym.lan	0	0	0	0	1	2	0	0	0	0
Sym.nov	0.167	1	0	0	1.25	2	0.656	3	2.604	6
Tor.pal	0	0	0	0	0.25	1	0	0	0	0
Tri.pra	0	0	3.125	1	2	2	0	0	0	0
Tri.rep	0	0	1.531	2	0.188	3	0	0	0	0
Typ.Ang	0	0	0	0	0	0	3.125	1	0	0
Typ.lat	0	0	2.375	3	4.25	3	5.75	2	3.917	3

C4	SCE 08	SCE 08f	SCE 10	SCE 10f	SCE 11	SCE 11f	SCE 12	SCE 12f	SCE 13	SCE 13f
Vic.sp	0.875	6	0.625	2	2.188	5	0.5	2	2.167	5

C4	SCEF 08	SCEF 08f	SCEF 10	SCEF 10f	SCEF 11	SCEF 11f	SCEF 12	SCEF 12f	SCEF 13	SCEF 13f
Ach.mil	0	0	0	0	0	0	0.4643	2	0	0
Agr.sto	0.5714	1	4.4286	2	3	1	0	0	4.2	3
Alo.pra	0	0	0.1429	1	0	0	0.1429	1	0	0
Bro.ine	3.5714	1	7	2	4.1667	1	10.714	3	0	0
Cal.sep	0	0	0	0	0	0	0.1429	1	0	0
Car.gyn	0	0	0	0	6.6667	4	0	0	0	0
Car.pal	0.8929	2	2.8571	4	0	0	3.5714	2	5.2	4
Cic.mac	0.4286	1	0	0	0.2083	2	0.2857	2	0.2	1
Cir.arv	0	0	0	0	0.6667	1	0.4286	2	0.8	1
Cir.mut	0	0	0	0	0	0	0.0357	1	0	0
Cir.vul	0	0	0.0357	1	0	0	0	0	0	0
Tar.off	1.1429	1	0.0357	1	0	0	0	0	0	0
Dau.car	0	0	0.1429	1	0	0	0	0	0	0
Ele.sp	0.2857	1	0	0	0	0	0	0	0	0
Ely.rep	0	0	0	0	0	0	1.5714	1	0	0
Ely.vir	3	3	7.4286	4	3.1667	3	1.5714	2	9	3
Equ.sp	3.4643	3	5	5	12	4	3.8571	4	8.6	3
Fes.rub	0	0	2.2857	1	0	0	3.7143	2	1.4	2
Fil.ulm	0.2857	1	0	0	0	0	0	0	0	0
Gal.mol	0.7143	1	0	0	0	0	0	0	0	0
Gal.pal	1.7143	4	1.6071	3	0.25	3	0.8571	1	0.6	2
Imp.cap	0	0	2.0357	3	0.4167	3	0.0357	1	0	0
Pha.aru	3.5714	1	0.1429	1	1	1	0	0	0	0
Poa.pal	0	0	0	0	1.6667	1	0	0	0	0
Poa.pra	0	0	1.1429	1	0	0	0	0	0	0
Pol.sag	0	0	0	0	0.0417	1	0.1429	1	0	0
Pot.pal	0	0	0.4286	2	0	0	0	0	0	0
Rum.cri	0.1429	1	0.4286	1	0.6667	1	0	0	0	0
Sci.acu	2.1429	3	3.4286	1	0	0	0	0	0	0
Sci.atr	0	0	6.7143	3	7.5	3	3.4286	1	4	2
Sci.cyp	5.8571	3	0	0	0	0	0	0	0	0
Sci.val	0	0	3	1	7.8333	3	1.1429	1	9.8	2
Scu.gal	0	0	0	0	0	0	0.1429	1	0	0
Spa.pec	15.143	5	10.286	6	8.3333	4	12.286	4	15.6	4
Sym.lan	0	0	0	0	0.1667	1	0	0	0	0

C4	SCEF 08	SCEF 08f	SCEF 10	SCEF 10f	SCEF 11	SCEF 11f	SCEF 12	SCEF 12f	SCEF 13	SCEF 13f
Sym.nov	2.6071	3	3.8929	3	2.5	1	4.4286	4	1.6	2
Tri.pra	0	0	0	0	0.1667	1	0	0	0	0
Vic.sp	0.5714	1	1.7143	2	4.3333	3	1	3	2.45	3

C5	SCW 08	SCW 08f	SCW 10	SCW 10f	SCW 11	SCW 11f	SCW 12	SCW 12f	SCW 13	SCW 13f
Ach.mil	0.1538	1	0.625	2	0.3077	2	0.2692	2	0	0
Agr.per	0	0	0.4231	1	0.6538	1	0	0	0	0
Agr.sto	1.7308	3	2.9615	10	3.5096	7	5.7692	12	12	15
Algae	0	0	1.7692	7	0	0	0	0	0.1154	1
Ali.tri	0	0	0	0	1.7788	6	1.6538	3	0.3077	1
Alo.gen	0	0	7.0385	13	9.2692	15	7.5865	15	0.9231	1
Alo.pra	0	0	3.4519	11	3.1923	7	2.5	5	1.1538	2
Ant.cot	0	0	0.0096	1	0	0	0	0	0	0
Atr.gla	0	0	0	0	0	0	0.9038	6	0.0769	1
Atr.has	0	0	0	0	1.4712	5	0	0	0	0
Atr.sp	0	0	0.0385	1	0.0385	1	0	0	0.3462	2
Bid.cern	0	0	0	0	0.0385	1	0	0	0	0
Bro.cil	0	0	0	0	0	0	0.2692	1	0	0
Bro.ine	0	0	0	0	0.4615	2	0.3077	1	0	0
Cal.can	0	0	0.1154	1	0	0	0	0	0	0
Car.gyn	0	0	0	0	0.8846	1	0	0	0	0
Car.lur	0.0385	1	0	0	0	0	0	0	0.0096	1
Car.pal	0	0	0	0	0	0	0.6923	1	0.7692	1
Car.sco	0.6923	4	0	0	0	0	0.1923	2	0	0
Car.sp	0	0	0	0	0.4231	2	0	0	0	0
Car.spi	0	0	0.0481	2	0.1154	1	0.1923	2	1.2692	2
Cen.nig	0	0	0	0	0	0	0.3077	1	0.3462	1
Cer.vul	0.0192	2	0.1923	1	0	0	0	0	0	0
Cir.arv	0.0096	1	0	0	0	0	0.0096	1	0.1154	1
Cir.vul	0.1538	1	0	0	0	0	0	0	0	0
Tri.sp	7.2404	18	0	0	0.0769	1	1.0385	3	0	0
Mal.syl	0	0	0	0	0	0	0.0769	1	0.9615	1
Tar.off	4.5673	19	0.7788	4	0.8173	5	0.2981	5	0.1154	2
Dau.car	0	0	0.0385	1	0	0	0	0	0	0
Ely.rep	0	0	1.9423	8	3.6538	7	2.2308	6	2.6923	8
Ely.tra	0	0	0	0	0.2308	1	0	0	0	0
Ely.vir	0	0	0	0	0	0	0	0	0.0385	1
Fil.ulm	0.1731	3	0	0	0	0	0	0	0	0

C5	SCW 08	SCW 08f	SCW 10	SCW 10f	SCW 11	SCW 11f	SCW 12	SCW 12f	SCW 13	SCW 13f
Gal.tet	0	0	0.1154	1	0.8942	2	0.0385	1	0.0096	1
Gal.mol	0.3462	1	0	0	0	0	0	0	0	0
Gal.pal	0	0	0.0769	1	0.125	2	0	0	0	0
Gle.hed	1.2692	2	1.1923	2	0.6154	1	1.6154	2	1	2
Gly.gra	0	0	0	0	0.2692	1	0	0	0.2308	2
Gna.uli	0	0	0	0	0.3846	3	0	0	0	0
Cra.sp	0	0	0.0096	1	0	0	0	0	0	0
Hie.pil	0.0769	1	0	0	0	0	0	0	0	0
Imp.cap	0	0	0	0	0.0769	1	0	0	0	0
Iri.ver	0	0	0	0	0	0	0.0385	1	0	0
Jun.art	0	0	0	0	1.5865	5	1.0385	3	0.5	1
Jun.bre	0	0	0.1538	1	0	0	0	0	0	0
Jun.buf	0	0	0	0	0.3942	2	0	0	0	0
Jun.eff	1.6635	6	0.8269	5	0.0769	1	0.5385	3	0.0385	1
Jun.ten	0.0385	1	0.0096	1	0	0	0	0	0	0
Leo.aut	0	0	0.6635	5	0.7404	4	0	0	0	0
Lol.per	0	0	1.8846	2	0.1923	1	0	0	0	0
Lyt.sal	0	0	0	0	0	0	0	0	0.0769	1
Moss	0.125	3	0	0	0	0	0	0	0	0
Oxa.sp	0	0	0	0	0	0	0	0	0.0769	1
Pas.gra	18.885	23	0	0	0	0	0	0	0	0
Pha.aru	0	0	0	0	0	0	0	0	0.2308	1
Phl.pra	0	0	0	0	0.3846	2	0.3077	2	0.7404	3
Pla.lan	0	0	0	0	0.1154	2	0	0	0.0385	1
Pla.maj	0.0481	2	0.1923	2	0	0	0.0385	1	0	0
Poa.pal	0	0	0	0	0	0	3.1923	7	1.2308	3
Poa.pra	0	0	8.1635	13	4.2308	8	1.8462	3	2.4615	3
Pol.hyd	0	0	0.0096	1	0.3846	2	0.2404	4	0.6154	1
Pol.lap	0	0	0.125	3	0.5577	5	0	0	0.0385	1
Pol.neg	0.0096	1	1.6923	5	3.2404	12	0.0096	1	0.3462	2
Pol.per	0	0	0	0	0.1154	1	0	0	0	0
Pol.ram	0	0	0	0	0.2692	2	0	0	0	0
Pol.sag	0	0	0	0	0.0096	1	0	0	0	0
Pol.sp	0	0	0	0	0	0	0.1538	1	0	0
Ran.rep	0.0769	1	0.0096	1	0	0	0	0	0	0
Ros.vir	0.9615	1	0	0	0	0	0	0	0.4231	1
Rub.all	0	0	0.9615	1	0	0	0	0	0	0
Rum.cri	0.6731	8	0	0	0	0	0.3462	2	0.1923	2
Gra.3	0	0	0	0	0.1538	1	0	0	0	0

C5	**SCW 08**	**SCW 08f**	**SCW 10**	**SCW 10f**	**SCW 11**	**SCW 11f**	**SCW 12**	**SCW 12f**	**SCW 13**	**SCW 13f**
Sci.acu	0	0	0	0	0	0	0	0	0.2692	1
Sci.atr	0	0	0	0	0.0769	1	0.4615	1	0.0385	1
Sci.mar	0	0	0	0	0.1923	2	0	0	0	0
Sci.val	0	0	0.4231	3	1.8077	7	2.9231	10	2.3077	5
Sp.6	0	0	0	0	0	0	0.0769	1	0	0
Son.arv	0	0	0	0	0	0	0	0	0.1154	1
Spa.alt	0	0	0.1346	3	5.6538	10	5.5	9	4.4615	6
Spa.pec	0	0	0.2692	2	1.0096	7	4.3558	10	7.0385	13
Ste.sp	0.0577	3	0.0769	1	0.0385	1	0	0	0	0
Sym.nov	0	0	0	0	0	0	0.0096	1	0	0
Sym.lat	0.125	3	0	0	0	0	0	0	0	0
Tri.pra	0	0	0.1154	1	0.0096	1	0	0	0	0
Tri.rep	0	0	1.2308	5	0.7308	3	0	0	0	0
Typ.Ang	0	0	0	0	0.5769	1	1.3558	3	4.0769	5
Typ.lat	0	0	0	0	0.3077	2	1.2692	2	3.4231	5

C5	**SCWF 08**	**SCWF 08f**	**SCWF 10**	**SCWF 10f**	**SCWF 11**	**SCWF 11f**	**SCWF 12**	**SCWF 12f**	**SCWF 13**	**SCWF 13f**
Agr.sto	1.125	1	4.5	2	7	3	15.43	5	13	4
Ali.tri	0	0	0	0	0.036	1	0	0	0	0
Alo.gen	0	0	8.167	2	8.857	3	2.143	2	0	0
Alo.pra	0	0	0	0	0	0	0.143	1	0	0
Ast.sp	0	0	0.167	1	0	0	0	0	0	0
Bro.ine	0	0	0	0	1.857	1	3.286	1	2.571	1
Cal.can	0	0	5.833	3	0	0	0	0	0	0
Car.gyn	0	0	0	0	1.429	2	0	0	0	0
Car.hor	0	0	0	0	0	0	1.857	1	0	0
Car.lur	0	0	0	0	0	0	0.286	1	0.286	1
Car.pal	0	0	1.208	2	0	0	3.036	2	2.143	3
Car.sco	0	0	0.5	1	1	1	0	0	1.429	1
Cic.mac	0	0	0	0	0.571	1	0	0	0	0
Cir.arv	1.125	1	0	0	0	0	1.714	1	0	0
Cir.vul	0	0	0	0	0.857	1	0	0	0	0
Tri.sp	5.375	3	0	0	0	0	0	0	0	0
Tar.off	1.125	3	0.167	1	2.286	2	1.036	2	0.143	1
Dau.car	0	0	0	0	0.036	1	0	0	0	0
Ely.rep	0	0	0	0	1.143	1	0	0	0	0
Equ.sp	0	0	2.667	1	0.036	1	0.286	1	0.036	1
Fes.rub	0	0	0	0	0	0	0	0	1.571	1

C5	SCWF 08	SCWF 08f	SCWF 10	SCWF 10f	SCWF 11	SCWF 11f	SCWF 12	SCWF 12f	SCWF 13	SCWF 13f
Gal.pal	0	0	0	0	0	0	0	0	0.036	1
Jun.art	0.75	1	0	0	1.571	1	0.143	1	0	0
Jun.bal	0	0	0	0	0.286	1	0	0	0	0
Jun.eff	0	0	0	0	0.571	1	0	0	0	0
Jun.ger	0	0	1.833	3	0.714	1	1.286	1	1.571	2
Lol.per	0	0	4.167	1	0	0	0	0	0	0
Men.arv	0.125	1	0	0	0	0	0	0	0	0
Pas.gra	9.25	3	0	0	0	0	0	0	0	0
Phl.pra	0	0	0	0	1.286	1	2	1	0.143	1
Pla.lan	0	0	0	0	0.571	1	0	0	0	0
Poa.pal	0	0	0	0	0	0	0.036	1	0	0
Poa.pra	0	0	0.333	1	0	0	2.286	1	0	0
Pol.lap	0	0	0	0	0.036	1	0	0	0	0
Pol.neg	0	0	0	0	0.179	2	0	0	0	0
Rum.cri	0	0	0.167	1	0	0	0	0	0.143	1
Sci.acu	3.375	4	0	0	0	0	0	0	0	0
Sci.ame	3.156	4	8.833	3	11.57	4	1.857	2	7	2
Sci.atr	0	0	6.667	3	5.429	4	2.607	3	1.429	2
Sci.cyp	4.875	3	0	0	0	0	0	0	0	0
Sci.val	0	0	2.167	1	6.571	4	6	2	2	2
Spa.alt	0.875	1	0	0	0.286	1	0	0	0	0
Spa.pec	0	0	3.875	4	2.75	4	4.75	4	11.29	4
Ste.sp	0.125	1	0	0	0	0	0	0	0	0
Sym.lan	0	0	0	0	0.429	1	0	0	0	0
Sym.nov	0	0	0.167	1	1.321	3	1.429	2	2.714	4
Tor.pal	0	0	0	0	0	0	0.143	1	0	0
Tri.pra	0	0	0.042	1	0.429	1	0	0	0	0
Tri.rep	0	0	5.167	2	0.714	1	0	0	0	0
Typ.lat	0	0	0	0	0.571	1	0.286	2	0	0

Appendix D – Structured Winter Walk: Conditions at St. Croix Reference and Restoration Sites

STRUCTURED WALK PHOTOGRAPHS SCP (select images):

Figure 1 SCP Line 1.

Figure 2 SCP Line 4.

STRUCTURED WALK PHOTOGRAPHS SCS (select images):

Figure 3 SCS Line 1.

STRUCTURED WALK PHOTOGRAPHS SCW (select images):

Figure 4 SCW landscape from road.

Figure 5 SCW Line 1.

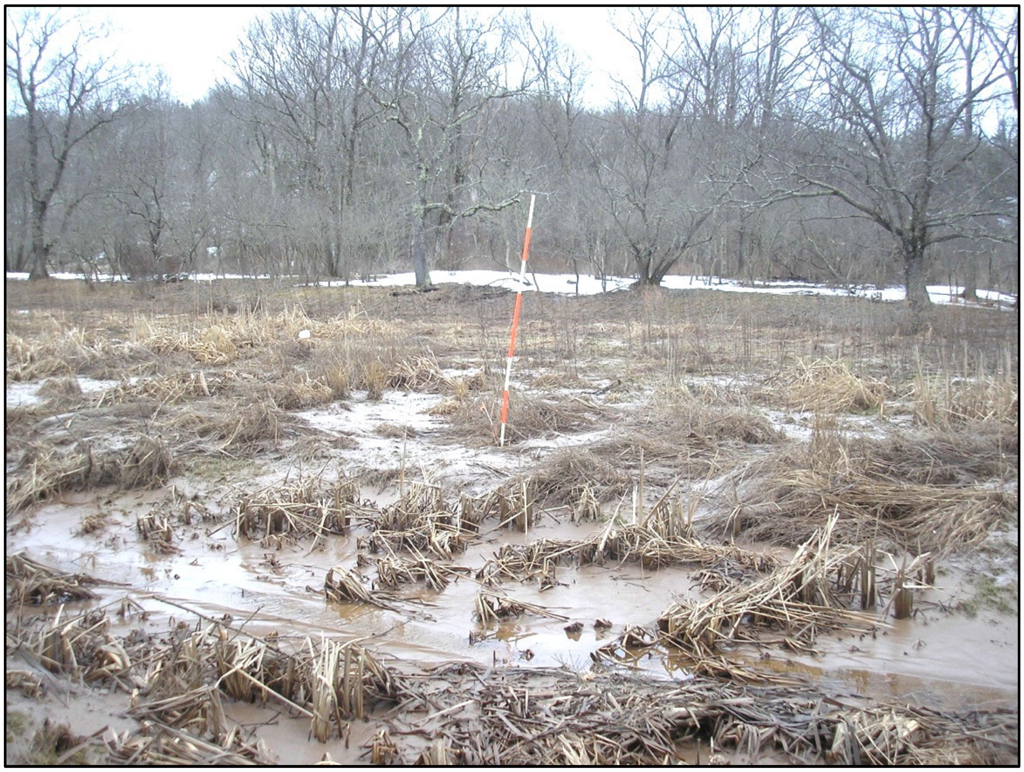


Figure 6 SCW Line 3.

Figure 7 SCW Line 5.

STRUCTURED WALK PHOTOGRAPHS SCE (select images):

Figure 8 SCE landscape.

STRUCTURED WALK PHOTOGRAPHS SCR (select images):

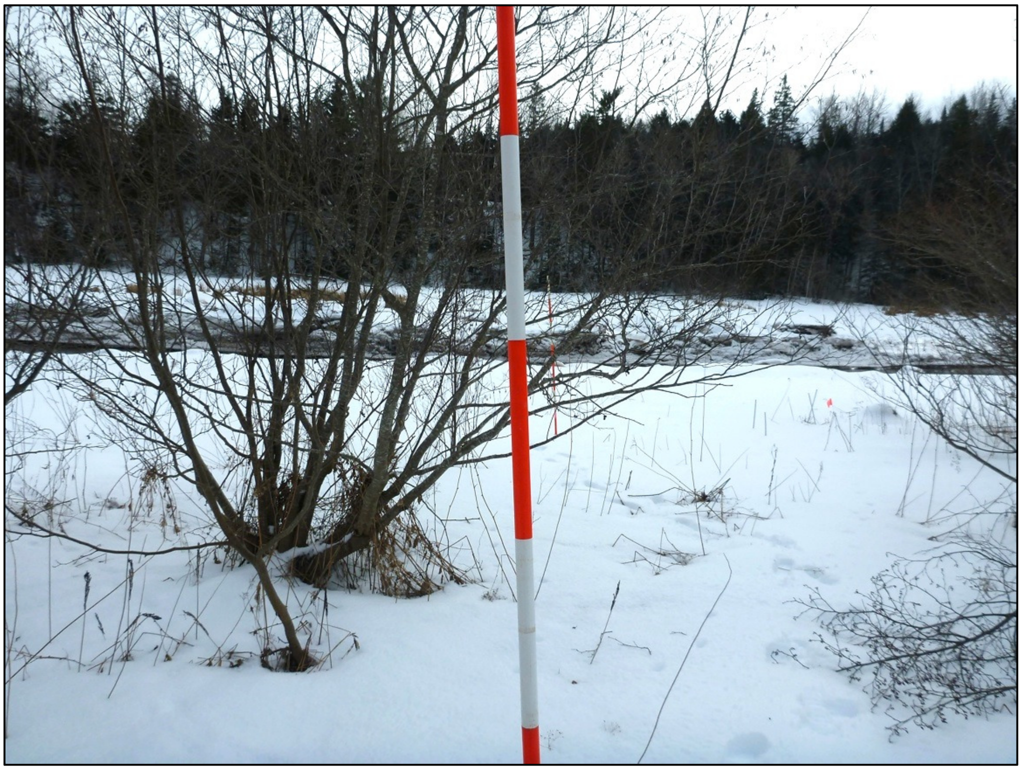


Figure 9 SCR Line 1.

Figure 10 SCR Line 4.