CB Wetlands &
Environmental Specialists

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

Post-Restoration Monitoring (Year 5) of the Smith Gut Salt Marsh Restoration Project

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March 2012
Publication No. 29

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Executive Summary

In August of 2006, the Nova Scotia Department of Transportation and Infrastructure Renewal (NSTIR) replaced the existing undersized and damaged culvert with three new, larger culverts in order to restore a more natural hydrological regime to the Smith Gut tidal wetland system. CBWES Inc. was commissioned to develop and implement a five-year post-restoration monitoring program as part of the Smith Gut Salt Marsh Restoration Project. The fifth (final) year of post-restoration monitoring took place during the period of June 2011 through December 2011 with a winter site visit conducted in March 2012.

The primary goals of NSTIR's restoration efforts at the Smith Gut Salt Marsh Restoration Project site were to:

- Significantly reduce the tidal restriction caused by causeway-culvert highway crossing;
- Improve hydrological conditions upstream of the causeway;
- Increase the extent and distribution of halophytic vegetation (tidal wetland area); and
- Improve fish passage to and within the wetland habitat upstream of the causeway.

To accomplish these goals, restoration activities at Smith Gut included the following components:

- Replacing the existing undersized culvert with three larger culverts to restore a more natural tidal regime to the system and to improve fish passage; and
- Conduct a pre- and post-restoration monitoring program to ensure project success.

The purpose of the monitoring program, and this years' phase of it, was to:

- Document the efficacy of the compensation being undertaken to restore the Smith Gut tidal wetland (salt marsh) system;
- Determine the nature, extent and direction of change, in the physical, chemical and biological indicators being studied, as a result of the restoration activity; and
- Document restoration progress and determine project success (restored marsh exhibits similar physical, chemical and biological characteristics as the reference site), by comparing the post-restoration habitat conditions to those that were present prior to restoration and to those of an adjacent reference site.

Data were collected over the five years following restoration for geospatial attributes, hydrology, soils and sediments, vegetation, nekton (fish) and benthic invertebrates at both the salt marsh restoration site (Smith Gut: SG) and a nearby reference site (Huggans Brook: SG-R). The information collected has not only provided insight into the changes to the site as a result of the restoration activities, but has contributed to our collective understanding of salt marsh ecology, and the effectiveness of restoration efforts in the region.

The results for the fifth (final) year of post-restoration monitoring are detailed in the following report and summarized below.

Geospatial Attributes

The Digital Elevation Model (DEM) for SG was updated using 2011 elevation survey data and low-altitude aerial photography. The improved resolution of the aerial imagery allowed for greater detail in habitat and channel delineation. Marsh surface elevation profiles for 2011 were higher than those of 2009, but still lower than the surface in 2007. This would suggest that the decreased elevation during the first three years following restoration, due to dewatering and consolidation of the marsh soils, was being offset by above ground (deposition) and below ground (build-up of organic matter) processes resulting in an increase in marsh surface elevation. A comparable change in marsh surface elevation at the reference site was not observed. Based on the 2011 data, the total restored wetland area was approximately 2.47 ha.

Hydrology

The highest recorded tide during the 2011 monitoring period was 2.13 m downstream and 2.18 m upstream of the causeway. This was over a half meter higher than the previously recorded highest tide. A tide elevation of 2 m would result in 100% of the study site (32,731 m^2; 3.2 ha) being under water. A tide such as the 30 September 2011 storm tide would not result in a larger area flooded, but rather a greater depth and duration of flooding. The 2.47 ha of restored wetland area would require a 1.1 m tide in order to flood (mean tide elevation for 2011 was 0.96 m). The updated hydrology and elevation data continue to show that the three culverts installed in 2006 do not represent a significant barrier to tidal flow.

Water Quality- Similar to previous years, there was little difference in the water quality conditions on either side of the causeway. Considering all years, the pH values recorded both upstream and down at SG, were at or just above the mean pH value for estuarine waters of 7.7. Water temperature was highly consistent for all years, and showed a consistent seasonal trend. Dissolved oxygen (DO) levels followed the expected trend of inverse relationship between DO levels and water temperature (ex. 2011: 23.2^{0}C and 3.37 mg/L and 7.71^{0}C and 20.18 mg/L). Salinity levels were within the mid to high range of brackish water across all years. With the exception of two sampling events, salinity readings were within the 15 ppt to 24 ppt range both upstream and downstream. With the elimination of the tidal restriction, the greatest influence on water quality was climate and seasonal conditions.

Soils and Sediments

Pore Water Salinity – In both 2008 and 2009 (Years 2 and 3), no significant difference was found between SG and SG-R. However, utilizing the 2011 data, a significant difference was detected between the two sites. No significant difference was detected between shallow and deep samples at SG in 2011, which was the opposite of what was found in 2009. Salinity levels at both sites generally fall within the low to mid- range (0 – 12 ppt), with SG-R having a more even distribution across the range categories including the higher range of 19-21 ppt. Over the five years following restoration, salinity levels have increased at SG, but continue to be lower than that of the reference site. The difference in mean salinity and in the range of salinities has decreased over time, bringing the two systems closer together. The continued differences between sites and between years is more likely due to natural variability between habitat conditions, climate and in the case of SG, beaver activity, rather than a failure of the restoration project.

Sediment Characteristics – In general, organic matter content increased with increasing distance from the tidal creek with the highest values at the upland sites in all years, and was found to increase at all stations from 2007 to 2009; however, values decreased between 2009 and 2011. Sediment samples with the highest and lowest water content values were associated with the highest and lowest organic matter content. As would be expected for a tidal marsh, bulk density decreased with increasing distance from the creek edge at both SG and SG-R. There was a slight decrease in bulk density between 2009 and 2011. The sediments at SG were slightly finer than those of SG-R and the post-restoration (2009, 2011) samples for both sites contained higher amounts of fines compared to earlier samples. Sediment characteristics over time indicate that SG is trending towards the conditions displayed at the reference site.

Vegetation

There were very few changes notable over time (between 2007 and 2011) in species composition, abundance and frequency. Species richness, halophyte richness and abundance were all consistently significantly higher at the reference site. The Non-metric multidimensional scaling ordination (NMDS) showed overall similarities across years between the two sites, and the plots of 2007 and 2011 showed that the restoration site has become more similar to the reference site over time. The main detectable difference between sites was that there were more plots at the reference site contained high marsh vegetation. Greatest change in species composition at SG largely occurred over the first two years following restoration and consisted of a loss of terrestrial species and an expansion of halophytes.

Nekton (fish)

Ten fish species and two crustaceans were captured at SG over the course of the five years of sampling. Species richness within the restoration site was equal to or greater than downstream for all years (except 2008). Species abundance was greatest the first year following restoration (2007). The decline in abundance over the five years following restoration has been observed at other restoration sites and is likely connected to changes in habitat conditions. *Fundulus heteroclitus* (mummichog) was the dominant fish species encountered upstream and downstream of the causeway; occupied >50% of the catch in all years. There appeared to be a trend towards larger (mature) individuals over time.

Benthic Invertebrates

Benthic Invertebrates: SG had moderate to high abundance and diversity and moderate to high biomass. Dominant species included the gastropod *Hydrobia totteni*, clams (*Macoma balthica* and *Mya arenaria),* polychaete worms (*Nereis diversicolor),* oligochaete worms, the amphipod *Corophium insidiosum,* and Tanaids, and chironomid (midge) larvae. The reference site had low to moderate diversity, abundance and biomass, dominated by the estuarine snail (*Hydrobia totteni)* and Hemiptera (Corixidae, water boatmen). Downstream samples had moderate to high abundance and diversity as well as high biomass of predominantly marine/ estuarine species, dominated by snails, clams and worms. Across all post-restoration sampling years, species richness and abundance was highest in the downstream samples and lowest in the reference. All three sites had a host of marine/estuarine species, but only the restoration site had significant representation by the larval stages of brackish/freshwater insects (diptera - chironomidae).

Aquatic Invertebrates: Samples from both sites typically contained a mix of estuarine, freshwater, planktonic, and meiofaunal and macrofaunal invertebrate animals and fish. Dominant species included freshwater insects (water boatmen, Corixidae), estuarine amphipods (*Gammarus tigrinus* and *Gammarus mucronatus*), with meiofaunal and planktonic types (ostracods and copepods: principally cyclopoid). The restoration site had lower species richness and abundance than reference site.

Summary

The results of the fifth (final) year of post-restoration monitoring of the SG salt marsh and tidal river restoration project were presented in this report. It was the intent of this monitoring program to provide a record of habitat conditions at both SG and SG-R, and to document the recovery of tidal wetland habitat conditions at the restoration site as a result of intervention.

Habitat changes in response to restoration, although more subtle than observed at other restoration sites in the province (Cheverie Creek and Walton River; Hants County), are continuing to occur at SG. The improved hydrology at SG has resulted not only in improving and increasing fish passage and access to the site, but has increased the frequency, extent and duration of tidal flooding of the full potential marsh area upstream of the causeway. The restoration and enhancement of tidal wetland conditions has, and will continue to, allow native and migratory salt marsh dependent species (i.e., plants, fish, invertebrates, birds, mammals) to be reestablished and/or to increase in number.

Further refinement of habitat mapping techniques and the incorporation of geo-referenced low-altitude aerial photography put the final estimate of restored wetland area at 2.47 ha. For a partially restricted site like SG, restoration of a more natural hydrological regime to the system resulted in the increase in the extent, duration and frequency of tidal inundation over the entire marsh surface, an increase in tidal wetland area and improved form and function of the entire wetland.

Overall, based on the changing biotic and abiotic (i.e., vegetation, soils) over time, SG is trending towards the conditions displayed at the reference site. The restoration site will continue to experience gradual change over time in response to the new hydrological regime. The restoration site will continue to retain some differences from the reference due to the relative positioning of the two sites within their respect estuaries and individual marsh morphology, rather than a failure of the restoration process.

Acknowledgements

We are indebted to Dr. Bob Pett (Nova Scotia Department of Transportation and Infrastructure Renewal) for championing projects such as this and our participation in them. We are also especially thankful to our mentors Dr. Danika van Proosdij and Dr. Jeremy Lundholm (Saint Mary's University - SMU), who have been and continue to be strong supporters of CBWES and partners on this project.

We wish to also thank Greg Baker (Maritime Provinces Spatial Analysis Research Centre (MP_SpARC) - SMU), Emma Poirier (Intertidal Coastal Sediment Transport (In_CoaST) Research Unit - SMU) and Patrick Stewart (Envirosphere Consultants Limited), for their assistance with data collection, sample processing, and data analysis.

Financial and in-kind supporters of this project include: Nova Scotia Department of Transportation and Infrastructure Renewal; Fisheries and Oceans Canada; Saint Mary's University (MP_SpARC; In_CoaST; Community-Based Environmental Monitoring Network); Nature Sciences and Engineering Research Council of Canada (NSERC); Nova Scotia Department of Economic and Rural Development; Human Resources and Skills Development Canada.

1.0 Introduction

In August 2006, the Nova Scotia Department of Transportation and Infrastructure Renewal (NSTIR) undertook construction activities to improve tidal flow to Smith Gut, an estuarine embayment of Merigomish Harbour, Pictou County, Nova Scotia (NS). The restoration of tidal flow, and ultimately of salt marsh habitat, to this site fulfills a compensation requirement (like-for-like estuarine habitat) noted in NSTIR's Harmful Alteration Disruption or Destruction (HADD) Compensation Proposal and Fisheries Act-Section 35(2) HADD Authorizations for the Lower Eel Creek and Sutherlands River Bridge Replacement Projects. Restoration activities consisted of the replacement of the existing tidally restrictive wooden box culvert (1.37 m X 1.52 m) with three round concrete culverts (2.1 m diameter), resulting in a five-fold increase in flow capacity.

A one year pre- and five years post-restoration monitoring of the physical and biological components of the Smith Gut salt marsh was a key component of the HADD Authorization. Fisheries and Oceans Gulf Region staff conducted the pre-restoration monitoring during the summer of 2006 prior to culvert replacement (Hulbert 2007).

CBWES Inc. was commissioned by NSTIR in the fall of 2006 to develop and implement the post-restoration monitoring program. In December of 2006, a digital elevation and hydrological survey were conducted by CBWES. Between June 2011 and March 2012, the fifth (final) year of post-restoration monitoring was carried out; the results of which are presented in this report.

The monitoring program utilized for the post-restoration monitoring was adopted and adapted from a set of regional protocols developed for use as part of tidal wetland restoration projects in the Gulf of Maine and Bay of Fundy (Neckles and Dionne 2000; Neckles et al. 2002). This was the same program utilized on six other salt marsh restoration and monitoring projects that NSTIR and its partners are engaged in throughout the province – Cheverie Creek, Walton River, Lawrencetown Lake, St. Croix River, Cogmagun River, and Three Fathom Harbour (Bowron et al. 2011a,b; Bowron et al. 2012a,b,c,d; Neatt et al. 2011; van Proosdij et al. 2010). Data were collected for geospatial attributes; hydrology, soils and sediments, vegetation, nekton, and benthic invertebrates on the restoration site as well as on a reference site.

1.1 Purpose of 2011 Study

The purpose of this project was to conduct the final year of the five-year post-restoration monitoring program for the Smith Gut Salt Marsh Restoration Project. The intent of the long-term monitoring program was to document the efficacy of the restoration being undertaken to restore tidal flow and tidal wetland habitat conditions to the system.

Salt marshes directly and indirectly support a wide range of commercial and recreational fish species through a range of functions including nursery and refuge areas for juvenile fish, feeding habitat for adult fish, primary production (plants) and the production of fish food (detritus, invertebrates). Salt marsh features associated with these functions include: existence of tidal streams and rivulets; providing access to the marsh surface and pannes for nekton; amount of marsh/water edge; and vegetation type and coverage.

In order to document restoration progress, facilitate adaptive management if required 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 assessed as part of this project included hydrology, soils and sediments, vegetation, nekton, and benthic invertebrates (Neckles et al. 2002). The changes in physical, chemical and biological indicators over the course of the post-restoration monitoring period were tracked against the conditions exhibited by the site prior to construction and to those of a reference site in order to determine restoration success.

All aspects of the post-restoration monitoring program 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, Ben Lemieux, Alison Bijman, and Christa Skinner with CBWES; Dr. Jeremy Lundholm, Dr. Danika van Proosdij, Greg Baker, and Emma Poirier with Saint Mary's University (SMU); and Heather Levy and Patrick Stewart (Envirosphere Consultants Limited).

1.2 CBWES Inc.

Since 2005, CBWES has been involved in the restoration and monitoring of nine salt marsh restoration projects in 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.

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 four of these projects. In 2009, an Industrial Undergraduate Student Research Award (IUSRA) enabled CBWES to hire a SMU undergraduate student to conduct a research project titled "The influence of soil seed bank on the colonization and restoration of a macro-tidal marsh". The resulting undergraduate thesis is available from the SMU library. In 2010, CBWES secured two two-year

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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, and Tennycape (Bowron et al. 2011a,b,c; Bowron et al. 2012a,b,c,d; CBCL 2011; Neatt et al. 2011; van Proosdij et al. 2010).
(CBWES reports available for download at www.gov.ns.ca/tran/enviroservices/enviroSaltMarsh.asp)

[2] 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). 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' 2007 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).

NSERC Industrial Postgraduate Scholarships to support post-graduate student research projects that are examining how surface morphology contributes to vegetative re-colonization following restoration, and developing a GIS-based model and protocol for use in the design of tidal wetland restoration projects in macro-tidal environments. A second IUSRA was received in 2011 to support a project exploring the influence of tidal creek networks on wetland vegetation colonization in a macro-tidal system. Summaries of these salt marsh restoration research projects, as well as the non-NSERC funded current and completed projects are provided in Appendix A.

In 2009, a peer-reviewed paper on the Cheverie Creek Salt Marsh Restoration Project titled "*Macro-Tidal Salt Marsh Ecosystem Response to Culvert Expansion*" was published in *Restoration Ecology* (Bowron et al. 2011a). A paper on the Walton River Restoration Project titled *Ecological Re-engineering of a Freshwater Impoundment for Salt Marsh Restoration in a Hypertidal System* appeared in the journal *Ecological Engineering* (van Proosdij et al. 2010). A book chapter titled "Chapter 14 – Salt Marsh Tidal Restoration in Canada's Maritime Provinces" has been submitted for peer-reviewed publication in the book *Restoring Tidal Flow to Salt Marshes: A Synthesis of Science and Management* (Roman and Burdick In Press). Plans are underway to produce additional peer-reviewed publications during the coming year in order to continue to share the lessons learned from these projects.

1.3 Report Organization

The focus of this report was to describe the 2011 monitoring activities and to complete the process of comparing the post-restoration habitat conditions to the conditions that were present prior to culvert replacement and to those exhibited by the reference site.

Information on the study site, the reference site and an overview of the monitoring program are provided in Chapter 2 (section 2.3). The parameter specific sampling techniques are given for each indicator category in Chapter 3. The results of the fifth 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 success. Chapter 6 contains information and recommendations for consideration in future tidal wetland restoration design and monitoring projects. Appendices provide: (A) Summary of CBWES-supported student research projects; (B) Photographs from the 2012 structured winter site walk.

2.0 Study Sites and Monitoring Program

2.1 Smith Gut Restoration Site

Smith Brook is a tributary to Merigomish Harbour near Lower Barneys River in Pictou County (62° 35′ 89.75″N, 45° 65′ 93.48″W) (Figure 1 and 2). NS Route 245 crosses Smith Gut (SG), the lower tidal component of the system, via a 50 m long causeway. Previous to the installation of three 2.1 m diameter culverts in 2006, a single wooden box-culvert (1.37 m wide by 1.52 m high) on the western end of the causeway, restricted tidal flow and fish to the upstream component of the system, including an area of approximately 2.3 ha of potential tidal wetland habitat immediately upstream of the causeway (Bowron et al. 2008b). Photographs from the causeway looking upstream (Figure 3), downstream (Figure 4) and of the new culverts (Figure 5 and 6) are provided below.

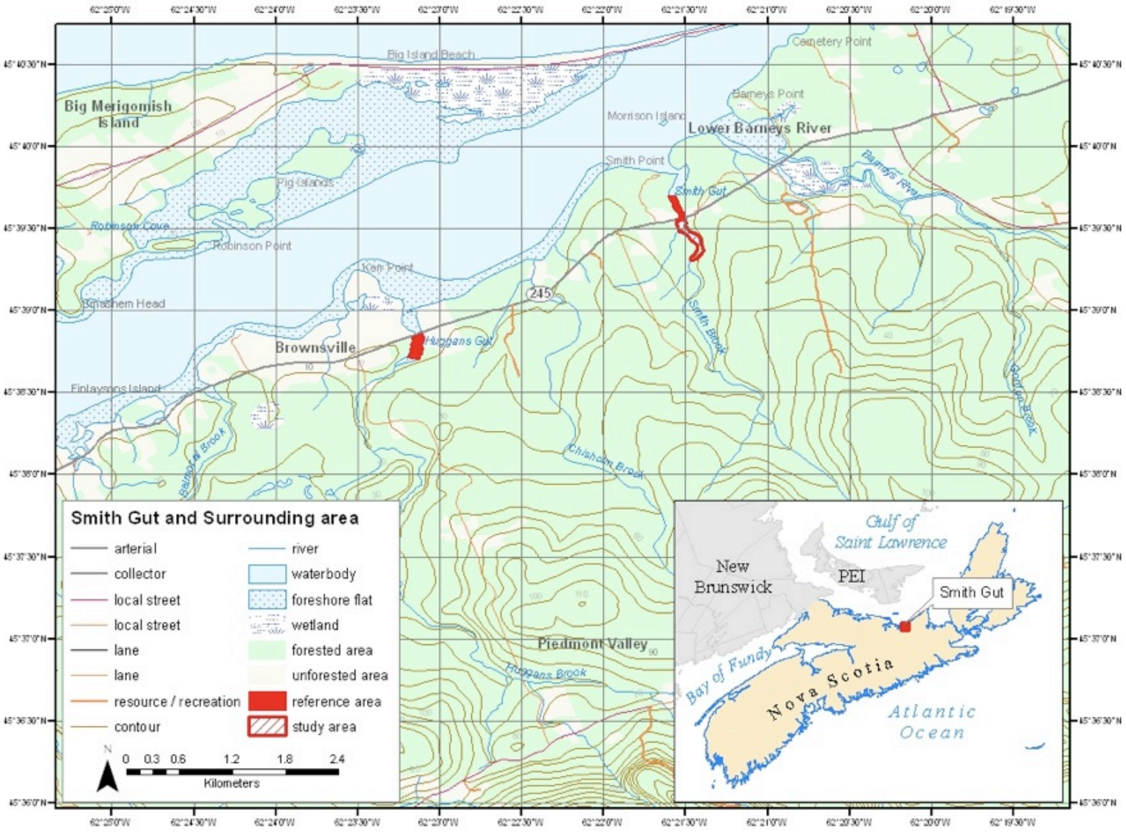

Figure 1 Location of Smith Gut (restoration site) and Huggans Brook (reference site) Pictou County, Nova Scotia (base map downloaded from: www.geogratis.ca/geogratis/en/product/search.do?id=28954).

Figure 2 Aerial photograph (1997; 1:10 000) of Smith Gut Salt Marsh Restoration Site (black box). The reference site was located 2.5 km west of the restoration site (red arrow).

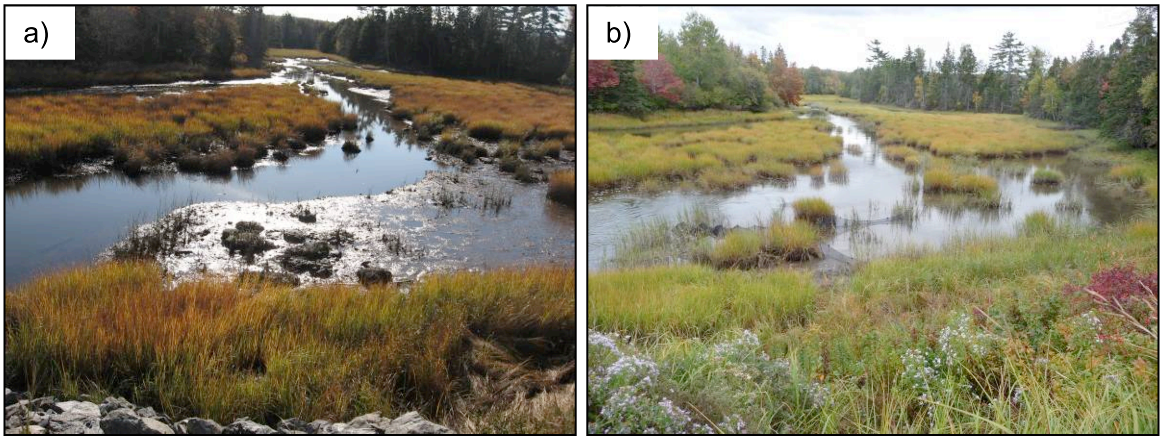

Figure 3 Photograph of SG upstream of the causeway a) 31 October 2007 (low tide) and b) 6 October 2009 (rising tide) taken from the causeway. Photographs by T. Bowron.

Figure 4 SG downstream of the causeway rising tide. Photograph by T. Bowron, 6 October 2009.

Figure 5 The three concrete culverts installed at SG in 2006 (downstream). Photograph was taken at low tide, when water only flows through one of the three structures (culvert in the fore ground). Photograph by T. Bowron, 2007. The inserted picture is of the original culvert, taken 2 May 2006, courtesy of Dr. Bob Pett.

Figure 6 The three culverts installed at SG in 2006 (Upstream). Photograph by T. Bowron, 11 March 2010.

2.2 Smith Gut Reference Site

Two sites were identified for use as reference condition sites for the SG project. The 300 m area immediately downstream of the causeway (1.43 ha) was used as a reference for hydrology (tidal signal, elevation, water quality) and nekton. Huggans Brook (SG-R) is an unrestricted tidal river and salt marsh system located in Brownsville, approximately 2.5 km west of SG (62^0 38' 54.43" N 45^0 64' 77.05" W) (Figures 1 and 2). As with SG, Route 245 crosses the river near its mouth. However, unlike the crossing at SG, the SG-R crossing is a combination causeway-bridge structure, whereby the bridge section spans the width of the main river channel (Figure 8). Being similar in structure and spatial extent as SG, the area (2.64 ha) immediately upstream of the causeway-bridge was identified as a suitable reference for soils and sediments and vegetation. SG-R does differ from SG in that the tidal channel at SG-R consists of a distinct central channel that meanders through the system, which is largely one contiguous marsh surface (Figure 7). The tidal channel at SG is less distinct and much of the marsh surface is comprised a series of vegetated islands (Figures 3 and 9).

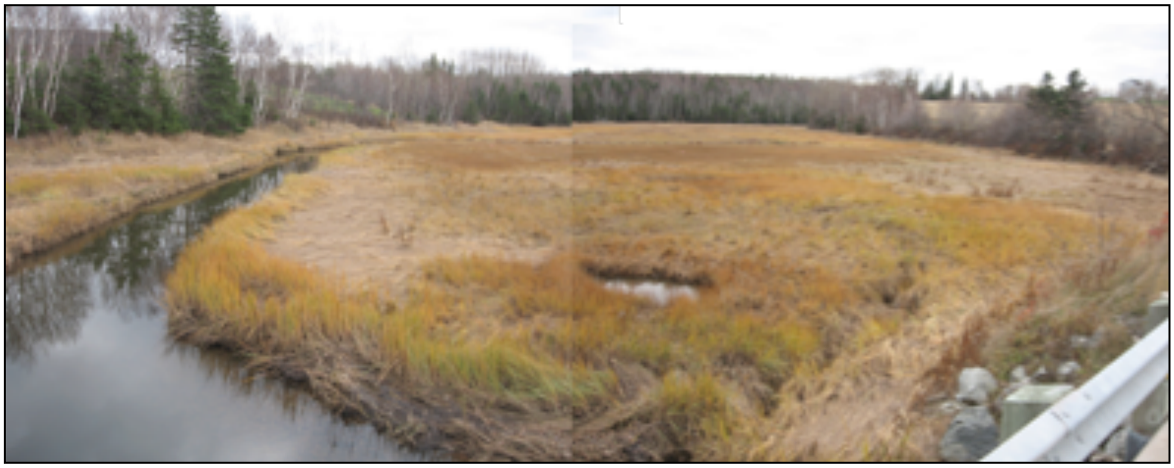

Figure 7 Photograph of Huggans Brook, looking upstream from the bridge. Photograph by T. Bowron, 2007.

Figure 8 Huggans Brook causeway-bridge tidal crossing. Photograph by T. Bowron, 2007.

Figure 9 Indistinct tidal channel at SG and series of salt marsh "islands" that comprise much of the front half of the salt marsh. Photograph by T. Bowron, 3 June 2009.

2.3 Monitoring Program

The SG post-restoration monitoring program (program) was developed based on the Global Programme of Action Coalition for the Gulf of Maine's Regional Monitoring Program (GPAC Protocol) (Neckles and Dionne 2000; Neckles et al. 2002) and on experience with similar restoration projects in the region (Bowron et al. 2011a; van Proosdij et al. 2010). The SG program expanded on the pre-restoration monitoring work that was completed by DFO in 2006 (Hulburt 2007), incorporating a wider range of biotic and abiotic factors, improved sampling techniques, sampling intensity, and statistical analysis, and the inclusion of an additional reference site. The modifications that were made for the post-restoration phase of the project were made in order to bring the monitoring activities of this project into parity with similar estuarine restoration projects occurring elsewhere in the province (Bowron et al. 2011a;b; Bowron et al. 2012a,b,c,d; CBCL 2011; Neatt et al. 2011; van Proosdij et al. 2010). For most of the parameters, due to the limited amount and usability of the pre-restoration data, much of the analysis and comparison of habitat conditions in this report focused mainly on the comparison between post-restoration years and reference site conditions.

The program involved five years post-restoration of data collection for a series of physical and biological parameters within the ecological indicator categories of hydrology (Neckles et al. 2002), soils and sediments (Neckles et al. 2002; Roman et al. 2001; van Proosdij et al. 2006), vegetation (Carlisle et al. 2002; Roman et al. 2001), fish (Dionne et al. 1999; Weldon et al. 2005) and invertebrates. These indicators are measures of wetland structure and function, which when applied pre- and post-restoration collectively provide information on ecosystem status and response to restoration. The indicator categories, physical and biological parameters, and data collection methods are described in Table 1.

Table 1 The Smith Gut Salt Marsh Restoration monitoring program, including ecological indicator categories, parameters, methodologies, and sampling frequency (X – completed sampling event at both sites; S – completed sample event at restoration site; H – completed sampling event at reference site; and Y – proposed future sampling event).

Category	Parameters	Sampling Method	Annual Sampling Frequency	Post-Restoration (2007-2011)				
				1	2	3	4	5
Hydrology	Tidal Signal	Automated water level recorders (5 minute intervals) (Solinst Levelogger (Model 3001) Minimum of three week sampling period	24/6/07 to 25/7/07 24/11/09 to 15/12/09 21/9/11 to 29/11/11	S		S		S
	Water Quality	YSI 650 MDS (with YSI 600QS sonde) and YSI 556 MPS pH Handheld Dissolved Oxygen Instruments[3] Matched with nekton sampling events	3/7/07; 25/9/07; 31/10/07; 7/08; 9/08; 10/08; 07/09; 10/09; 5/7/11; 28/10/11	S	S	S		S
Soils & Sediments	Marsh Surface Elevation	Digital elevation model (DEM). Total Station; Differential and RTK GPS	SG: 12/06; 11/09 SG-R: 11/07; 11/09; 30/5/11 (SG); 25/7/11 (SG-R)	H		X		X
	Pore Water Salinity	Sipper; Refractometer (2007 – 2009) FieldScout EC 110 Meter	SG & SG-R monthly from 7/07 to 9/07; 7/08 to 09/08; 6/09 to 9/09; 6/11 to 9/11	X	X	X		X
	Sediment Characteristics (bulk density, organic matter content, sediment type)	Sediment cores (soil samples): Paired samples: (30 ml cut syringe w/ 5 cm x 15 cm core).	SG: 6 paired samples SG-R: 6 paired samples 11/07; 6/09; 29/11/11	X		X		X
Vegetation	Composition	Point Intercept method (1 m^2 plots) Annually SG: 20 plots; SG-R: 21 plots	8/07; 8/08; 8/09; 25&26/8/11	X	X	X		X
	Abundance							
	Height							
	Habitat map	Aerial photograph, DGPS & RTK GPS, Total Station, low-level aerial photography (blimp); GIS	Once per sampling year	X		X	S	S

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[3] www.ysi.com

Category	Parameters	Sampling Method	Annual Sampling Frequency	Post-Restoration (2007-2011)				
				1	2	3	4	5
Nekton	Composition	Minnow traps in main channel: 2 upstream & 2 downstream (small fish); beach seine (upstream/downstream) and fyke net (upstream) on marsh surface (all sizes). Spring tide.	3/7/07; 25/09/07; 31/10/07; 24/7/08; 30/9/08; 14/10/08; 24/7/09; 6/10/09 5/7/11; 28/10/11	S	S	S		S
	Species richness							
	Density							
	Length							
Benthic & Other Aquatic Invertebrates	Abundance and species richness (benthic)	Ekman Dredge (Bulk samples) Once per year SG: 4 samples; SG-DS: 2 samples; SG-R: 2 samples	10/07; 9/08; 09/09; 21/9/11	X	X	X		X
	Abundance and species richness (aquatic) (pannes)	Invertebrate Activity Traps (IAT) SG & SG-R: 2 traps each	7/08; 7/09; 08/09; 25/7/11; 25/8/11	X	X	X		X
Winter Conditions	Ice/snow conditions	Structured winter walk; photographs along each transect Appendix B Annually (January to early March)	21/3/08; 11/2/09; 11/3/10; 20/3/11; 24/3/12	X	X	X	X	X

3.0 Methods

Sampling was conducted at both the restoration and reference site using transects established in a non-biased, systematic sampling design. Six transects, 75 m apart running perpendicular to the main river channel and marked along the upland edge by two permanent wooden stakes, were established at SG (Figure 10). Three transects were established downstream of the causeway (not shown) and another five on SG-R (Figure 11). A combination of 100 m field tape, compass, Trimble R8 GNSS Real Time Kinematic (RTK) Global Positioning System (GPS) surveying system[4] and Leica TCR-705 Total Station[5] were employed to produce and digitally map straight, reproducible transects. Data collection was conducted at sampling stations established at equal intervals along transects at each site.

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[4] www.trimble.com/index.aspx

[5] www.leica-geosystems.com/corporate/en/lgs_405.htm

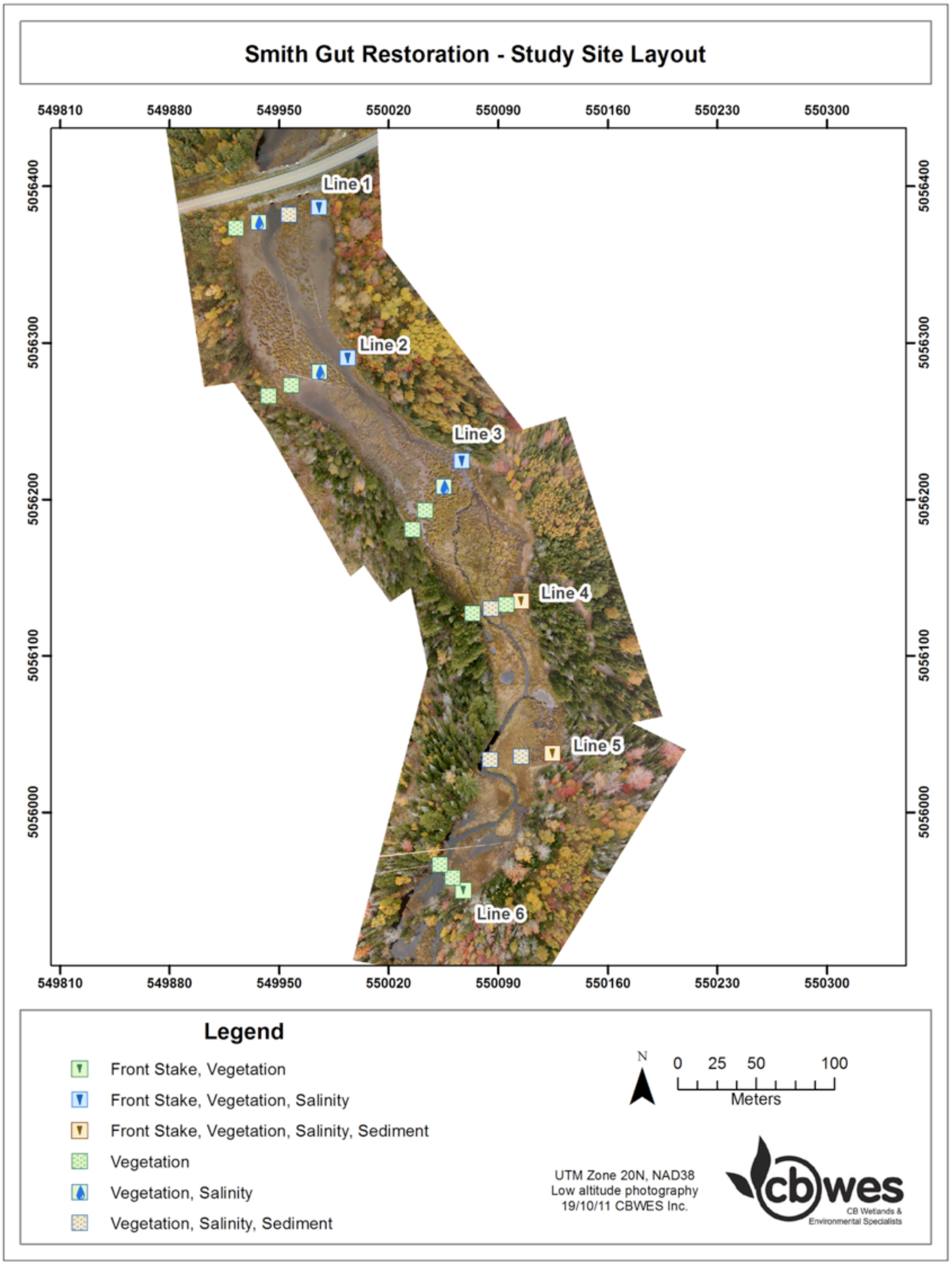

Figure 10 Sample design and layout map overlaid on the 2011 low-altitude aerial photograph for SG (main marsh features, transects, and sampling locations).

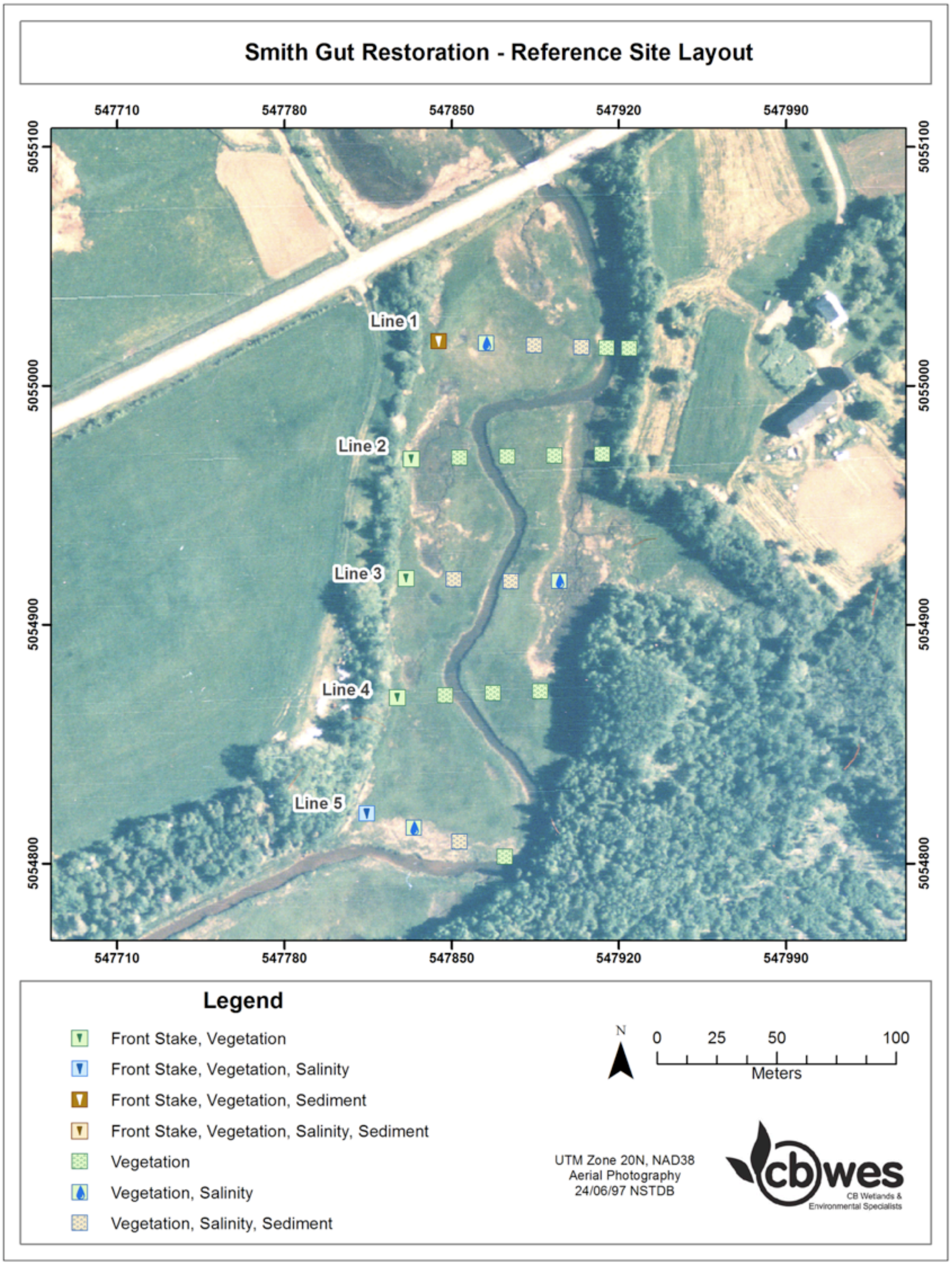

Figure 11 Sample design and layout map for SG-R (marsh features, transects and sampling stations).

3.1 Geospatial Attributes: Digital Elevation Model and Habitat Map

The original habitat map and DEM for SG and SG-R were developed using the 1997 and 2007 (SG and SG-R respectively) 1:10,000 aerial photographs and on-site surveys (Bowron and Neatt 2007) and have been updated as conditions at the respective sites changed and additional mapping activities were undertaken each year following restoration. The 2006 DEM was used for the initial estimate of restorable area (approximately 0.6 ha), while the habitat map provided a foundation for monitoring activities and a visual record of changes in habitat conditions following restoration.

Habitat maps (surface cover) were also generated to document vegetation community structure and other important habitat features identified from provincial air photographs, on-site surveys, and low-altitude aerial photography that was conducted in both 2010 and 2012. The low-altitude photographs were taken from a small format aerial photographic platform using a helium filled blimp with a suspended camera (Canon Eos Rebel XSi[6]) and lens system (Canon EFS 10-22 mm ultra wide zoom[7]) controlled by an operator on the ground using a remote control (Figure 12). The system was similar to other platforms used to map vegetation change on wetlands (eg: Miyamoto et al. 2004; Aber et al. 2008). The resulting orthorectified image mosaic was used as the base layer for the maps.

Through the use of a series of ground control points (GCP; Figure 13; Aber et al. 2010) at known locations and target signals, which help identify GCPs on the aerial photographs, a series of site images were captured. Following post-processing to correct for lens distortion, imagines were geo-referenced using orthorectification techniques to create a single mosaic image.

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[6] http://www.canon.ca/inetCA/products?m=gp&pid=897

[7] http://www.canon.ca/inetCA/products?m=gp&pid=2298

Figure 12 The CBWES-SMU helium blimp and remote operated suspended camera system used to capture low-altitude geo-referenced air photographs. Photograph by T. Bowron, September 2010.

Figure 13 A deployed ground control point (GCP). Photograph by T. Bowron, September 2010.

3.2 Hydrology

The fundamental control on the structure and function of salt marsh habitat is flooding with salt water (Mitsch and Gosselink 1986; Neckles and Dionne 2000). It is the hydroperiod (frequency and duration of tidal flooding) of a salt marsh that determines the area of marsh directly available as fish habitat. The hydroperiod of a salt marsh is determined by the tidal signal (pattern of water level change with respect to a reference point) and marsh surface elevation.

When attempting to understand changes in vegetation, water table level can be a valuable parameter to monitor as it provides information on the degree of waterlogging or drainage that is occurring on a marsh (Roman et al. 2001). Surface water quality (salinity, dissolved oxygen, pH and temperature) of flood waters can also influence the diversity, distribution and abundance of plants and animals in a salt marsh.

Hydroperiod and Tidal Signal

The hydroperiod (frequency and duration of tidal flooding) was modeled using the 2011 tidal signal data (pattern of water level change with reference to a fixed point) and the marsh surface elevation (DEM) and presented as a hypsometric curve (Figure 27). The tidal signal upstream and downstream of the causeway was measured using a pair of Solinst Model 3001 Levelogger Golds and a Solinst Barologger[8] (Figure 12). One Levelogger was installed (in a still well) in the main river channel downstream of the causeway, while the second Levelogger was installed within the river channel in line with the first transect on the upstream side (Figure 10). Both Leveloggers were installed below the low tide line in order to ensure that they would remain submerged at all times during sampling. The Barologger was installed in the woods, well above the high tide line, on the west side of the restoration site.

The Leveloggers and Barologger were deployed on 21 September 2011 and retrieved 29 November 2011 (9 weeks) in order to capture tide levels throughout at least one neap to spring tide cycle. The Leveloggers were programmed to collect both water level and water temperature at five-minute intervals. The Barologger was programmed to collect atmospheric pressure and temperature simultaneously with the Leveloggers. At the time of retrieval, the positions (elevation) of the Leveloggers were surveyed using the RTK GPS. Using the tidal elevation information from the Levelogger, a tide signal graph was created in MS Excel. The hypsometric curves for SG were created using the flood metrics extension in ArcGIS. The extension calculates the area of marsh flooded at a given tide height using a DEM provided by the user. In this case, increments of 10 cm were used and a scatter plot was created in MS Excel. This data was also used to identify the submerged marsh area associated with the highest, lowest and mean tides recorded during the time of deployment.

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[8] www.solinst.com/Prod/3001/3001.html

Figure 14 Solinst Levelogger (model 3001) on the left and still well on the right. Photographs by N. Neatt, 2007.

Water Quality

For the 2011 field season, a YSI 650MDS display datalogger and the YSI 600QS sonde were 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 readings were taken per sampling event within thirty minutes of peak tide (spring tide). Sampling was matched with beach seine sampling for nekton. The YSI probe was submerged approximately at mid-depth in the vicinity of the nekton sample area.

3.3 Soils and Sediments

Monitoring pore water salinity, marsh surface elevation and soil characteristics can provide insight into the processes controlling vegetation type, cover and productivity and the vertical growth of a marsh following restoration (Neckles and Dionne 2000). Soil salinity (interstitial pore water salinity) is one of the main controls on the distribution and abundance of plant species in salt marshes (Niering and Warren 1980).

The accretion of inorganic and organic material on and within the marsh surface is one of the main processes that allow marshes to build vertically over time, offsetting increases in 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 changes in marsh surface elevation and determining organic content of marsh soils prior to engaging in restoration activities can reveal insights regarding pre-restoration conditions on the marsh (subsidence due to oxidation of organic matter in sediments) and the process of recovery following restoration.

Marsh soil characteristics are determined by the sediment source and tidal current patterns (Mitsch and Gosselink 1986). As tidal waters flow over the marsh surface, increasing elevation and vegetation slows the water allowing coarse-grained sediment to drop out of suspension close to the main channel edge while finer sediments drop further inland (Redfield 1972; Mitsch and Gosselink 1986). 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 1986). 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).

Determining interstial pore water quality, elevation and soil characteristics can provide insight into the processes controlling vegetation type, cover, and productivity and the vertical growth of the marsh following restoration.

Pore Water Salinity

Sampling locations for interstitial pore water salinity were matched with a subset of vegetation sampling stations upstream at SG and SG-R (Figures 10 and 11). Prior to the 2001 field season, samples at each of the nine locations at SG and five at SG-R, both a shallow (15 cm) and a deep (45 cm) pore water sample were taken using a soil probe (sipper). The sipper was constructed according to the design specifications outlined in Roman et al. (2001). Samples were taken by sequentially inserting the sipper into the soil to the target depth and drawing out a water sample. Due to the high sediment concentration of water samples collected by the sipper, samples were bottled and returned to the lab and allowed time for the sediment to settle out before a refractometer (nearest 2 ppt) reading was taken. For the 2011 monitoring season, a FieldScout EC 110 Meter[9] was used to collect the data on pore water salinity (shallow and deep readings). Data was collected using both methods for two consecutive sampling events ("double read") in order to ensure consistency and minimize sampling error. When using the FieldScout EC 110 Meter, measurements were taken *in situ*, and readings recorded in the field.

Pore water salinity at both locations was conducted on 23 June, 25 July, 25 August and 21 September 2011. For both SG and SG-R descriptive statistics, including mean, range, and standard error were calculated for shallow and deep salinity samples. These statistics were used to create bar graphs to illustrate temporal patterns. Pore water salinity was not sampled in 2006, so a pre- versus post-restoration comparison was not possible. For tests comparing salinity levels between SG and SG-R (shallow samples, deep samples, and all samples) a two-sample test was run, assuming unequal variances. For tests comparing shallow to deep samples a paired two-sample test was performed. All t-tests were run at a 95% confidence interval ($p<0.05$) in Excel software.

Marsh Surface Elevation Change

The DEM for SG and SG-R was completed in December 2006 and updated with additional transect data in 2007 and 2009 (Bowron et al. 2008b; Bowron et al. 2010). Both sites were re-surveyed in 2011 and a new DEM was completed for each site. The change in elevation over the five years post-restoration was examined by comparing the elevation profiles for each transect as well as the change in elevation for each sampling station. The results of this comparison are presented in Section 4.1.

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[9] http://www.specmeters.com/brands/field-scout/ec110/

Sediment Characteristics

Field Methods

Six paired sediment samples were collected at both SG and SG-R. Sampling locations were paired with soil salinity and vegetation plots and selected to represent the different target habitat zones (low, mid and high marsh).

At each sampling station two sediment samples (cores) were taken. A small (30 ml) sample was taken using a 60 ml plastic syringe (1” diameter) (with the end cut off) and a larger sample taken with a metal tube (4” long and 1½ ” diameter). Samples were taken by pressing the syringe into the soil to the 30 ml depth and removed by cutting around the syringe with a knife and lifting out with a metal trowel. The metal tubes were pressed into the ground until the top of the tube was level with the marsh surface and removed using a knife and trowel.

The syringes were placed individually into Ziploc bags, sealed, labeled and transported in a cooler with ice back to the lab where they were placed in a freezer and frozen. Some soil compaction did occur during the coring process, but every attempt was made to avoid further compaction of the samples during transport and storage prior to freezing. The metal tubes were capped on both ends using plastic caps, bagged and labeled. Some compaction did occur during the sampling process but no further compaction/disruption should have occurred prior to the samples freezing. All cores were carefully labeled and sealed using duct tape.

Laboratory Methods

Sediment samples were analyzed by the Intertidal Coastal Sediment Transport Research Unit (In_CoaST) at SMU for organic content using loss on ignition and water content using ‘standard’ protocols as published in the literature.

Sample preparation and documentation: The sediment cores were thawed before being extruded from their containers. The samples were photographed and split open to see the color, texture and composition of the core for a qualitative description.

Organic content (using a loss-on-ignition technique): The sediment cores were thawed and removed from the tubes and a known volume of the core was removed, weighed and placed in a crucible for drying at 105 ˚C for 24 hours to determine water content. Once dried, each sample was weighed and placed in a muffle furnace for two hours at 550 ˚C. Samples were then cooled and weighed again to get loss on ignition (LOI) of organic material.

Bulk Density: Dry bulk density was determined from a known volume of material extruded from the syringe cores. Wet samples were weighed and dried at 105 ˚C for 24 hrs, cooled and dry weight determined. The dry weight was divided by the volume to determine dry bulk density.

Analysis

Dr. Danika van Proosdij (SMU) conducted the organic matter content, water content and bulk density analysis and prepared the results and discussion presented below.

3.4 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 the salt 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 marsh vegetation community at SG and SG-R were surveyed using permanent 1 m^2 plots positioned at equal intervals (20 m starting from front stake with last plot 0.5 m from edge of river channel) along each transect. A total of twenty plots were originally established at SG and twenty-one plots at SG-R. Landscape photographs were taken along each transect, as well as close-up photographs of each plot. Species composition, abundance and height (of dominant species) were determined within each plot using a point intercept method (Roman et al. 2001). The 2011 vegetation survey was conducted on 25/26 August.

Each 1 m^2 plot (quadrat) used was offset 1 m to the left of the transect (facing main tidal channel) and oriented towards the upland end of the transect. The quadrat was divided into a grid of 25 squares (20 cm x 20 cm) and the resulting 25 intercept points were used as sampling points. All plant species present in a plot were recorded and then a wooden dowel (3 mm diameter, 1 m length) was held vertical to the first intercept point and lowered through the vegetation to the ground below. Any species that touched the rod (a "hit") were recorded. This was repeated for all 25 intercept points. Other categories, such as water, bare ground, rock or debris, were also recorded if hit by the dowel.

Statistical Methods

Plant species richness, halophytic species and abundance, and unvegetated area in 1 m^2 plots were compared between the study (SG) and reference (SG-R) sites across three years using repeated measures ANOVA. Halophytic species abundance was estimated as the total number of contact points by halophytic species per plot. Species found at these sites classified as halophytic are: *Atriplex glabrisculata*, *Carex palacea*, *Glaux maritima*, *Juncus gerardii*, *Potentilla anserina*, *Spartina alterniflora*, and *S. patens*.

Because the total number of hits was counted, this can result in a halophytic abundance of greater than 25 (the number of points sampled in each quadrat) when more than one halophytic species were present in the plot. Non-metric multidimensional scaling ordination (NMDS) was used to compare species composition and abundance between plots. Differences in overall vegetation composition and species abundance among plots were assessed using non-parametric multivariate ANOVA. Site-level summaries for mean abundance of each species and frequency of each species are presented in table format. Mean abundance allows us to detect changes in biomass or productivity (measured by the average number of contact points/m^2) whereas frequency allows us to detect changes in spatial extent for each species.

3.5 Nekton

Salt marshes 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).

Nekton, specifically fish, are central to the purpose of this project – the restoration of fish habitat. However, they are a challenging group to quantify due to their mobility and temporal variability, as well as the difficulties of sampling in, what can be, a heavily vegetated environment with a varied hydrological regime. Two species commonly found in salt marsh habitats are the mummichog (*Fundulus heteroclitus*) and Atlantic silverside (*Menidia menidia*). The mummichog or salt water minnow is a resident of salt marshes and Atlantic silversides are known to swim into salt marshes at high tide searching for food, and both are prey for larger fish within the tidal rivers and salt marshes during high tide (Gibson 2003). Similar to mummichogs, the *S. alterniflora* dominated low marsh areas of salt marshes is one of the substrates Atlantic silversides use for reproduction (egg attachment) (Fay et al. 1983). Atlantic silversides may also be important exporters of secondary production and biomass from marsh and estuarine systems to offshore areas as they usually die after spawning or during their second winter of life (Fay et al. 1983).

A combination of a beach seine, fyke net and a set of four minnow traps were used to sample fish species on the marsh surface and tidal channel during spring tide events. Smaller species accessing the marsh surface and salt pannes were sampled using the minnow traps baited with bread. The traps were deployed (two upstream and two downstream) in advance of high tide and retrieved once the tide level had dropped (approximately 3.5 hours).

Sampling with the beach seine was conducted according to the methodology developed and used by the Community Aquatic Monitoring Project (CAMP; Weldon et al. 2005). This method allowed for the sampling of an area approximately 225 m^2 per draw, achieved by walking the beach seine out 15 m perpendicular to the shore, then 15 m parallel to the shore and returning the entire seine to the shore. Between two and three sampling events per site per year (summer and fall) were conducted during a spring tide, allowing for a minimum of two draws of the beach seine. This sampling method requires a spring tide to ensure adequate depth and duration of flooding of the marsh surface. As in the previous year, the beach seine was modified to 15 m total length due to site conditions and area constraints (Hulbert 2007). The area fished by the modified seine was approximately 56 m^2. Sampling locations are indicated in Figure 16.

The fyke net design and [modified] methodology was taken from Dionne et al. (1999). A single net was set at low tide and retrieved following high tide once the water level dropped low enough to approach the net while still ensuring the cod end remained submerged. The fyke net, which samples for all species and size ranges of fish utilizing the marsh surface, enables sampling over a greater range (approximately three hours) of the high tide cycle, not just the peak as with the beach seine, and locations not accessible to other methods. The fyke net was deployed at a different location on the marsh surface each sampling event (Figure 16).

Sampling with all three methods took place on 5 July 2011 and 28 October 2011. All captured specimens were placed in a plastic storage tote, identified to species using identification guides (Audubon Society 1993; Graff and Middleton 2002; Scott and Scott 1988), counted, and measured for length (15 individuals per species). A representative of each unknown species was retained for identification purposes, while all remaining individuals were returned to the site of capture.

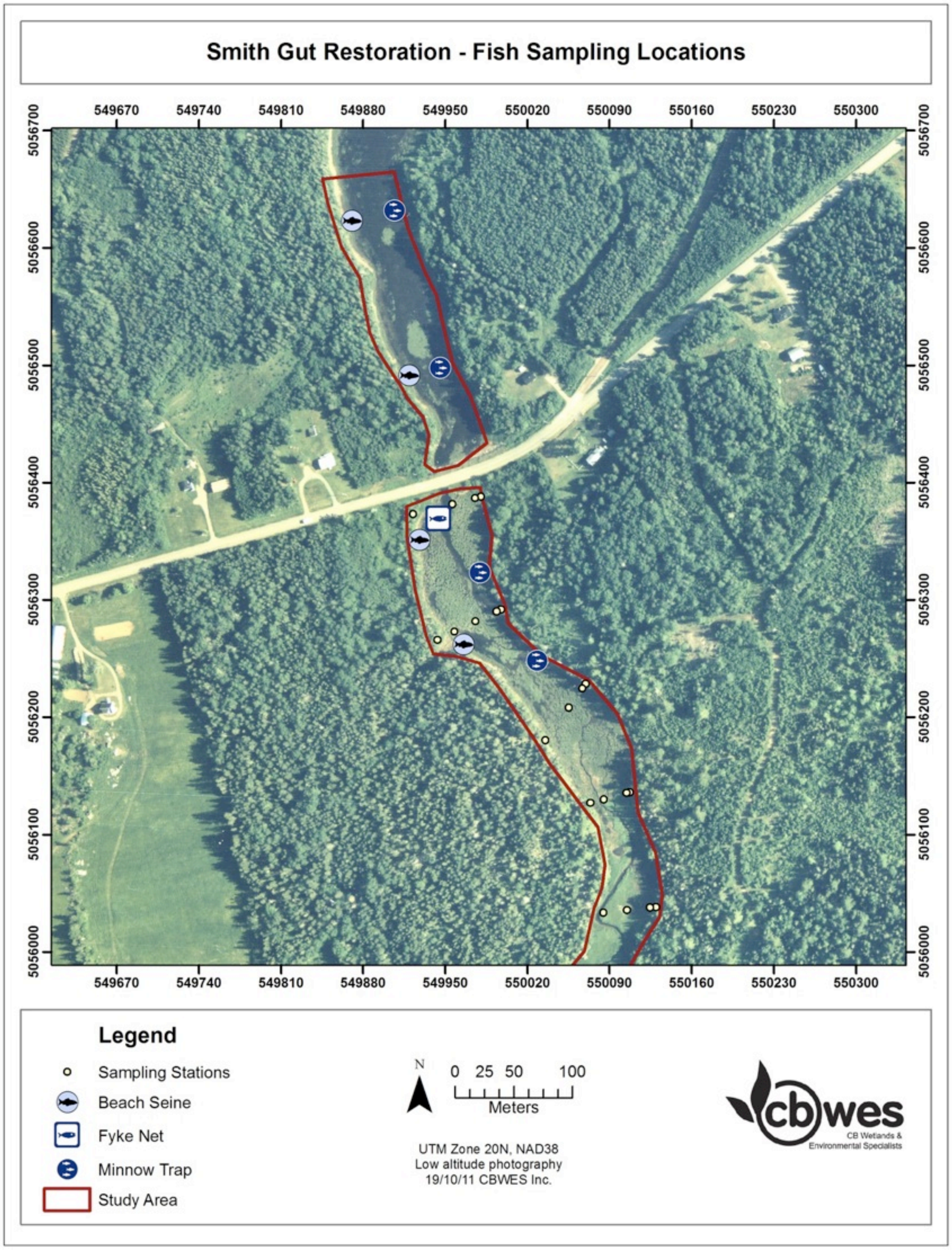

Figure 15 Location of 2011 fish sampling events.

Figure 16 Sampling with the fyke at the Walton River Restoration Site. Photograph by T. Bowron 2008.

3.6 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/).

Field Methods

Benthic Invertebrates

Benthic invertebrate samples were taken using a standard 6” x 6” Ekman Dredge (0.023 m^2 sediment sample) (Figure 17). Samples were analyzed for biological species composition and abundance. Six samples were taken at SG and two at SG-R on 21 September 2011. Sampling locations at SG were divided between downstream (river channel at L2 and L3) and upstream (L1, L3, and L5 river channel and L5 salt panne). The samples at SG-R were both taken along L3 with one taken from a salt panne and the other from the channel. Samples from the river channel were obtained by wading into the river at low tide, along the respective transect, to a depth of approximately 0.5 m and deploying the Ekman Dredge. The panne samples were taken in middle of the panne at the point where the transect intersected the panne. 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.

Figure 17 Ekman Dredge**.**

Aquatic Invertebrates

Aquatic invertebrates within the water column of representative salt pannes at SG and SG-R (Figure 10 and Figure 11) were sampled using Aquatic Invertebrate Activity Traps (IAT) (Figure 18). The IAT samples a cross-section of organisms from the aquatic biological community including freshwater, estuarine, and marine macroinvertebrates; meiofauna (small organisms such as nematodes, ostracods, harpacticoid copepods); plankton (e.g. copepods and planktonic stages of invertebrates); and fish (of which various stages including eggs, larvae and adult may be present).

IATs were submerged and anchored within the water column of the panne being sampled and allowed to passively sample over a single tide cycle (approximately 24 hour period). Two samples per site were taken on 25 July and 25 August 2011 (eight samples total). Traps were set on the dates indicated and then retrieved the following day. Samples were emptied into a 0.5 mm sieve and all captured materials and organisms were field-preserved in 70% isopropyl alcohol for transport to the lab for processing. Species identification was conducted by Envirosphere Consultants Ltd.

Figure 18 Invertebrate Activity Trap (IAT). Photograph by T. Bowron 2007.

Laboratory Methods

The Ekman samples were emptied shortly after receipt onto an 0.5 mm sieve and washed to remove fines. Organisms and material remaining on the sieve were stored in 10% formalin and later transferred to 70% isopropanol. The preserved samples were typically sub-sampled by 25% before further processing, due to the large bulk of the samples and to maintain a reasonable processing time. IAT samples were not sub-sampled.

For sub-sampling, Ekman samples were separated uniformly in a tray with four identical inserts to divide the sample into quarters, one of which was routinely processed in its entirety. The sample quarters were visually checked for homogeneity and then, to ensure the sediment was distributed evenly, the four inserts were individually weighed and verified to be within 0.5 to 1 gram of each other. Following analysis, the counts and biomass for the sub-samples were multiplied by a factor to restore the numbers to an estimate for the sample as a whole and per unit area. Sub-sampling affects measures of animal abundance and biomass by increasing variability, and leads to slightly reduced estimates of taxon richness compared to whole samples.

Prior to sorting, samples and sub-samples were rinsed on an 0.5 mm sieve to remove preservative. Samples were examined at 6 to 6.4x magnification on a stereomicroscope, with a final brief check at 16x, and all organisms were removed, and subsequently stored in labeled vials in 70% isopropyl alcohol. Sorting efficiency for lab personnel was checked periodically by resorting samples, to ensure average recovery levels of about 90% or better. Wet weight biomass (grams per square metre) was estimated for each Ekman dredge sample by weighing animals to the nearest milligram at the time of sorting, after blotting to remove surface water.

Organisms were identified to an appropriate taxonomic level, typically to species, using conventional literature for the groups involved (e.g. Barnes 1987; Gosner 1971). Species abundance, number of species, and wet weight biomass were estimated from the data. All taxa found, including meiofauna and planktonic taxa (e.g. copepods) as well as fish, were included in estimates of taxon richness and biomass.

3.7 Structured Winter Walk

On 24 March 2012, a structured winter site-walk was conducted at SG and SG-R. Landscape photographs were taken along each transect from the associated back stake at each site. Additional photographs were taken of key features such as snow, ice, debris, areas of erosion, river channel and upstream and downstream landscape photographs from the highway at both locations.

4.0 Results and Discussion

4.1 Geospatial Attributes: Digital Elevation Model, Elevation Change and Habitat Map

Digital Elevation Model and Marsh Surface Elevation Change

The 2011 DEM for the restoration and reference sites were constructed using survey elevation points collected with a RTK GPS and 10 cm contour data extracted from the 2011 DEM (Figure 19 and Figure 20). Several distinct changes in the SG DEM are clearly visible and can be explained in part by improvements in technology as well as by on the ground changes due to restoration. Use of the RTK GPS survey equipment and the availability of high-resolution low-altitude aerial imagery have improved our ability to accurately identify features such as channel thalweg and pond locations. Figure 21 illustrates the improvements made using the example of the main channel centerline using 2011 low-altitude photography (10 cm resolution) compared to 2007 provincial aerial photography (1 m resolution) which was used in previous analysis. The improved resolution of the imagery allowed greater detail in the channel delineation. For example, in previous elevation models the channel centerline was believed to lie close to the eastern upland edge. Examination of the low-altitude imagery showed that the largest branch of the channel lies closer to the western edge. Although it is not entirely clear, we believe most of the change in this region was due to improved technology rather than an actual channel migration.

Examination of surveyed transects and sampling stations also illustrates changes in the marsh surface elevation. Figure 22 and Figure 23 show transect profiles at both sites, extracted from the 2007, 2009 and 2011 DEM surfaces. At the restoration site, in most cases the 2011 surface was higher than the 2009 surface but lower than the 2007 surface (Figure 22). However, the variation between profiles can be largely explained by three factors. The vertical error associated with the RTK GPS survey points is on the order of 10-15 cm. Although some areas show greater change, much of the surface variation is within this margin of error. When individual sampling station elevations were compared between years (Table 2), a mean increase of 10 cm was detected between 2007 and 2011, but a 2 cm decrease was found between the 2009 and 2011 years. Some variation in the data may also be associated with seasonal changes at the site, as the 2011 survey was conducted earlier in the season (July; lower elevation due to decreased water content of marsh soils) than the 2007 and 2009 (December; greater water content of soils leading to an increase in surface elevation). Although the survey data does not conclusively indicate an increase in overall marsh surface elevation, other evidence does suggest a consolidation of soils and an increase elevation in some locations, particularly the colonization and expansion of halophytic vegetation (*Spartina alterniflora*) of previously unvegetated areas. Marsh surface elevation remained relatively constant at SG-R, with some variation indicated at the upland edge and at the creek, more the result of technology used than a significant change in actual elevation.

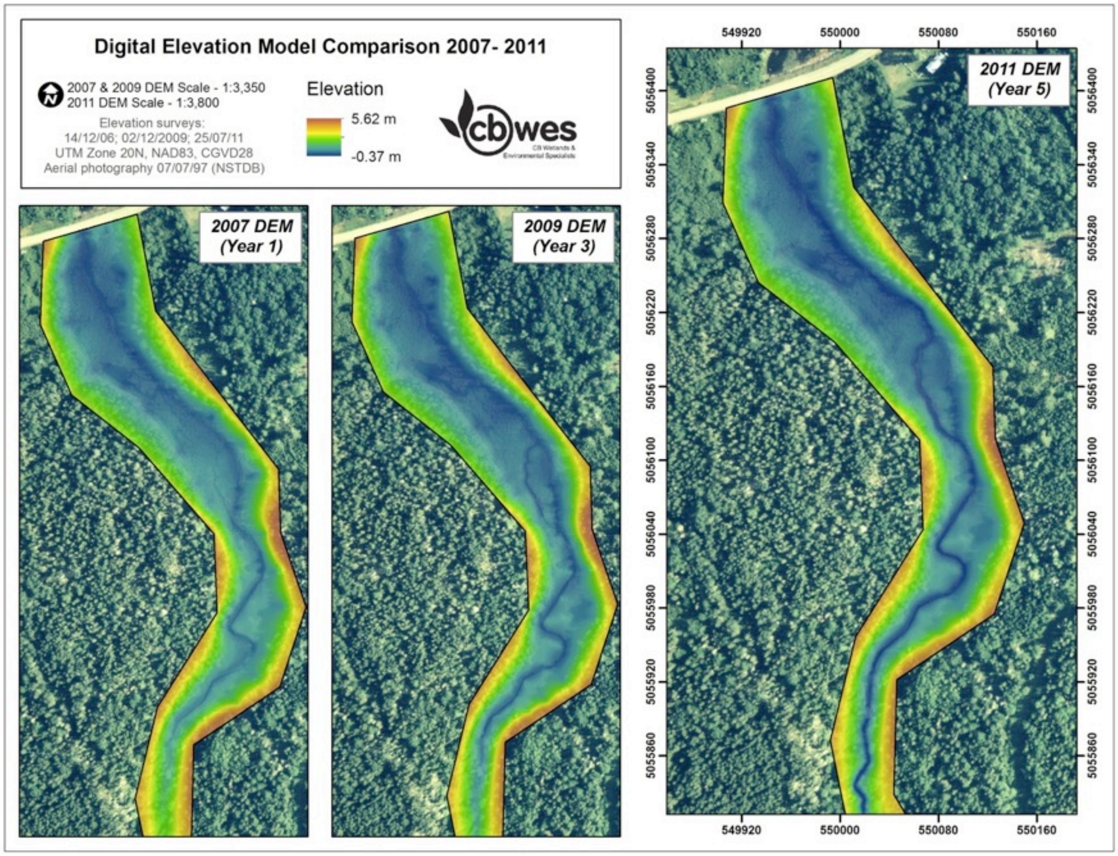

Figure 19 DEM comparison 2007; 2009 and 2011 for SG.

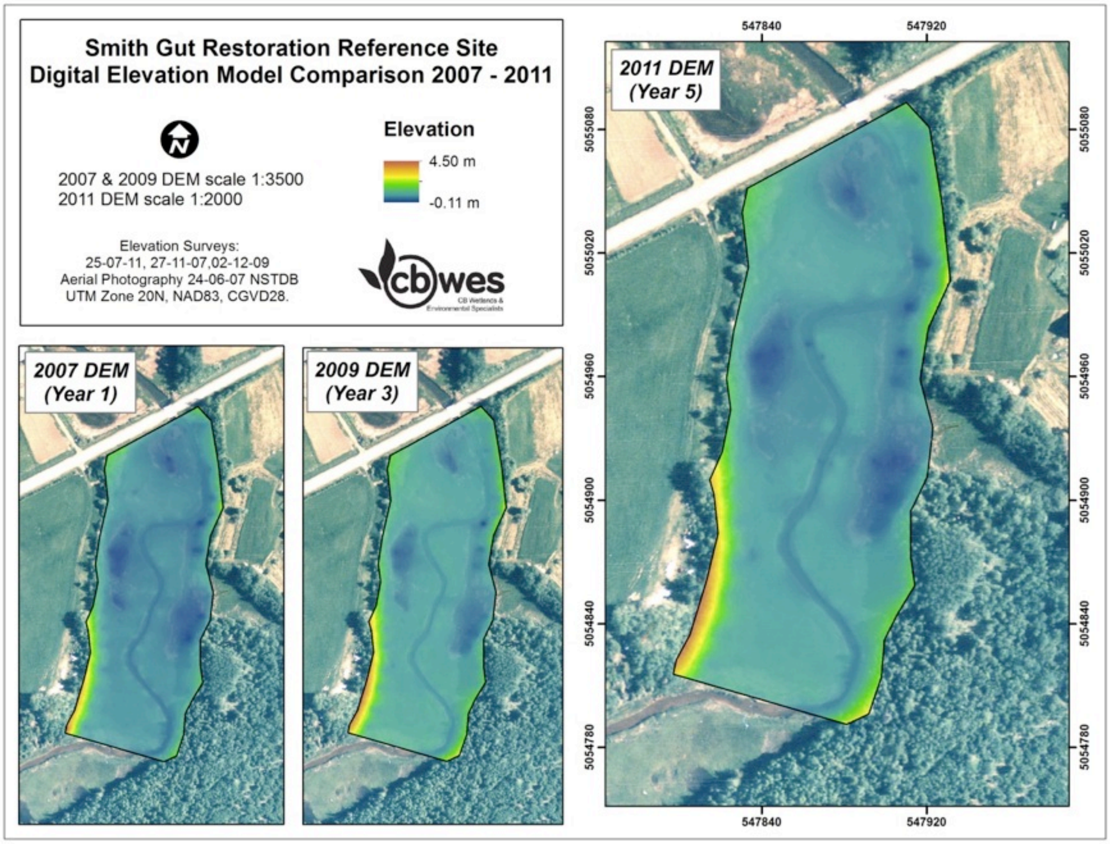

Figure 20 DEM comparison 2007; 2009 and 2011 for SG-R.

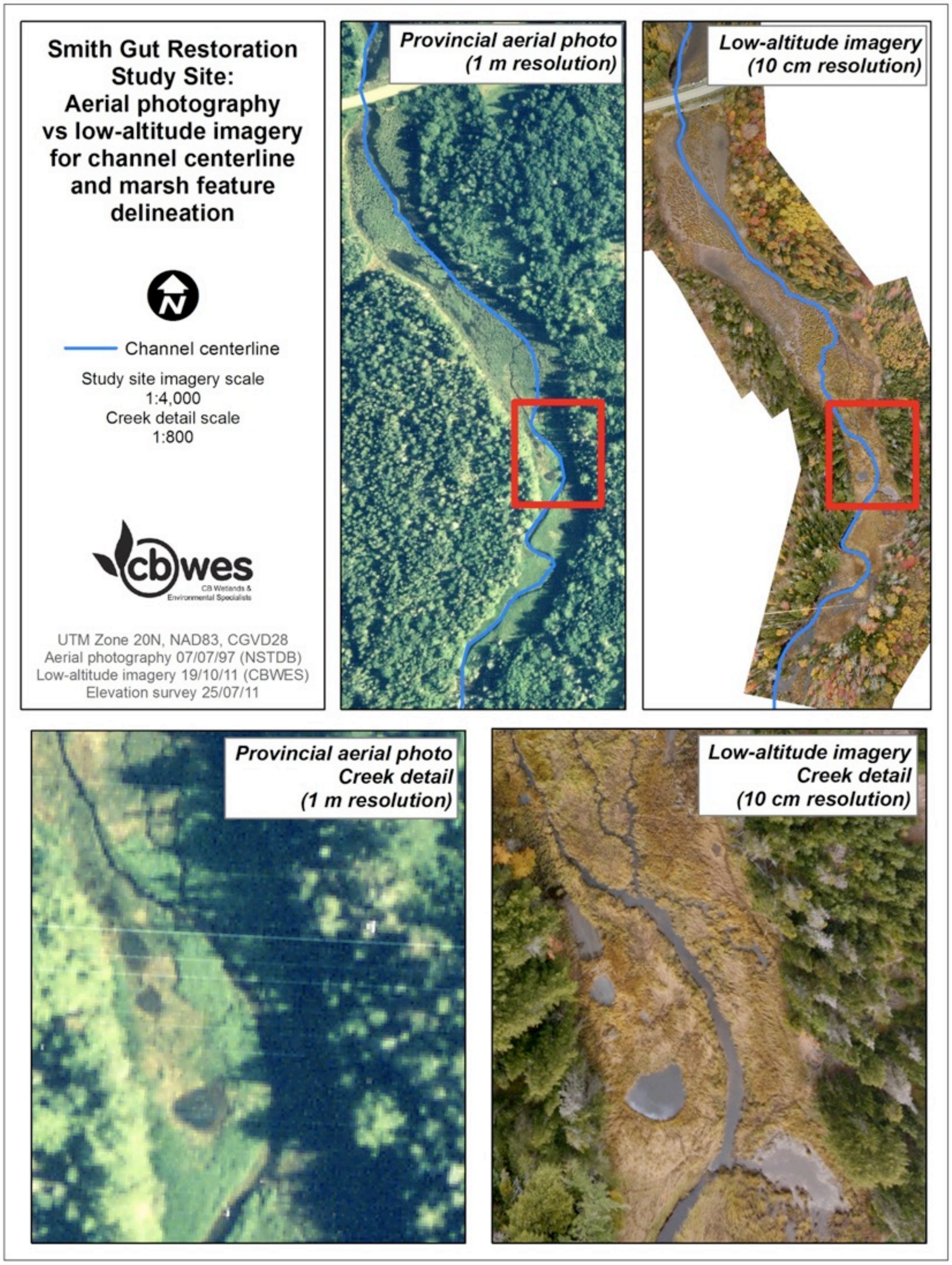

Figure 21 Comparison of the location of the main channel centerline as delineated using 2011 low-altitude photography versus 2007 provincial aerial photography (1 m resolution) which was used in previous analysis.

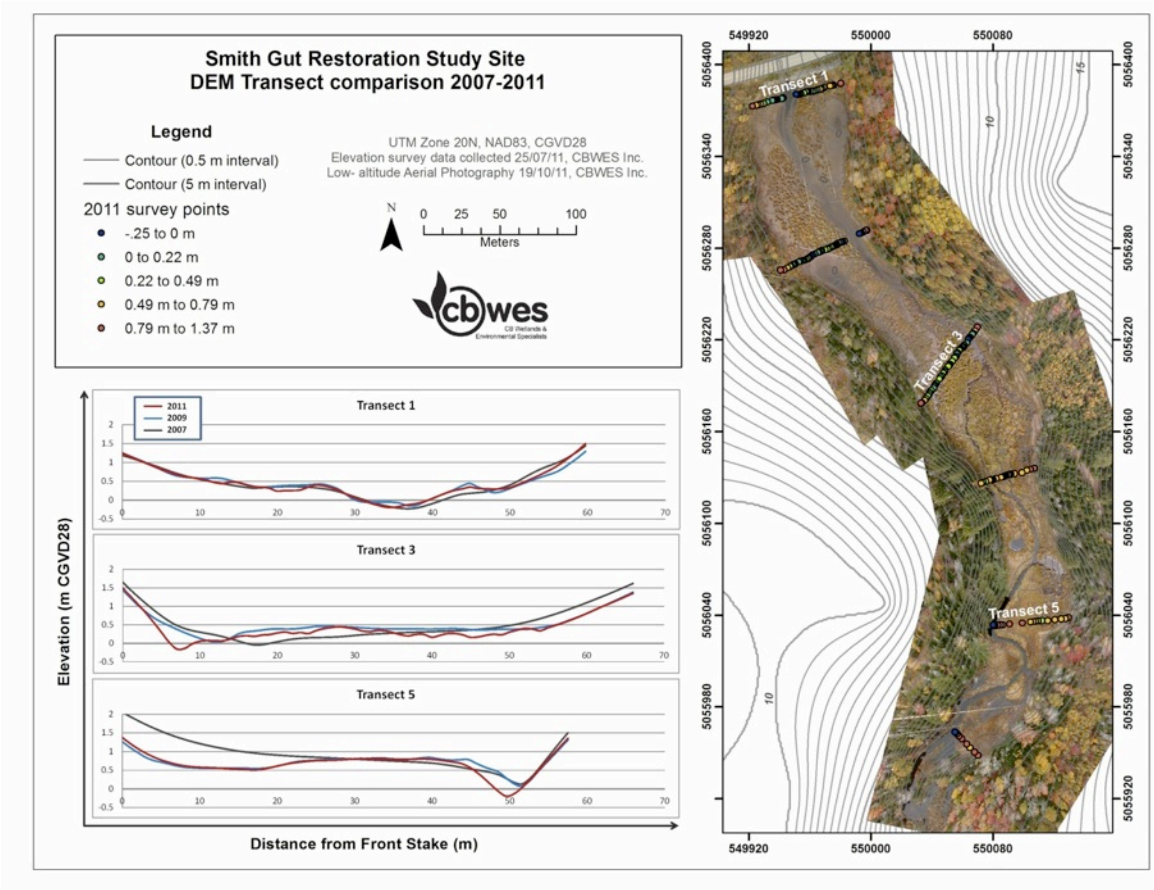

Figure 22 Transect elevation profiles for SG comparing 2007, 2009 and 2011.

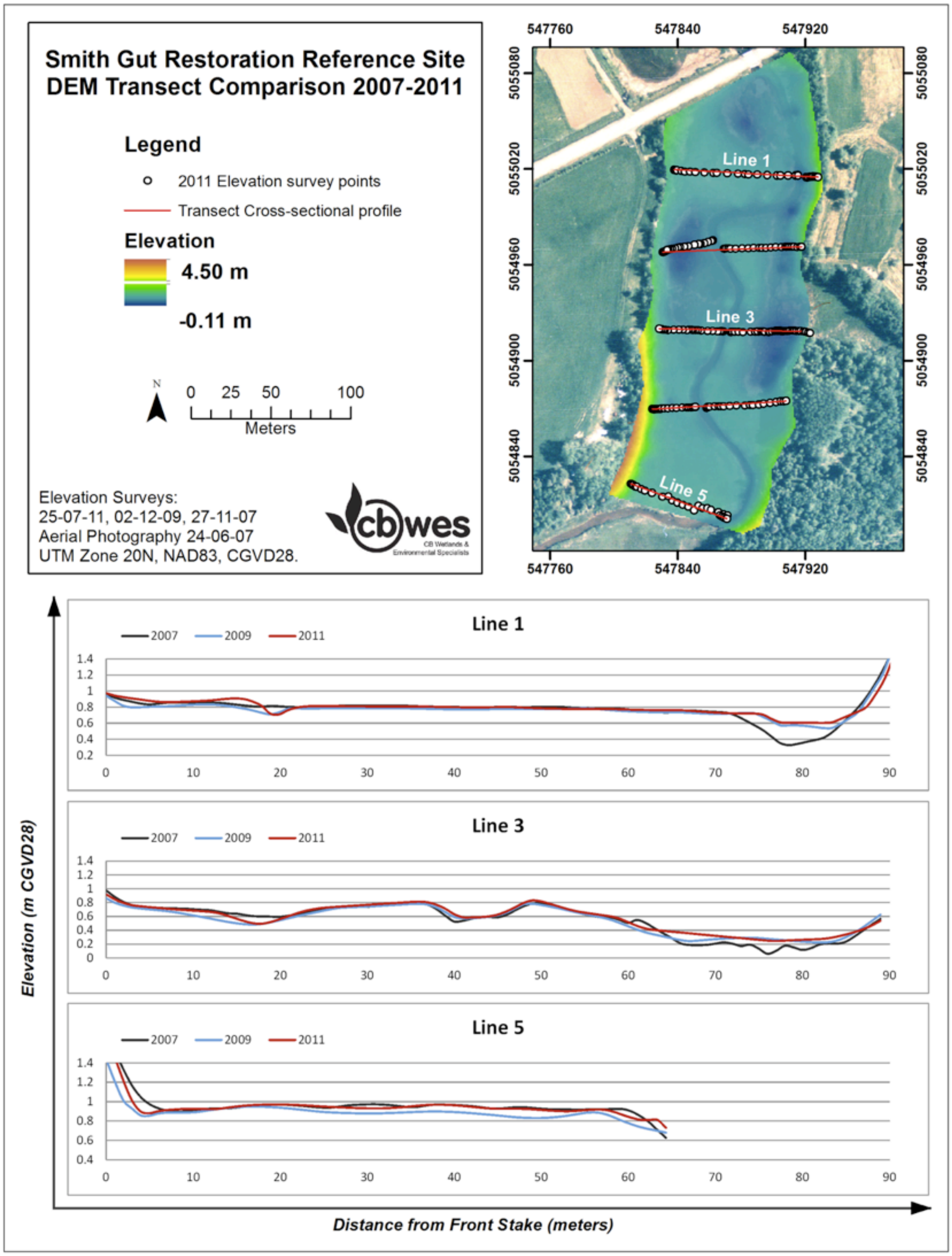

Figure 23 Transect elevation profiles for SG-R comparing 2007, 2009 and 2011.

Table 2 Comparison of elevation and elevation change at individual sampling stations – SG.

	Elevation (m CGVD28)			*Change in Elevation*		
Station ID	**2007**	**2009**	**2011**	**2011-2007**	**2011-2009**	**2009-2007**
L1BS	1.20	1.23	1.25	0.05	0.01	0.04
L1FS	0.85	0.86	0.87	0.03	0.01	0.02
L1S2	0.47	0.46	0.45	-0.02	-0.01	-0.01
L1S3	0.30	0.51	0.44	0.15	-0.06	0.21
L1S4	0.95	0.98	1.00	0.06	0.03	0.03
L2BS	1.17	1.15	1.15	-0.02	0.00	-0.02
L2FS	0.30	0.29	0.13	-0.17	-0.16	-0.01
L2S2	0.28	0.31	0.30	0.01	-0.02	0.03
L2S3	0.07	0.28	0.25	0.18	-0.03	0.22
L2S4	0.76	0.84	0.85	0.09	0.01	0.08
L3BS	1.10	1.19	1.17	0.07	-0.02	0.09
L3FS	0.32	0.47	0.38	0.06	-0.09	0.15
L3S2	0.34	0.47	0.46	0.12	-0.01	0.13
L3S4	0.59	0.73	0.61	0.01	-0.13	0.14
L4BS	0.85	0.94	0.98	0.14	0.04	0.10
L4FS	0.75	0.85	0.89	0.14	0.04	0.10
L4S2	0.58	0.64	0.59	0.01	-0.05	0.06
L4S3	0.33	0.50	0.44	0.11	-0.05	0.16
L5BS	0.89	0.95	0.98	0.09	0.04	0.06
L5FS	0.52	0.68	0.64	0.11	-0.04	0.16
L5S2	0.73	0.81	0.76	0.04	-0.05	0.08
L5S3	0.76	0.84	0.84	0.07	-0.01	0.08
L6BS	0.83	0.94	0.91	0.08	-0.03	0.10
L6FS	0.94	1.04	1.03	0.10	0.00	0.10
L6S2	--	--	--	--	--	--
L6S3	--	--	--	--	--	--
Average	--	--	--	**0.10**	**-0.02**	**0.13**
	--	--	--	**0.07**		

Habitat Map

High resolution, orthorectified, low-altitude aerial photography was used, in combination with the 2011 vegetation survey, to develop the SG habitat map (Figure 24) and facilitated the analysis of surface cover changes between 2010 and 2011 (Figure 25). To examine surface cover changes the 2010 (first year for which low-altitude photography was obtained) and 2011 orthorectified mosaics were classed into either a ‘water class’ or ‘vegetation class’. The final surface change map showed that there had been very little change in surface cover between 2010 and 2011 at SG. In 2010 there was 15,890 m^2 of the image (wetland) classed as vegetation and 8,890 m^2 as water. In 2011 these numbers increase to 16,193 m^2 for vegetation and 9,363 m^2 for water. The total area difference between the two years was 774 m^2. The difference in total area, in part, arose as the techniques used to produce orthorectified images from low-altitude aerial photography platforms are better understood and refined.

In 2007, the tidal wetland habitat upstream of the causeway was estimated at 2.3 ha. In 2009, improved survey/mapping techniques combined with a larger hydrological data set enabled the refinement of the wetland area estimate to 2.8 ha. This area was not a horizontal expansion of overall wetland area, but rather an improved mapping of the extent of the tidal waters upstream. The 2011 elevation and hydrological data did not result in a change of the overall marsh area. Given that there has not been an overall increase in the size of the wetland area, the increase in area of both vegetation and water at the site detected between 2010 and 2011 (774 m^2) was a factor of the technology.

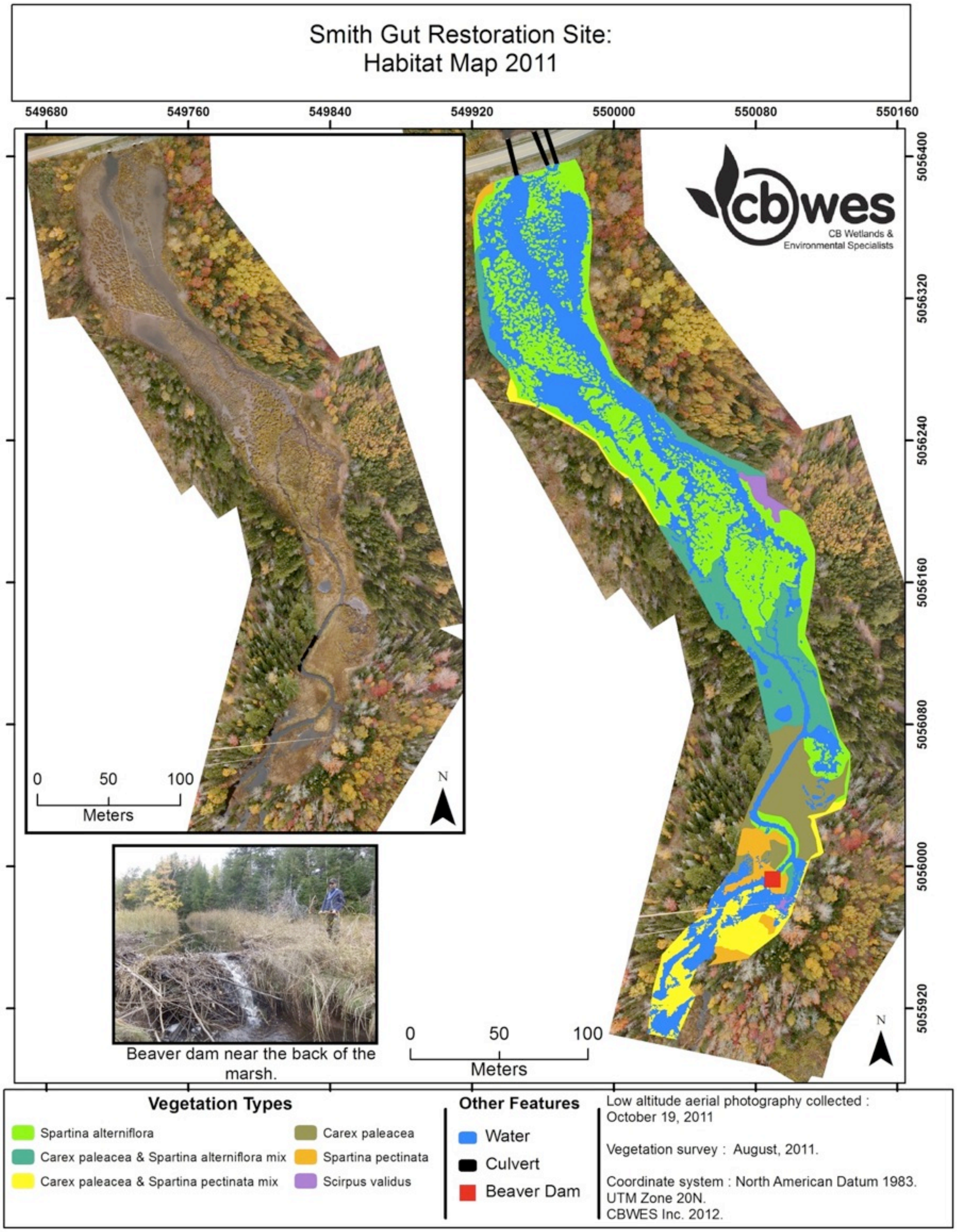

Figure 24 2011 SG habitat map.

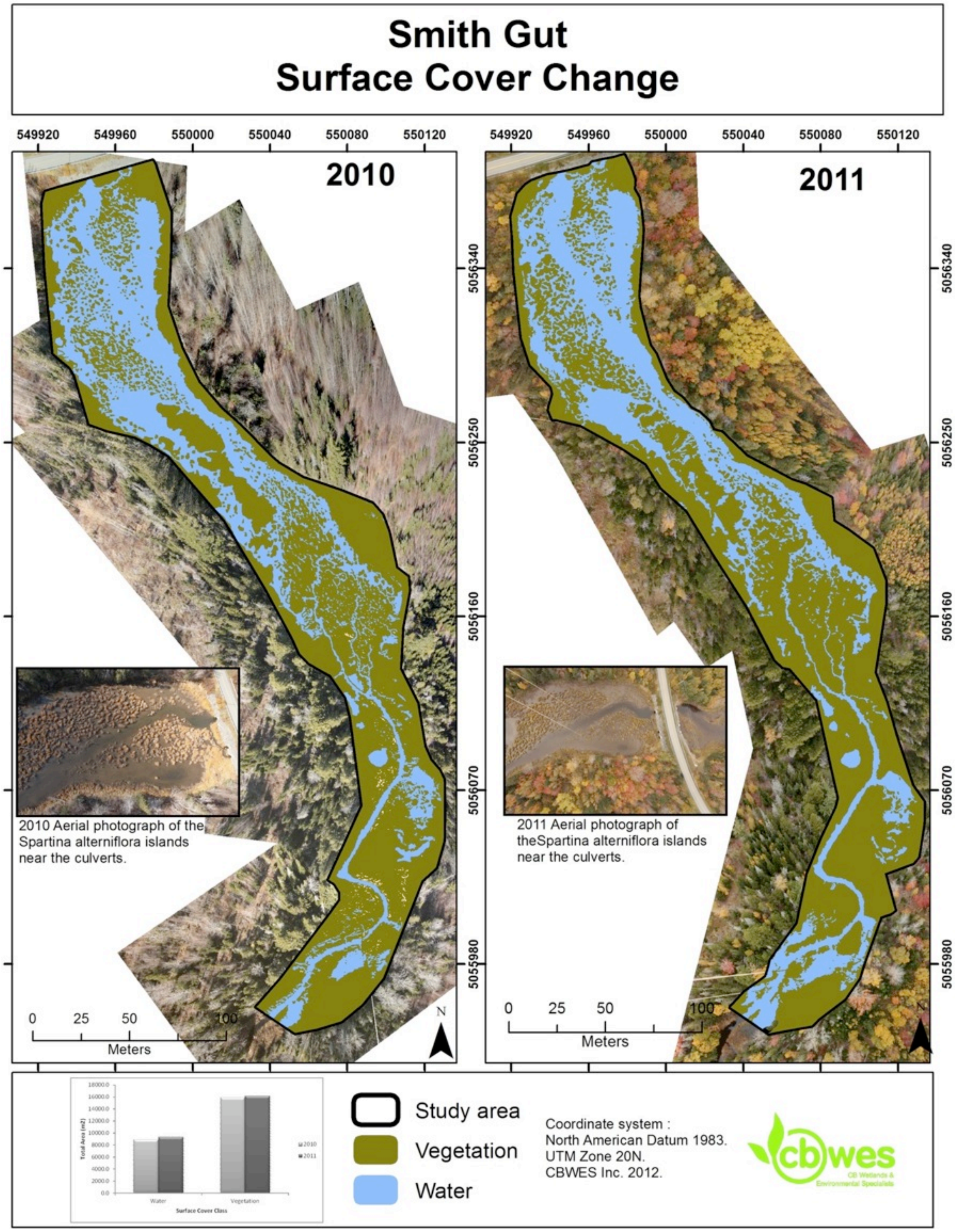

Figure 25 Surface cover change map for SG (2010 to 2011).

4.2 Hydrology

Hydroperiod and Tidal Signal

The tide level data collected in 2011 (21 September to 29 November) showed that the high tides at SG were in the 0.54 – 2.13 m (downstream) and 0.59 – 2.18 m (upstream) range (Figure 26 and Figure 27). The tide level data was combined with the updated 2011 DEM for SG to produce the hypsometric curve (Figure 28). A storm event on 30 September produced a maximum tide level of 2.18 m, which was over a half meter higher than the previously highest recorded tide for the site (Figure 27 and Figure 28). It was previously determined that a water level of 2 m would result in 100% of the study site (32,731 m^2; 3.2 ha) being under water. A tide such as the 30 September 2011 would not result in a larger area flooded, but rather a greater depth and duration of flooding. The estimated area of restored tidal wetland was on the order of 2.47 ha, which would require a tide level of 1.1 m, which was just above the mean high tide level of 0.96 m (upstream) recorded for 2011. An updated flood map was also produced for the study site showing the area flooded by the highest recorded tides for 2007, 2009 and 2011 (Figure 29).

The updated hydrology data continued to show that the three culverts do not represent a significant barrier to tidal flow. The continued difference in water level between upstream and downstream is expected due to the influence of freshwater flow on upstream elevations. The tide signal over the storm induced high tide event in September indicated that aside from the minor difference in water level, there was no delay in the timing of peak water level events (Figure 28).

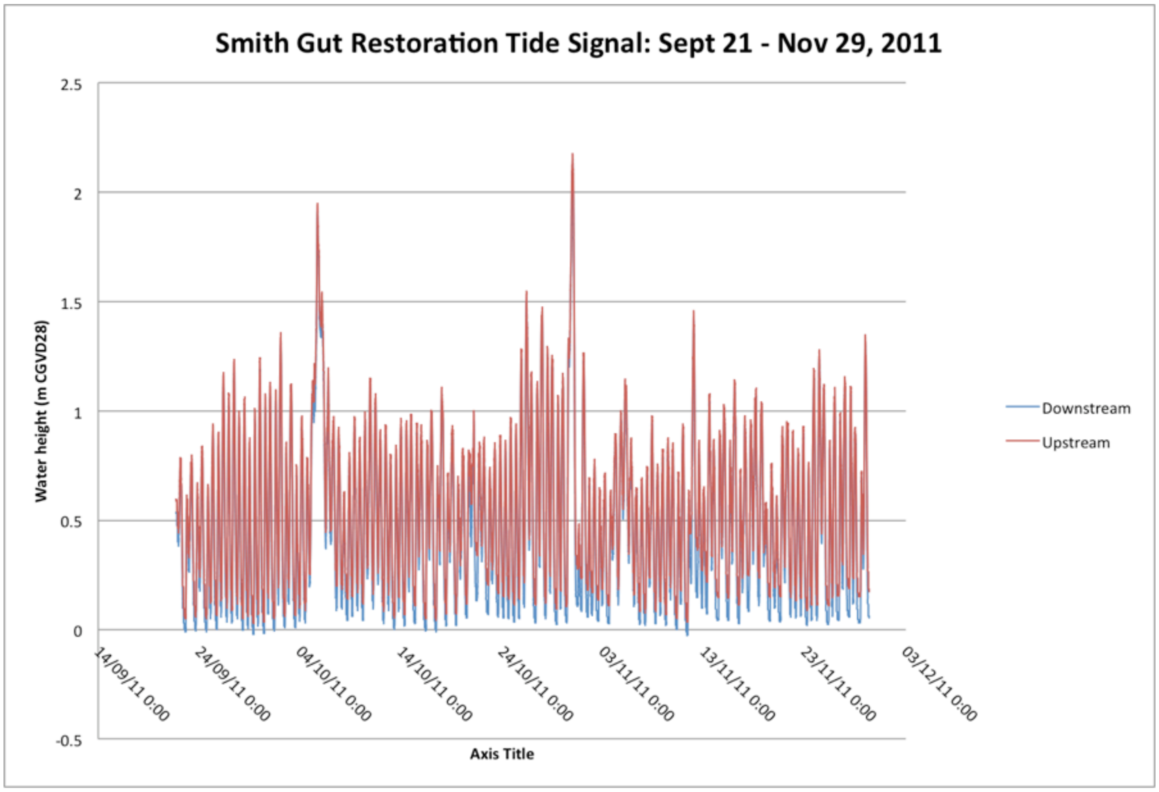

Figure 26 The 2011 tide signal for SG upstream and downstream.

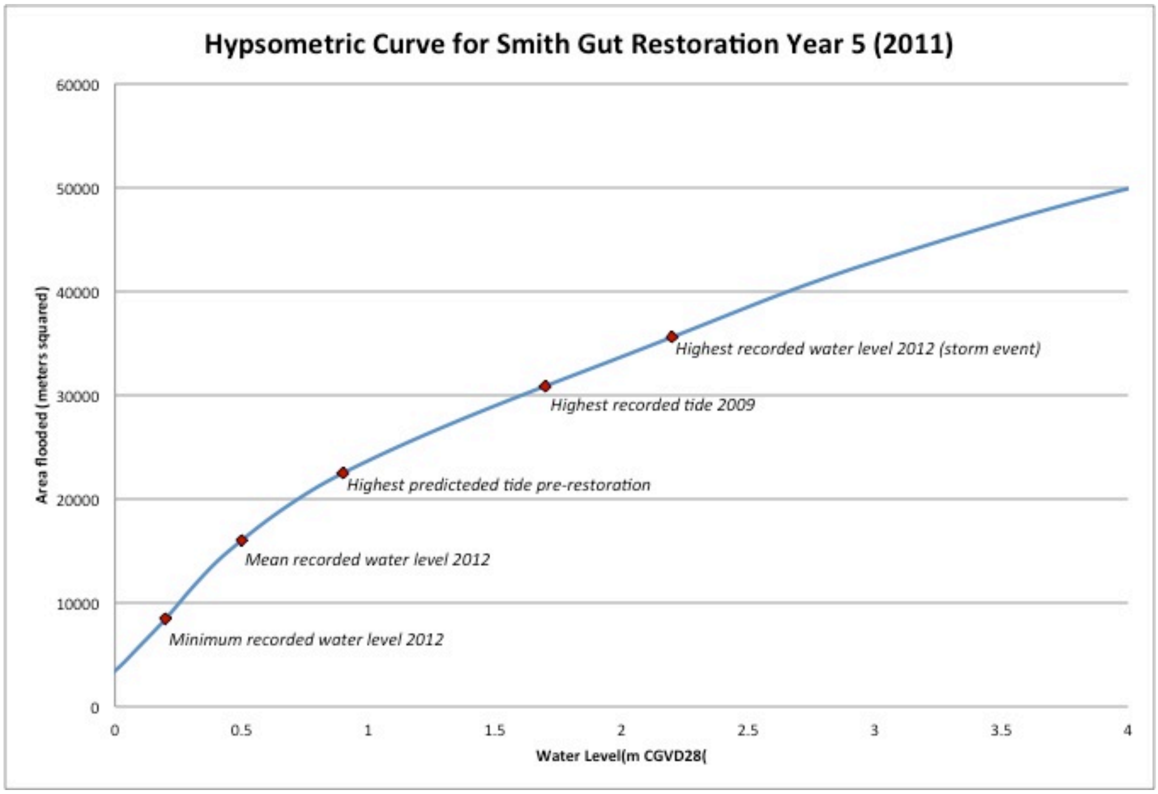

Figure 27 The 2011 hypsometric curves for SG.

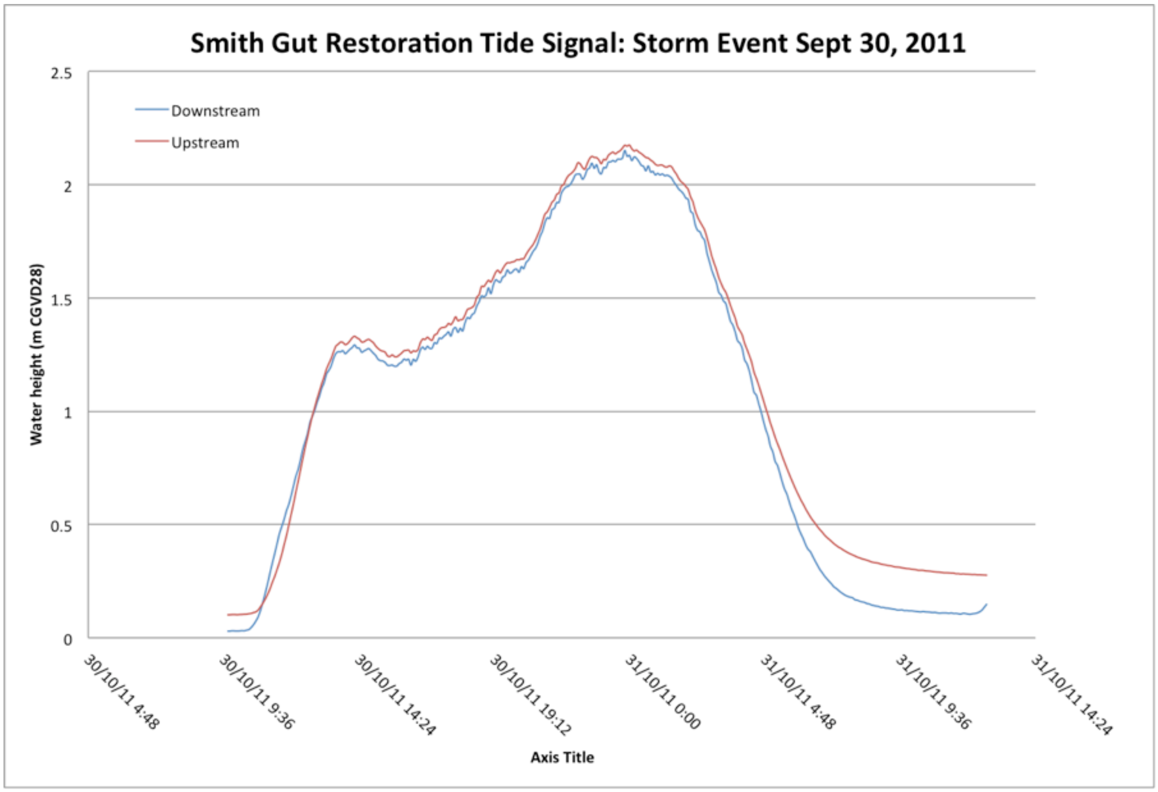

Figure 28 Tide signal for SG during a storm event on 30 September 2011.

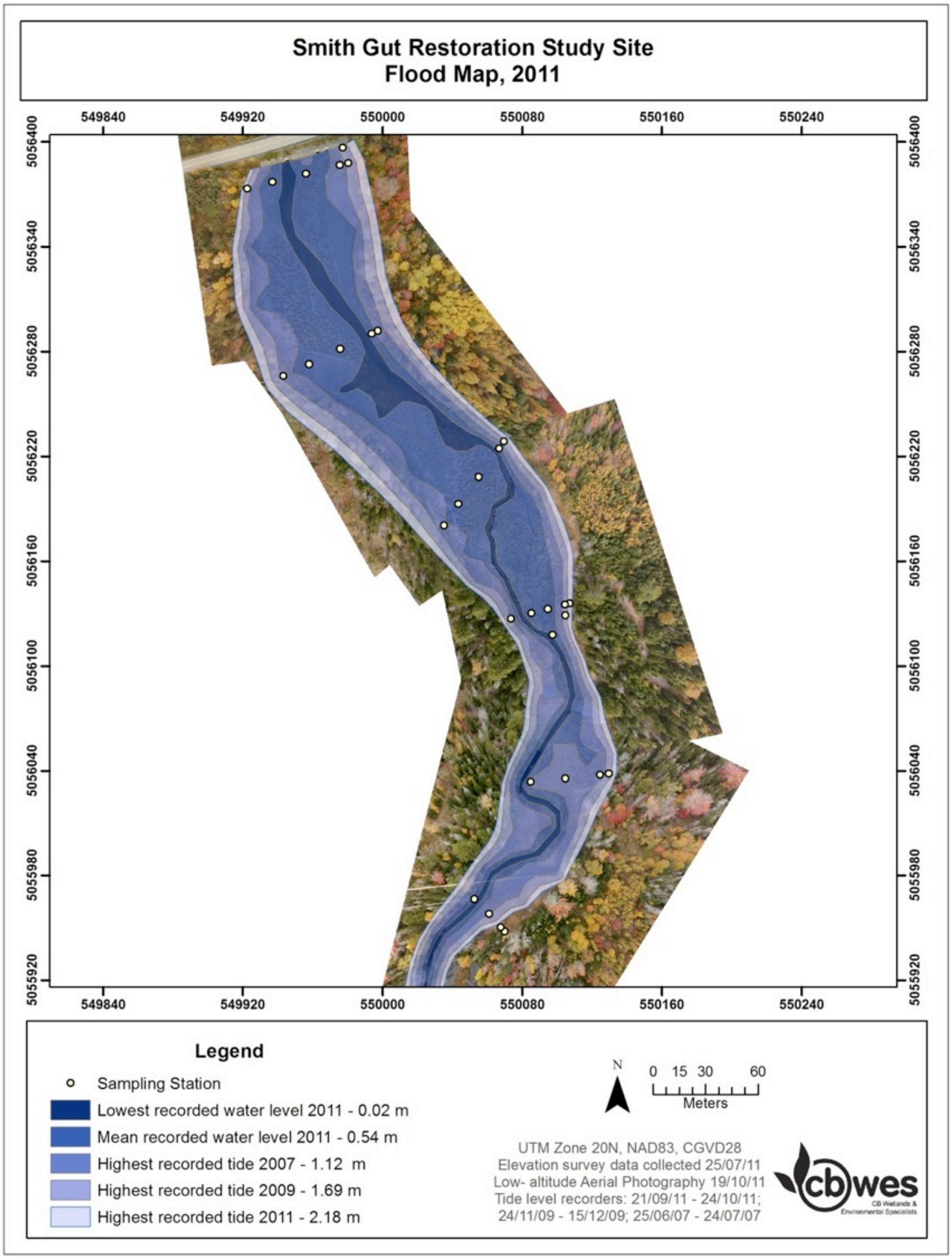

Figure 29 Flood map of SG, 2011.

Water Quality

Water quality (salinity, temperature, DO, and pH) readings for tidal floodwaters were obtained from both upstream and downstream of the causeway at SG during the 2011 season in conjunction with fish sampling (Table 3). Similar to previous years, there was little difference in the water quality conditions on either side of the causeway. This was expected given the proximity of the sampling locations and unrestricted flow of water facilitated by the new culverts. The minor variations between upstream and downstream readings are the result of time delay between sampling – in some cases up to a thirty minute delay. Of the four parameters, dissolved oxygen showed the greatest variation between readings.

pH is the measure of whether a solution is acidic or alkaline. A solution with a pH of 7.0 would be considered neutral. Estuarine waters generally range from 4.6 – 9.4 with a mean pH value of 7.7. Considering all years, the pH values recorded both upstream and down at SG, were at or just above the mean pH value.

Within sampling events, water temperature was highly consistent and showed a seasonal trend; high temperature during summer sampling events and low during the fall. Dissolved oxygen and water temperature have an inverse relationship; therefore, when the water temperature reading is high, dissolved oxygen is low and vice versa. This relationship was evident in the SG data for most years, with the highest levels of DO recorded during those sample days when the water temperature was low (ex. 2011: 23.2^{0}C and 3.37 mg/L and 7.71^{0}C and 20.18 mg/L) (Table 3).

Salinity is generally considered to be a practical field method for basic assessment of water quality. Saline, or ocean water has salinity levels greater than 30 parts per thousand (ppt), whereas brackish or estuarine water has salinity levels below 30 ppt, but greater than zero (fresh water). Tidal waters of the Northumberland Strait are generally between 28 ppt and 30 ppt. Salinity levels for both SG and SG DS were consistently lower all years post-restoration than that of Northumberland Strait waters, but were still within the mid to high range of brackish water. However, several of the salinity readings for 28 October 2011 were considerably lower than all previous measurements (ex., 11.83 ppt) (Table 3). Rainfall levels for that month were higher than for previous sampling periods (119.2 mm), with the majority of the rainfall having occurred during the week prior to the sampling date. This could have resulted in a higher than normal freshwater influence within the study site, and thus reducing salinity levels.

With the elimination of the tidal restriction, the greatest influence on water quality has become climate and seasonal conditions.

Table 3 Water quality of tidal flood waters downstream (SG DS) and upstream (SG) of the causeway at high tide (+/- 30 minutes of peak tide).

pH				**Dissolved Oxygen (mg/L)**		
	SG	**SG DS**			**SG**	**SG DS**
14/07/06*	n/a	n/a		14/07/06*	8.3	7.52
25/09/07	7.71	7.51		25/09/07	8.55	8.45
31/10/07	7.92	7.87		31/10/07	13.47	13.74

pH		
	SG	SG DS
30/09/08	7.46	7.39
24/07/09	8.42	8.48
24/07/09	8.42	8.54
24/07/09	7.79	n/a
06/10/09	7.61	7.62
06/10/09	7.73	7.73
05/07/11	8.16	8.24
05/07/11	7.89	8.21
28/10/11	7.61	7.79
28/10/11	7.42	7.67

Dissolved Oxygen (mg/L)		
	SG	SG DS
30/09/08	7.16	7.36
24/07/09	8.8	8.75
24/07/09	8.9	8.82
24/07/09	9.81	n/a
06/10/09	8.55	8.83
06/10/09	8.37	8.62
05/07/11	4.26	5.18
05/07/11	3.37	5.45
28/10/11	13.58	10.59
28/10/11	20.18	12.54

Temperature (^{0}C)		
	SG	SG DS
14/07/06*	21.2	21.5
25/09/07	16.6	15.5
31/10/07	8.33	8.69
30/09/08	16.95	16.58
24/07/09	20.43	20.87
24/07/09	20.64	20.82
24/07/09	18.6	n/a
06/10/09	13.15	12.97
06/10/09	13.1	13.05
05/07/11	23.58	23.03
05/07/11	23.2	23.34
28/10/11	7.87	7.77
28/10/11	7.71	7.79

Salinity (ppt)		
	SG	SG DS
14/07/06*	19.9	19.7
25/09/07	21.82	21.87
31/10/07	15.85	15.66
30/09/08	16.41	16.57
24/07/09	18.19	8.48
24/07/09	17.84	19.34
24/07/09	22.3	n/a
06/10/09	22.41	22.46
06/10/09	22.49	22.57
05/07/11	24.42	24.56
05/07/11	23.86	24.42
28/10/11	12.09	13.56
28/10/11	11.83	12.75

*Taken from Hulbert (2007).

4.3 Soils and Sediments

Pore Water Salinity

Descriptive statistics, including mean, range, and standard deviation were calculated for all years and samples (Table 4). A post- versus pre-restoration comparison of pore water salinity levels was not possible due to the absence of baseline measurements (Hulbert 2007). The analysis of salinity levels focused on a comparison of pore water salinity levels within each site and between the two sites.

As a result of the switch to the FieldScout EC 110 meter in 2011, a direct comparison of salinity levels between years was not possible. Results of t-tests for SG Year 1 versus Year 3 (2007 vs.

2009) showed a statistically significant increase (t-test, t = -5.71106, df = 40, P = 1.2E-06) in mean salinity potentially due to the re-introduction of tidal flow. In both 2008 and 2009 (Years 2 and 3) no significant difference (t-test, t = 1.545561, df = 72, P = 0.126595) was found between SG and SG-R. However, utilizing the 2011 data, a significant difference was detected between the two sites (t-test, t=2.34, P=0.02, p=0.05). As well, no significant difference was detected between shallow and deep samples at SG in 2011 (t=-1.33, P= 0.19, p=0.05), which was opposite of the 2009 findings (t = -2.99861, df = 26, P = 0.005905). This would suggest that something was occurring at the restoration site during the fifth year post-restoration that was different from previous years.

Two possible explanations for this difference could be the increased beaver activity at SG resulting in altered hydrology, or the increased frequency and duration of tidal flooding as a result of the larger Saros and Nodal tides occurring over the period of 2011-2016 (18 and 18.6 year tidal cycles; Desplanque and Mossman, 2004; Baart et al, 2012). The reference site would have also experienced the same higher tides, but did not show a significant difference between shallow and deep samples (t=-1.33, P= 0.19, p=0.05). The difference in salinity values detected in the study site data, between Years 3 and 5, could have been the result of increased beaver activity (Figure 42).

Salinity levels at both sites generally fall within the low to mid range (0 – 12 ppt), with SG-R having a more even distribution across the range categories including the higher range of 19-21 ppt (Figure 30, Figure 31, Figure 32). Over the five years following restoration, salinity levels have increased at SG, but are still lower than levels of the reference site. The difference in mean salinity and in the range of salinities has decreased over time, bringing the two systems closer together. Given the differences between the two sites in terms of hydrology, elevation, and size, one would not expect the two sites to be equal. The variation in salinity readings between the two sites, and even within the sites between years, is to be expected.

The mean salinity levels found at SG and SG-R (Table 4) continued to be lower than those found at restoration and reference sites being monitored along the Bay of Fundy such as Cheverie Creek (Bowron et al. 2011) and Walton River (Neatt et al. 2011). This was expected given that salinity levels of estuarine tidal waters in the Northumberland Strait tend to be lower than those along the province's other two coasts (Atlantic and Bay of Fundy) (DFO 2007; Petrie et al. 1996). However, the mean levels are similar to those of the Lawrencetown Lake sites on the Atlantic Ocean side of the Province at 10.33 ppt and 12.88 ppt for the study site and reference respectively (Bowron et al. 2010b). These two sites experience similar tidal conditions (lower tidal range than Bay of Fundy), and both are fairly removed and protected from direct ocean influence – SG a tributary to Merigomish Harbour and the Lawrencetown Lake restoration site at the upper reaches of the Lawrencetown Lake tidal system.

Table 4 SG and SG-R descriptive statistics (mean, range, and standard deviation) for pore water salinity for all samples.

Year	Site	Mean	Standard Deviation	Min	Max
2007	**SG**	5.66	0.99	0	19
	SG-R	7.83	1.02	0	20
2008	**SG**	8.29	0.79	0	20
	SG-R	9.91	0.81	5	17
2009	**SG**	9.56	0.6	0	21
	SG-R	11.44	0.71	0	25
2011*	**SG**	6.13	2.23	1	19
	SG-R	8.02	3.57	0	17
2011**	**SG**	4.18	1.26	0.43	9.87
	SG-R	5.5	1.13	2.33	11.07

*Based on single sampling event. Previous years based on a minimum of n=3.
**FieldScout EC 110 Meter.

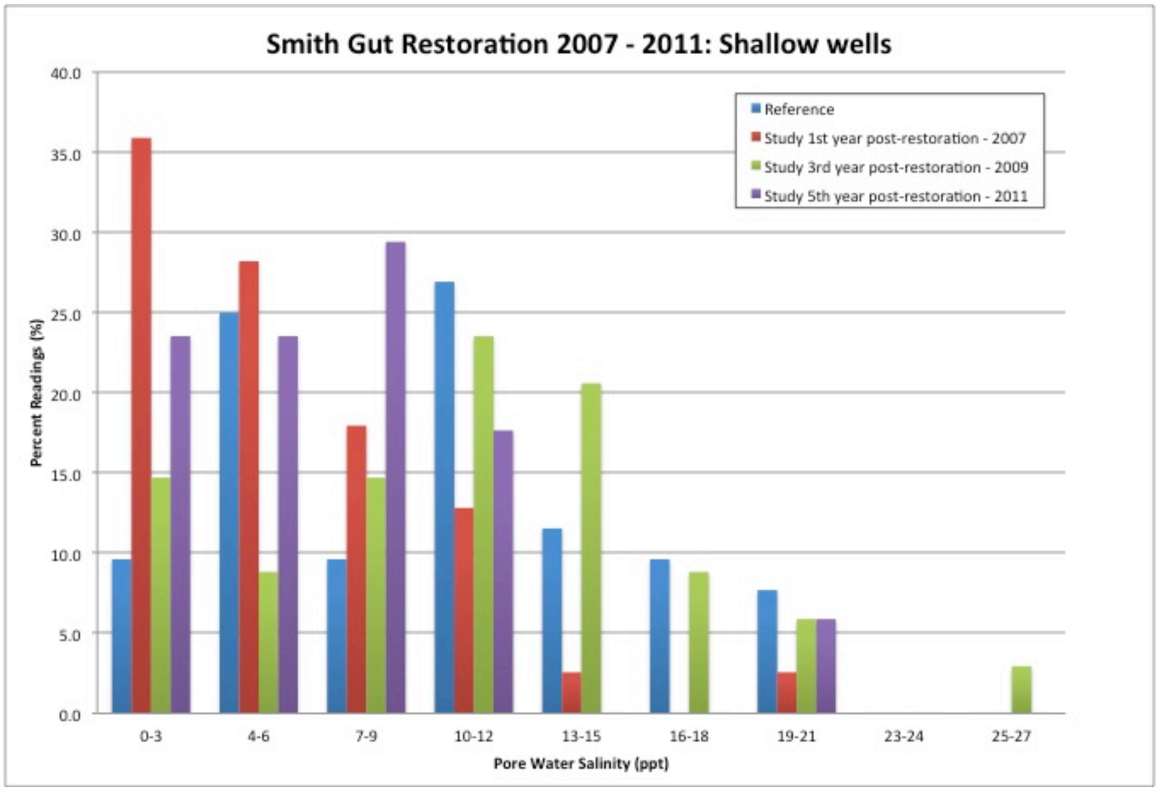

Figure 30 Frequency of pore water salinity values for shallow sample readings at SG (post-restoration years 1, 3 and 5) and SG-R (combined).

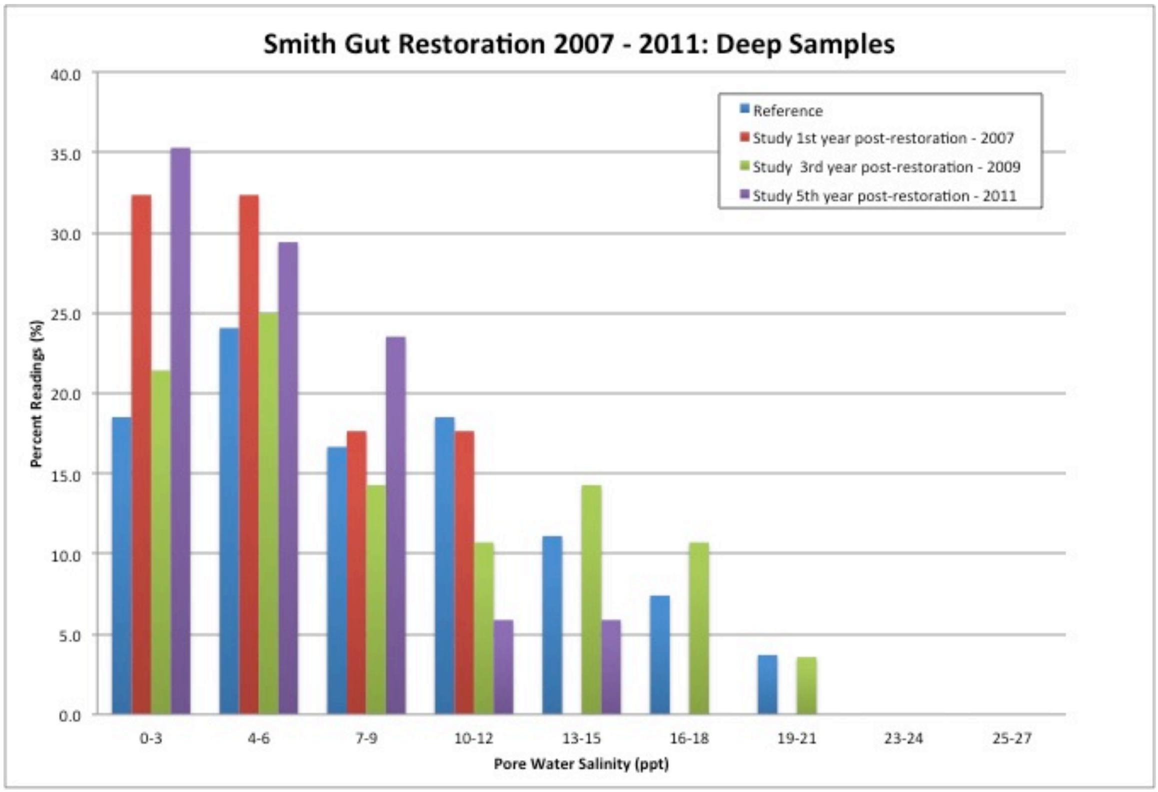

Figure 31 Frequency of pore water salinity values for deep sample readings at SG (post-restoration years 1, 3 and 5) and SG-R (combined).

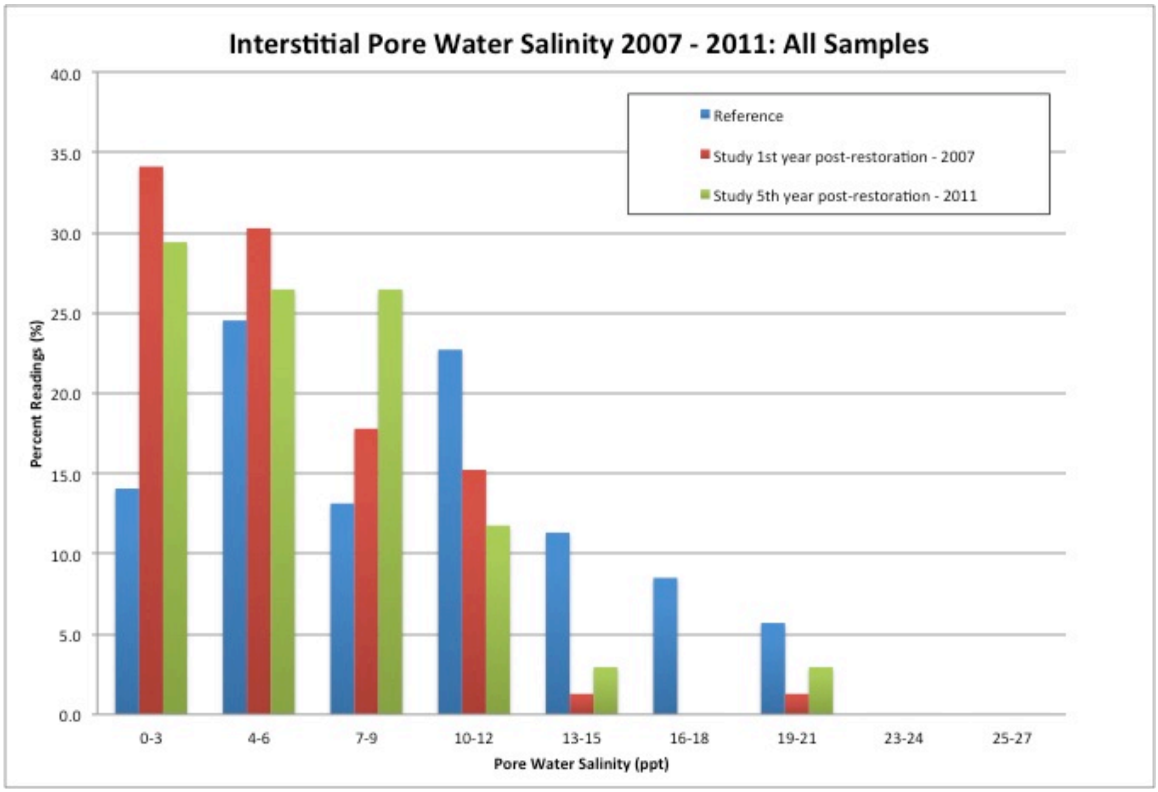

Figure 32 Frequency of pore water salinity values for all readings at SG and SG-R.

Sediment Characteristics

Soil characteristics at each sample location are highly influenced by the site's elevation within the tidal frame, distance from the mouth of the estuary (causeway) and distance from the creek bank. Bulk density, water content and organic matter content are influenced primarily by the sediment characteristics of the underlying substrate and presence or absence of vegetation. These characteristics will be discussed initially at the restoration site then compared to those observed at the reference site.

A total of twelve cores and bulk density samples were collected at SG and SG-R (Table 5). All cores were processed at the In_CoaST research lab for bulk density, water and organic matter content and grain size analyses using a Coulter Multisizer 3^tm[10]. The 2007 and 2009 grain size analyses were performed at Mount Allison University using a Coulter Laser instrument. The Coulter Multisizer 3^{tm} is more accurate in the analysis of fines and results from the Coulter laser will need to be compared with caution since it tends to overestimate grain size (McCave et al. 2006) and miss the tail of fines. McCave et al. (2006) suggests that coarse clay and fine silt recorded using a Coulter Multisizer would show up as medium to coarse silt on the Coulter laser due to differences in the type of measurement. Fine sediments are typically platy in nature with a large surface area which is overrepresented using the laser method. Grain size statistics were derived using Gradistat (Blott and Pye 2001) within In_CoaST.

At the restoration site, sampling stations L1S2, L4S2 and L5S3 are all situated adjacent to the tidal creek whereas L4S1 and L5S1 are located along the upland edge of the marsh. In general, organic matter content increases with increasing distance from the tidal creek with the highest values at the upland sites in all years at L4S1 (55,108,49%) and L5S1 (41, 60, 48%) in 2007, 2009 and 2011 respectively (Table 5a). Organic matter increased at all stations from 2007 to 2009 (Table 1a), however, decreased between 2009 and 2011. Both of these sites also have the highest water content, which remains relatively consistent between years (Table 5a).

Table 5 Sediment characteristics at a) SG and b) SG-R, in 2007, 2009 and 2011. Elevations surveyed relative to CGVD28 vertical datum. Dry BD = dry bulk density in g•cm^{-3}, H_20 = water content (%), OM = organic matter content (%).

a)		**2007**			**2009**			**2011**		
ID	**Elev (m)**	**Dry BD g•cm^{-3}**	**H_20 (%)**	**OM (%)**	**Dry BD g•cm^{-3}**	**H_20 (%)**	**OM (%)**	**Dry BD g•cm^{-3}**	**H_20 (%)**	**OM (%)**
SGL1S2	0.47	0.42	65.09	16.12	0.32	59.96	23.28	0.32	69.0	20.7
SGL4S1	0.75	0.20	86.58	55.25	0.11	87.98	108.30	0.12	88.6	48.9
SGL4S2	0.58	0.47	58.37	16.32	0.45	52.96	17.46	0.37	61.2	12.6
SGL5S1	0.52	0.19	82.57	41.40	0.10	85.38	60.11	0.12	84.8	48.7
SGL5S2	0.73	0.26	74.52	30.17	0.28	71.07	37.40	0.18	83.1	25.7
SGL5S3	0.76	0.36	65.12	18.21	0.34	59.06	27.78	0.25	67.9	15.2

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[10] www.beckmancoulter.com/wsrportal/wsrportal.portal?_nfpb=true&_windowLabel=UCM_RENDERER &_urlType=render&wlpUCM_RENDERER_path=%2Fwsr%2Findustrial%2Fproducts%2Fcoulter-counter-analyzers%2Fmultisizer-3%2Findex.htm

b) **ID**	**Elev (m)**	**Dry BD $g•cm^{-3}$**	**$H_2$0 (%)**	**OM (%)**	**Dry BD $g•cm^{-3}$**	**$H_2$0 (%)**	**OM (%)**	**Dry BD $g•cm^{-3}$**	**$H_2$0 (%)**	**OM (%)**
SGRL1S1	0.81	0.29	73.81	30.00	0.16	77.09	40.87	0.13	82.3	28.7
SGRL1S3	0.78	0.43	60.53	21.90	0.35	54.30	18.47	0.28	68.3	17.3
SGRL1S4	0.74	0.39	64.33	19.92	0.20	54.20	20.27	0.25	64.6	16.4
SGRL3S2	0.64	0.44	63.40	16.27	0.48	51.22	15.00	0.33	63.9	13.7
SGRL3S3	0.66	0.61	47.22	12.22	0.78	36.70	8.97	0.57	42.4	7.5
SGRL5S3	0.88	0.44	58.58	18.17	0.42	56.95	19.87	0.34	56.4	13.5

At the restoration site, sampling stations L1S2, L4S2 and L5S3 are all situated adjacent to the tidal creek whereas L4S1 and L5S1 are located along the upland edge of the marsh. In general, organic matter content increased with increasing distance from the tidal creek with the highest values at the upland sites in all years at L4S1 (55,108,49%) and L5S1 (41, 60, 48%) in 2007, 2009 and 2011 respectively (Table 5a). Organic matter increased at all stations from 2007 to 2009 (Table 1a), however, decreased between 2009 and 2011. Both of these sites also have the highest water content, which remained relatively consistent between years (Table 5a).

The lowest organic matter contents were found at the creek edge at L4S2 (16, 17, 13%) and L5S3 (18, 28, 15%) in 2007, 2009 and 2011 respectively (Table 5a). The marsh surface gently slopes along both of those lines towards the creek facilitating subsurface drainage from the creek bank, which accounts for the lower water contents (Table 5a). At Line 5 Station 3, the marsh surface slopes away from the creek, however, there are still relatively low organic matter and water contents. The trend of highest organic matter content being found along the upland edge is similar to trends found on some marshes (e.g., Cheverie) in the Bay of Fundy, New England and Louisiana (Bowron and Chiasson 2006a,b; Bowron and Chiasson 2007; Delaune et al. 1979 and Ward et al. 1998.).

At the reference site, organic matter content ranged from a low of 12, 9 and 7%, in 2007, 2009 and 2011, at L3S3 near the tidal creek similar to the restoration site to a high of 30, 41 and 29% in 2007, 2009 and 2011, at L1S1 at the upper edge of the marsh (Table 5b). This value is around the mid-range of values found at the restoration site and is similar to unrestricted reference site values found in the Bay of Fundy (Bowron and Chiasson 2006a,b and 2008). The highest and lowest water content values are found associated with the highest and lowest organic matter contents at L1S1 and L3S3 respectively similar to the restoration site (Table 5). L3S3 can drain either through the creek bank or towards the depression area at L3S4.

Dry bulk density decreases with increasing distance from the creek edge at SG. This is similar to what has been found elsewhere in the region (Bowron and Chiasson 2006a,b). Values range from approximately 0.20 $g·cm^{-3}$, 0.10 $g·cm^{-3}$ and 0.12 $g·cm^{-3}$ near the forest edge in 2007, 2009 and 2011 respectively to 0.47 $g·cm^{-3}$, 0.45 $g·cm^{-3}$ and 0.37 $g·cm^{-3}$ at L4S2 adjacent to the creek (Table 5a). At SG-R, along Line 1, bulk density decreased from the creek edge to L1S3 as would be expected and as is observed at other marshes in the region. L1S1 also saw highest bulk densities, which is likely associated with the presence of a creek running parallel to the back edge of the marsh, which could deliver fine sediments in the area. The range of bulk density values in 2011 go from a minimum of 0.13 g·cm^{-3} at L1S1 to a maximum of 0.57 g·cm^{-3} at L3S3, which is directly comparable to the range of values found at the SG restoration site (Table 5). There was a slight decrease in bulk density between 2009 and 2011 with the exception of SG-R_L1S4, which increased by 0.05 g·cm^{-3}. This may be associated with the polymodality[11] observed in the sediments.

Soil bulk density, is an expression of the mass to volume relationship for a given material and it takes into account solid space as well as pore space. In general, as clay content increases, the bulk density should decrease. Since sandy soils have more solid space, they will generally have higher bulk densities. In addition, with an increase in organic matter content, bulk density should decrease. These trends were observed at SG. Both sites have similar mean grain sizes of approximately 27-28 microns in the coarse silt range (Table 6) (Blott and Pye 2001). There was a slight fining of sediments between 2007 and 2009, which may explain the decrease in bulk density between those years. This will have implications for the nutrient holding ability of the soil adjacent to the tidal creek networks (Delaune et al. 1979).

Comparison of grain size statistics between 2011 and all other years was not directly possible due to the different instruments (and principles) used in their analyses. The pre-restoration, Year 1 and Year 3 samples were coarser than Year 5 samples which could simply be a reflection of being analyzed with a Coulter Laser Particle Size Analyzer at Mount Allison University as compared to the Coulter Multiziser 3^{tm} used by In_CoaST (McCave et al. 1996) (Table 6). However, spatial variations in grain size parameters within a site and between restoration and reference sites within a year are still possible. The dominant sediment type at SG was medium to very coarse silt according to the modified Udden-Wentworth Grain size classification scheme (Blott and Pye 2001) (Table 6a, Figure 33) in 2007 and 2009. As expected due to the change in analytical methods, mean grain sizes decreased and fell into the medium silt class in 2011. There was a general increase in the proportion of fines between 2007, 2009 and 2011, and shift in folk size classification (Table 6a). In 2009, the smallest grain sizes (medium silt range) were found at L1S2 and L5S2 adjacent to the tidal creek. In 2011, the smallest grain size was recorded at L1S2 near the creek and L4S2 near the forest edge (Table 7). The largest was found in both years at L4S2, however in 2011, this station recorded the lowest mean grain size. Interestingly, the largest grain size in 2011 was recorded at L5S2 adjacent to the creek (Table 8). Both L4S2 and L5S3 had bimodal grain size distributions and are located adjacent to the tidal creek which suggests they have experienced different sediment transport mechanisms. These could either represent ice deposition, overwash events during spring run-off, or altered hydrology patterns resulting from presence of beaver (dams) in this part of the marsh. All samples in 2011 were classified as

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[11] Sediment derived from a single transport mechanism typically follows a simple modal distribution (normal distribution; one hump); polymodality means more than one 'hump' or peak which reflects different sediment populations. This typically means an additional source of material or transport mechanism or both (e.g. storm deposit).

polymodal, however this is likely due to the Coulter analysis method rather than a change in processes controlling sediment deposition.

Table 6 Comparison of grain size characteristics for a) SG and b) SG-R from 2007 and 2009 (Coulter Laser instrument) and 2011 (Coulter Multisizer instrument – produced smaller size classes). Classification based on modified Udden-Wentworth scale. Elevation expressed relative to CGVD28. Size = mean grain size; Folk = folk classification, mod= modality f. silt = fine silt, m.silt = medium silt, c.silt = coarse silt, vc.silt = very coarse silt, vf.sand = very fine sand, f. sand = fine sand. Uni = unimodal; bi = bimodal, poly= polymodal.

a)		**2007**			**2009**			**2011**		
ID	**Elev (m)**	**Size (µm)**	**Folk**	**Mod**	**Size (µm)**	**Folk**	**Mod**	**Size (µm)**	**Folk**	**Mod**
SGL1S2	0.47	18.96	c.silt	uni	11.25	m.silt	uni	5.6	m.silt	poly
SGL4S1	0.75	28.26	c.silt	uni	19.09	c.silt	Uni	6.6	m.silt	poly
SGL4S2	0.58	51.9	Vc.silt	bi	24.47	c.silt	Bi	5.9	m.silt	poly
SGL5S1	0.52	31.75	Vc.silt	uni	15.03	m.silt	Uni	8.7	m.silt	poly
SGL5S2	0.73	34.76	Vc.silt	uni	17.53	c.silt	Uni	8.2	m.silt	poly
SGL5S3	0.76	27.25	c.silt	bi	23.47	c.silt	bi	6.9	f.silt	poly
b) **ID**	**Elev (m)**	**Size (µm)**	**Folk**	**Mod**	**Size (µm)**	**Folk**	**Mod**	**Size (µm)**	**Folk**	**Mod**
SGRL1S2	0.81	27.25	c.silt	Bi	13.32	m.silt	Uni	6.5	m.silt	poly
SGRL1S3	0.78	36.46	Vc.silt	Uni	21.61	c.silt	Uni	6.3	m.silt	poly
SGRL1S4	0.74	42.75	Vs.silt	Bi	21.82	c.silt	Uni	6.0	m.silt	poly
SGRL3S2	0.64	38.36	Vc.silt	Uni	21.10	c.silt	Uni	6.9	m.silt	poly
SGRL3S3	0.66	100.4	vf.sand	Bi	35.39	Vc.silt	Poly	5.6	f.silt	poly
SGRL5S3	0.88	43.94	Vc.silt	bi	20.19	c.silt	uni	7.2	m.silt	poly

The sediments at SG-R were slightly coarser than those found at the restoration site, falling primarily in the very coarse silt class with some very fine sand. The cores appear to contain higher amounts of fines in 2009 compared with 2007 and a general decrease in grain size classification by one class (e.g. shift from very coarse silt to coarse silt) (Figure 33). In 2009 and 2011, the smallest mean grain sizes were 13 µm and 6.0 µm found at L1S1 and L1S4 respectively (Table 9; Table 10). The coarsest were located at the edge of the creek at L3S3 and L3S5 in 2009 and 2011 respectively (Table 6b; Table 10). Interestingly, L3S3 had the coarsest fraction in 2009 yet the same station exhibited the finest fraction in 2011. Based on the Coulter analysis, there was very little variation in grain size composition between stations at the reference site (Table 6b; Table 9; Table 10) and more variation at the restoration site (Table 6a; Table 7; Table 8). Based on the digital elevation model, there appears to be a clear creek levee which has developed over time due to spring overwash events and explains the polymodality of the sample.

Overall, based on the changing sediment characteristics over time, SG is trending towards the conditions displayed at the reference site, however, will retain some differences due to differences in elevation range and marsh width. The lack of accretion or surface elevation change data however precludes our ability to accurately project the trajectory of the marsh surface and comment on its fate relative to sea level rise. A series of RSET (Rod Sediment Elevation Tables) and Marker Horizons[12] would need to be installed in order to obtain this data, and it was decided at the onset of the project that these would not be installed due to the (small) size and location (upper portion of the estuary) of the site.

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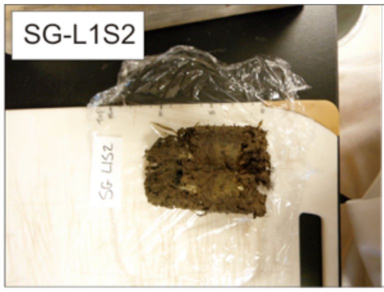
[12] www.pwrc.usgs.gov/set/

Table 7 Sediment Characteristics based on Coulter Multisizer Particle Size Analysis from core samples L1S2, L4S1 and L4S2 at SG; Sediment characterization determined using Folk and Ward method in GRADISTAT (Blott and Pye 2001).

	L1S2	L4S1	L4S2
ANALYST AND DATE:	In_CoaST, Feb 25, 2012	In_CoaST, Feb 25, 2012	In_CoaST, Feb 25, 2012
SIEVING ERROR:			
SAMPLE TYPE:	Polymodal, Poorly Sorted	Polymodal, Poorly Sorted	Polymodal, Poorly Sorted
TEXTURAL GROUP:	Mud	Mud	Mud
SEDIMENT NAME:	Medium Silt	Fine Silt	Medium Silt
MEAN ($\bar{x}_a$):	5.645	6.629	5.911
SORTING (σ_I):	2.539	2.845	2.732
SKEWNESS (Sk_G):	-0.061	0.026	-0.020
KURTOSIS (K_G):	0.848	0.833	0.841
MEAN:	Fine Silt	Fine Silt	Fine Silt
SORTING:	Poorly Sorted	Poorly Sorted	Poorly Sorted
SKEWNESS:	Fine Skewed	Symmetrical	Symmetrical
KURTOSIS:	Platykurtic	Platykurtic	Platykurtic
% GRAVEL:	0.000	0.000	0.000
% SAND:	0.000	0.045	0.000
% MUD:	100.000	99.955	100.000
% V COARSE GRAVEL:	0.000	0.000	0.000
% COARSE GRAVEL:	0.000	0.000	0.000
% MEDIUM GRAVEL:	0.000	0.000	0.000
% FINE GRAVEL:	0.000	0.000	0.000
% V FINE GRAVEL:	0.000	0.000	0.000
% V COARSE SAND:	0.000	0.000	0.000
% COARSE SAND:	0.000	0.000	0.000
% MEDIUM SAND:	0.000	0.000	0.000
% FINE SAND:	0.000	0.000	0.000
% V FINE SAND:	0.000	0.045	0.000
% V COARSE SILT:	1.782	6.771	3.669
% COARSE SILT:	11.897	15.199	15.866
% MEDIUM SILT:	25.731	21.924	22.846
% FINE SILT:	24.931	23.402	21.767
% V FINE SILT:	21.794	20.614	21.206
% CLAY:	13.864	12.046	14.646



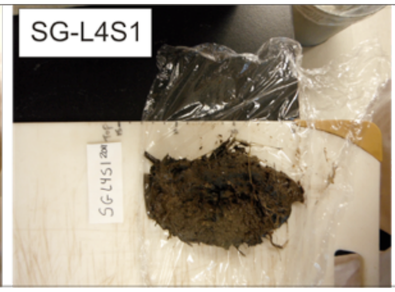


Table 8 Sediment Characteristics based on Coulter Multisizer Particle Size Analysis from core samples L5S1, L5S2 and L5S3 at SG. Sediment characterization determined using Folk and Ward method in GRADISTAT (Blott and Pye 2001).

	L5S1	L5S2	L5S3
ANALYST AND DATE:	In_CoaST, Feb 25, 2012	In_CoaST, Feb 25, 2012	In_CoaST, Feb 25, 2012
SIEVING ERROR:			
SAMPLE TYPE:	Polymodal, Poorly Sorted	Polymodal, Poorly Sorted	Polymodal, Poorly Sorted
TEXTURAL GROUP:	Mud	Mud	Mud
SEDIMENT NAME:	Medium Silt	Medium Silt	Medium Silt
MEAN ($\bar{x}_a$):	8.727	8.204	6.919
SORTING (σ_I):	3.122	3.123	2.924
SKEWNESS (Sk_G):	-0.041	-0.057	-0.028
KURTOSIS (K_G):	0.852	0.830	0.818
MEAN:	Medium Silt	Medium Silt	Fine Silt
SORTING:	Poorly Sorted	Poorly Sorted	Poorly Sorted
SKEWNESS:	Symmetrical	Symmetrical	Symmetrical
KURTOSIS:	Platykurtic	Platykurtic	Platykurtic
% GRAVEL:	0.000	0.000	0.000
% SAND:	1.456	1.646	0.101
% MUD:	98.544	98.354	99.899
% V COARSE GRAVEL:	0.000	0.000	0.000
% COARSE GRAVEL:	0.000	0.000	0.000
% MEDIUM GRAVEL:	0.000	0.000	0.000
% FINE GRAVEL:	0.000	0.000	0.000
% V FINE GRAVEL:	0.000	0.000	0.000
% V COARSE SAND:	0.000	0.000	0.000
% COARSE SAND:	0.000	0.000	0.000
% MEDIUM SAND:	0.000	0.000	0.000
% FINE SAND:	0.000	0.000	0.000
% V FINE SAND:	1.456	1.646	0.101
% V COARSE SILT:	13.087	10.424	7.213
% COARSE SILT:	19.418	20.160	18.602
% MEDIUM SILT:	20.594	20.699	22.288
% FINE SILT:	19.455	19.679	20.914
% V FINE SILT:	16.194	16.833	18.439
% CLAY:	9.797	10.559	12.442

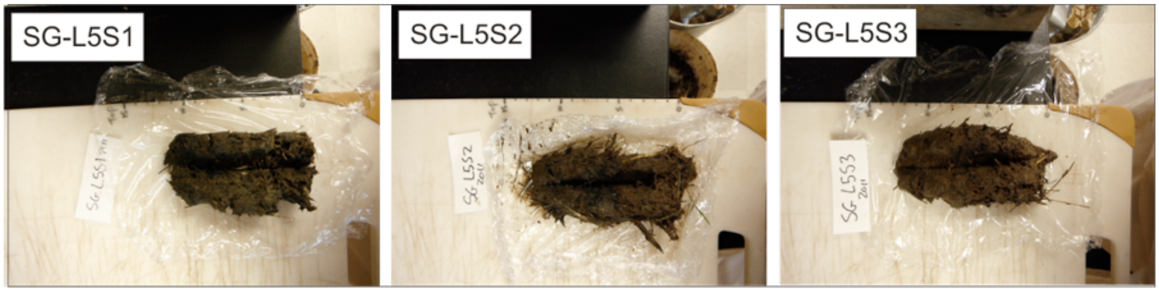
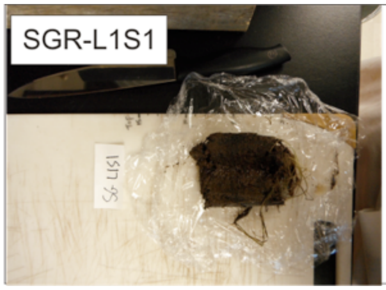
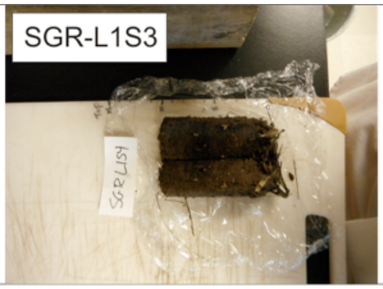


Table 9 Sediment Characteristics based on Coulter Multisizer Particle Size Analysis from core samples L1S1, L1S3 and L1S4 at SG-R. Sediment characterization determined using Folk and Ward method in GRADISTAT (Blott and Pye 2001).

	L1S1	L1S3	L1S4
ANALYST AND DATE:			
SIEVING ERROR:			
SAMPLE TYPE:	Polymodal, Poorly Sorted	Polymodal, Poorly Sorted	Polymodal, Poorly Sorted
TEXTURAL GROUP:	Mud	Mud	Mud
SEDIMENT NAME:	Medium Silt	Medium Silt	Medium Silt
MEAN ($\bar{x}_a$):	6.462	6.276	6.022
SORTING (σ_G):	2.587	2.635	2.605
SKEWNESS (Sk_G):	-0.087	-0.095	-0.075
KURTOSIS (K_G):	0.868	0.819	0.877
MEAN:	Fine Silt	Fine Silt	Fine Silt
SORTING:	Poorly Sorted	Poorly Sorted	Poorly Sorted
SKEWNESS:	Symmetrical	Fine Skewed	Symmetrical
KURTOSIS:	Platykurtic	Platykurtic	Platykurtic
% GRAVEL:	0.000	0.000	0.000
% SAND:	0.000	0.000	0.000
% MUD:	100.000	100.000	100.000
% V COARSE GRAVEL:	0.000	0.000	0.000
% COARSE GRAVEL:	0.000	0.000	0.000
% MEDIUM GRAVEL:	0.000	0.000	0.000
% FINE GRAVEL:	0.000	0.000	0.000
% V FINE GRAVEL:	0.000	0.000	0.000
% V COARSE SAND:	0.000	0.000	0.000
% COARSE SAND:	0.000	0.000	0.000
% MEDIUM SAND:	0.000	0.000	0.000
% FINE SAND:	0.000	0.000	0.000
% V FINE SAND:	0.000	0.000	0.000
% V COARSE SILT:	3.638	2.961	3.130
% COARSE SILT:	16.184	16.808	13.437
% MEDIUM SILT:	26.685	25.589	25.531
% FINE SILT:	24.004	22.658	24.640
% V FINE SILT:	18.650	19.532	20.479
% CLAY:	10.838	12.452	12.783





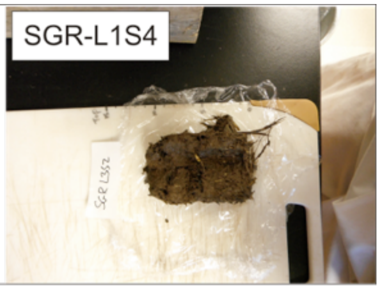
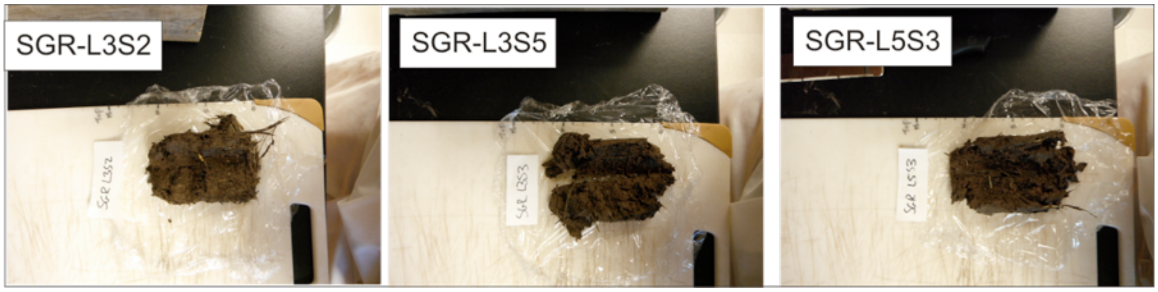


Table 10 Sediment Characteristics based on Coulter Multisizer Particle Size Analysis from core samples L3S2, L3S5 and L5S3 at SG-R. Sediment characterization determined using Folk and Ward method in GRADISTAT (Blott and Pye 2001).

	L3S2	L3S3	L5S3
ANALYST AND DATE:			
SIEVING ERROR:			
SAMPLE TYPE:	Polymodal, Poorly Sorted	Polymodal, Poorly Sorted	Polymodal, Poorly Sorted
TEXTURAL GROUP:	Mud	Mud	Mud
SEDIMENT NAME:	Medium Silt	Fine Silt	Medium Silt
MEAN ($\bar{x}_a$):	6.445	6.336	6.242
SORTING (σ_G):	2.733	2.683	2.695
SKEWNESS (Sk_G):	-0.056	-0.070	-0.019
KURTOSIS (K_G):	0.848	0.833	0.821
MEAN:	Fine Silt	Fine Silt	Fine Silt
SORTING:	Poorly Sorted	Poorly Sorted	Poorly Sorted
SKEWNESS:	Symmetrical	Symmetrical	Symmetrical
KURTOSIS:	Platykurtic	Platykurtic	Platykurtic
% GRAVEL:	0.000	0.000	0.000
% SAND:	0.062	0.061	0.036
% MUD:	99.938	99.939	99.964
% V COARSE GRAVEL:	0.000	0.000	0.000
% COARSE GRAVEL:	0.000	0.000	0.000
% MEDIUM GRAVEL:	0.000	0.000	0.000
% FINE GRAVEL:	0.000	0.000	0.000
% V FINE GRAVEL:	0.000	0.000	0.000
% V COARSE SAND:	0.000	0.000	0.000
% COARSE SAND:	0.000	0.000	0.000
% MEDIUM SAND:	0.000	0.000	0.000
% FINE SAND:	0.000	0.000	0.000
% V FINE SAND:	0.062	0.061	0.036
% V COARSE SILT:	4.392	3.774	4.191
% COARSE SILT:	16.568	15.379	15.744
% MEDIUM SILT:	23.924	24.674	23.367
% FINE SILT:	22.922	23.819	23.217
% V FINE SILT:	19.650	19.697	20.485
% CLAY:	12.481	12.596	12.958



Grain Size		Descriptive term	
phi	mm		
		Very Large	Boulder
-10	1024		
		Large	
-9	512		
		Medium	
-8	256		
		Small	
-7	128		
		Very small	
-6	64		
		Very coarse	Gravel
-5	32		
		Coarse	
-4	16		
		Medium	
-3	8		
		Fine	
-2	4		
		Very fine	
-1	2		
		Very coarse	Sand
0	1		
	microns	Coarse	
1	500		
		Medium	
2	250		
		Fine	
3	125		
		Very fine	
4	63		
		Very coarse	Silt
5	31		
		Coarse	
6	16		
		Medium	
7	8		
		Fine	
8	4		
		Very fine	
9	2		
		Clay	

Figure 33 Size scale adopted in the GRADISTAT program, modified from Udden (1914) and Wentworth (1922) (Blot and Pye 2001).

4.4 Vegetation

There were very few changes notable over time (2007 to 2011) in species composition, abundance and frequency (Table 11; Table 12). Species abundances are very consistent across years for both sites (Table 11). Species frequencies show little change in the spatial extent in both sites (Table 12). Note that due to sampling variability, small changes in both metrics are expected from year to year even when there is no real ecological change occurring, especially with small or uncommon species. The NMDS ordination shows overall similarities across years between the two sites (Figure 34), but plots from 2007 and 2011 only show that the study site (SG) has become more similar to the reference site (SG-R) over time (Figure 35). These trends do not show up as statistically significant (Table 13), likely because only a small number of plots at the reference site have shifted over time (this is one of the reasons why the site-level summary tables (Table 11; Table 12) are insufficient to capture these trends. The main detectable differences are more plots at the reference site containing high marsh vegetation (*Juncus gerardii*, *Spartina patens*, *Solidago sempervirens,* etc.).

Richness, halophyte richness and abundance were all significantly higher at the reference site (Figure 36 to Figure 38; Table 14 to Table 16), and the repeated measures ANOVAs showed only one change over the five years of the experiment: in 2009, halophyte abundance was lower than normal at the reference site (site x year interaction (Table 16). However, for the reference site, the overall picture is one of stasis. The study site had greater unvegetated area across all years (Figure 39; Table 17). Overall, there was little evidence of directional change over time for any of the vegetation variables at the study site. As indicated in the Year 3 post-restoration monitoring report, changes in species composition at SG largely occurred over the first two years following restoration (2006 and 2007) and consisted of a loss of terrestrial species and an expansion of halophytes within the site (Bowron et al. 2010). This relative stability in vegetation community structure in the later years of the monitoring program was represented in the surface cover maps for the site (Figure 25) and the annual landscape photographs taken as part of the vegetation survey (Figure 40).

While salt marsh vegetation was present over much of the study site five years following restoration, there was no evidence of an increase in overall wetland area. The continued differences in vegetation community structure between restoration and reference five years following culvert replacement, was more likely the result of the positioning of the two sites within their respective estuaries (SG occurs at a higher relative elevation) and morphological differences (SG-R is larger/wider/longer) rather than a failure of the restoration measures to allow for sufficient tidal flow.

Table 11 Mean species abundances (# contact points/m^2 (out of a maximum of 25)).

	SG07	**SG-R07**	**SG08**	**SG-R08**	**SG09**	**SG-R09**	**SG11**	**SG-R11**
Acer rubrum	0.01							
Agrostis stolonifera	3.25	4.81	4.66	4.68	6.16	4.27	5.15	5.47
Algae					0.16			
Angelica sp.		0.01		0.05				

	SG07	**SG-R07**	**SG08**	**SG-R08**	**SG09**	**SG-R09**	**SG11**	**SG-R11**
*Aster.*sp								0.09
Atriplex glabrisculata	0.05	0.08	0.05	0.01	0.05	0.10		0.18
Calystegia sepium	0.36	0.48	1.21	1.36	1.32	1.27	0.61	0.47
Carex hormathodes	0.05		0.20	0.01	0.05	0.01	0.20	
Carex palacea	8.16	11.71	6.95	12.32	8.84	12.01	9.00	14.15
Elymus repens	0.61		0.05	0.10	0.11	0.14	0.45	
Elymus trachycaulis						0.19		0.27
Festuca rubra	0.75	4.15	0.65	4.64	0.74	6.59	1.25	1.73
Glaux maritima								0.09
Hierochloe odorata	1.15	0.48	1.20	0.45	0.05	0.36	0.65	0.36
Juncus balticus	1.60	0.29	1.85	0.32	1.89	0.27	1.26	0.01
Juncus gerardii	1.65	9.33	0.70	7.51	1.16	4.92	1.10	10.59
Lathyrus palustris	0.35	0.14		0.18	0.01			
Oxalis sp.				0.01				
Picea glauca	0.45				0.11		0.15	
Polygonum sagittatum			0.01		0.11			
Potentilla anserina	0.10	4.24	0.03	4.74	0.11	3.25		6.00
Rosa virginiana			0.10					
Scirpus acutus			0.01		0.01		0.65	
grass	0.01							
Solidago sempervirens		1.30		0.47		1.09		2.41
Spartina alterniflora	9.95	7.52	8.55	5.77	8.89	6.82	9.95	7.82
Spartina patens	1.70	3.43	0.98	4.55	0.47	2.91		2.68
Spartina pectinata	6.95	5.54	6.85	8.86	6.95	8.95	7.80	5.59
Symphotrichum lanceolatum			0.05	0.33				
S. novi-belgii	0.31	2.38	0.06	2.00	0.43	3.41	0.55	2.82
Teucrium canadense				0.05		0.01		
Vicia sp.			0.05	0.41	0.05	0.55		

Table 12 Species frequencies (total # of plots where species was encountered).

	SG07	SG-R07	SG08	SG-R08	SG09	SG-R09	SG11	SG-R11
Acer rubrum	1	0	0	0	0	0	0	0
Agrostis stolonifera	6	9	8	11	8	6	8	11
Algae	0	0	0	0	1	0	0	0
Angelica sp.	0	1	0	1	0	0	0	0
*Aster.*sp	0	0	0	0	0	0	0	1
Atriplex glabrisculata	1	4	1	1	1	3	0	2
Calystegia sepium	2	1	3	4	2	4	3	3
Carex hormathodes	1	0	1	1	1	1	1	0
Carex palacea	10	15	10	15	9	16	10	16
Elymus repens	3	0	1	2	1	2	2	0
Elymus trachycaulis	0	0	0	0	0	2	0	2
Festuca rubra	2	12	1	6	3	8	3	2
Glaux maritima	0	0	0	0	0	0	0	1
Hierochloe odorata	3	2	2	1	1	2	3	1
Juncus balticus	2	1	3	2	3	1	3	1
Juncus gerardii	3	12	2	10	2	9	3	11
Lathyrus palustris	2	1	0	1	1	0	0	0
Oxalis sp.	0	0	0	1	0	0	0	0
Picea glauca	1	0	0	0	1	0	1	0
Polygonum sagittatum	0	0	1	0	1	0	0	0
Potentilla anserina	2	10	2	11	1	12	0	13
Rosa virginiana	0	0	1	0	0	0	0	0
Scirpus acutus	0	0	1	0	1	0	1	0
grass	1	0	0	0	0	0	0	0
Solidago sempervirens	0	5	0	5	0	7	0	7
Spartina alterniflora	12	10	10	9	11	9	13	9
Spartina patens	3	6	4	10	2	8	0	3
Spartina pectinata	8	11	8	13	8	11	10	9
Symphotrichum lanceolatum	0	0	1	2	0	0	0	0
S. novi-belgii	3	6	2	5	3	6	2	5
Teucrium canadense	0	0	0	1	0	1	0	0
Vicia sp.	0	0	1	1	1	2	0	0

Table 13 Multivariate repeated measures ANOVA comparing species abundances between Smith Gut study and reference sites across years.

	Df	Sum Sq	Mean Sq	F	P
Site	1	3.07	3.07	10.59	0.25
Year	1	0.11	0.11	0.37	0.17
Site X Year	1	0.07	0.07	0.24	0.43
Residuals	161	46.64	0.29		

Table 14 Repeated measures ANOVA comparing mean plot species richness between SG and SG-R across years.

Between-subject effects

	Df	Sum Sq	Mean Sq	F	P
Site	1	117.0	117.05	8.870	0.005
Year	2	12.9	6.47	0.490	0.62
Site x Year	1	9.1	9.11	0.691	0.41
Residuals	38	501.4	13.20		
Within-subject effects					
Year	3	4.61	1.535	1.268	0.289
Site X Year	3	3.66	1.221	1.009	0.392
Residuals	117	141.65	1.211		

Table 15 Repeated measures ANOVA comparing mean plot halophyte species richness between Smith gut study and reference sites across years.

Between-subject effects

	Df	Sum Sq	Mean Sq	F	P
Site	1	56.53	56.53	14.84	0.000437
Year	2	16.59	8.30	2.17	0.13
Site X Factor	1	10.95	10.95	2.875	0.10
Residuals	38	144.77	3.81		
Within-subject effects					
Year	3	0.61	0.20	0.48	0.70
Site X Year	3	0.08	0.0275	0.06	0.98
Residuals	117	49.31	0.4215		

Table 16 Repeated measures ANOVA comparing mean plot halophyte species abundance between SG and SG-R across years.

Between-subject effects						
		Df	Sum Sq	Mean Sq	F	P
Site	1	10689	10689	12.21	0.00123	
Year	2	556	278	0.32	0.73	
Site X Year	1	2056	2056	2.349	0.13	
Residuals	38	33275	876			
Within-subject effects						
Year	3	909	303.06	3.799	0.0122	
Site X Year	3	779	259.59	3.254	0.0242	
Residuals	117	9333	79.77			

Table 17 Repeated measures ANOVA comparing mean unvegetated area between SG and SG-R across years.

Between-subject effects					
	Df	Sum Sq	Mean Sq	F	P
Site	1	182.0	182.03	4.56	0.04
Year	2	14.8	7.39	0.18	0.83
Site X Year	1	0.0	0.02	0.00	0.98
Residuals	38	1517.9	39.94		
Within-subject effects					
Year	3	32.5	10.84	1.095	0.35
Site X Year	3	37.8	12.61	1.27	0.28
Residuals	117	1158.9	9.90		

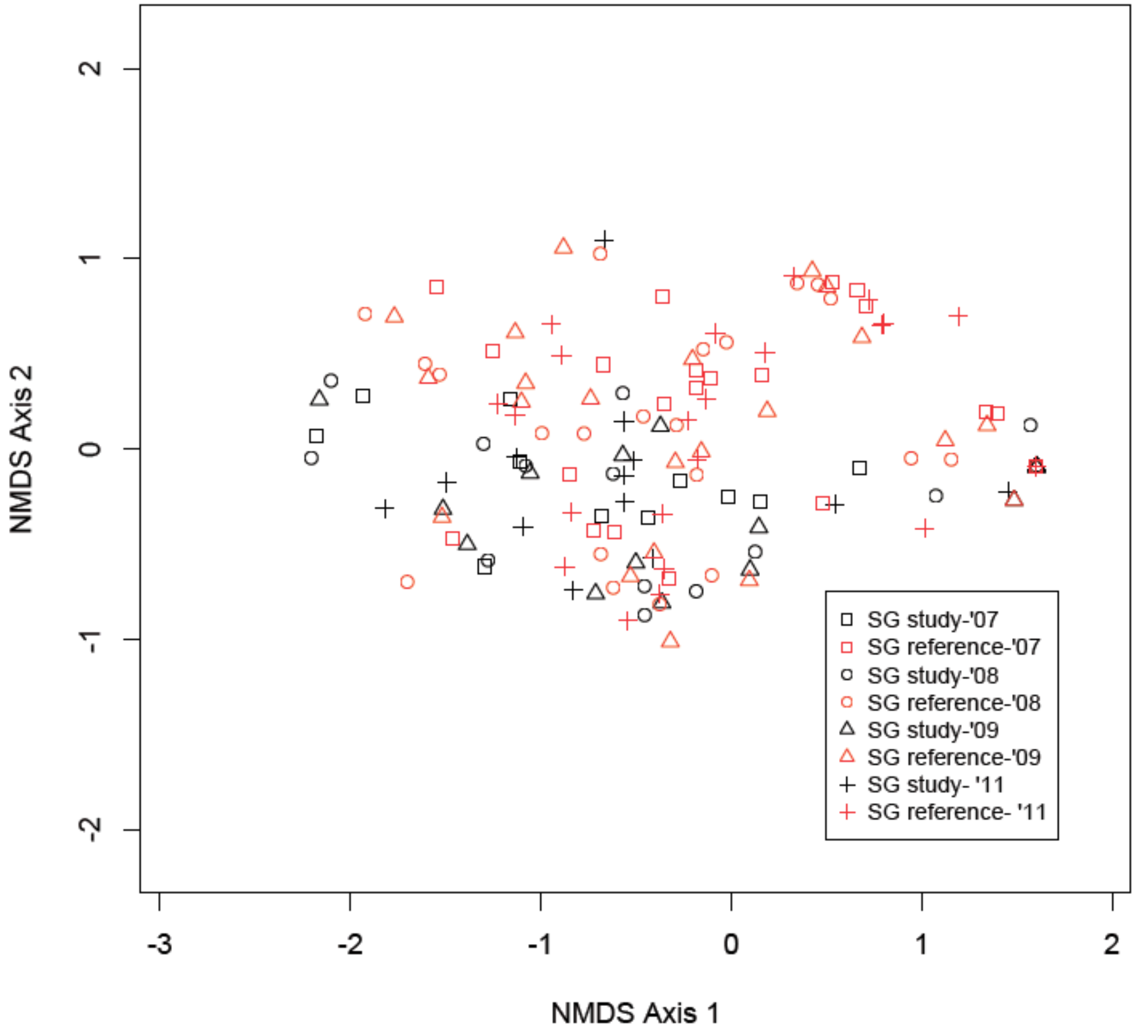
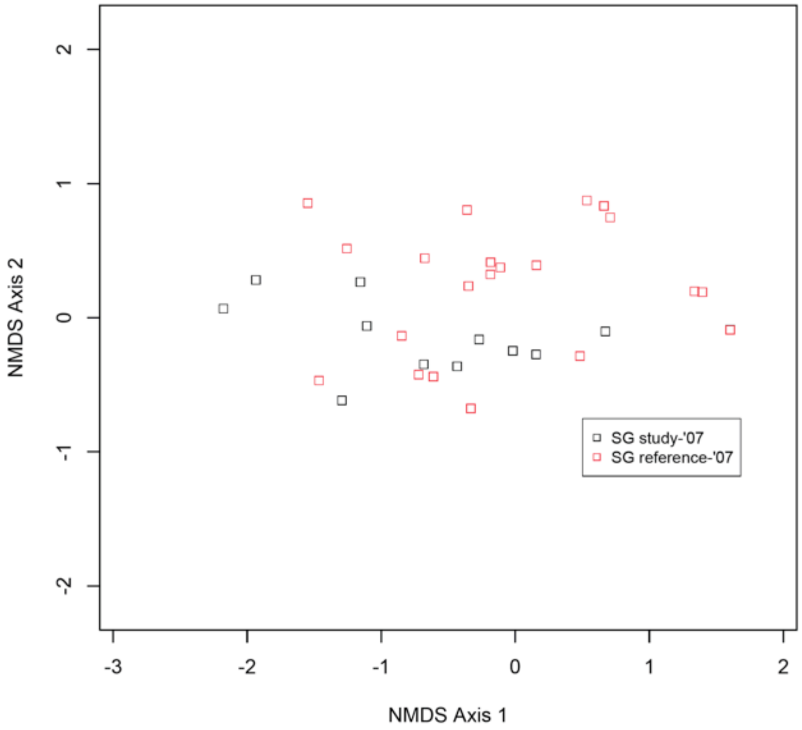
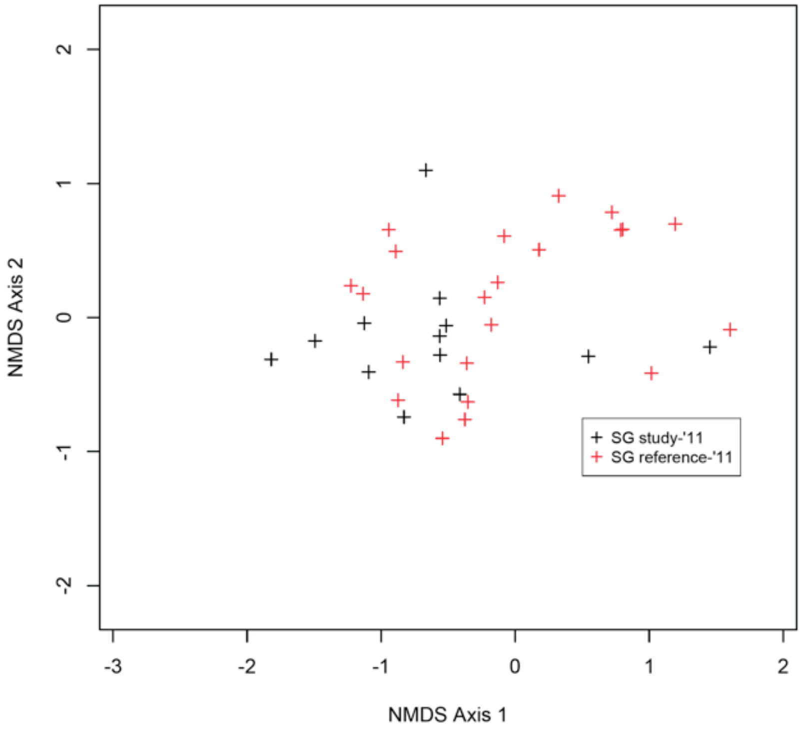


Figure 34 Non-metric multidimensional scaling ordination of plots at SG and SG-R, showing changes over time (stress=0.13).

a)


2
1
0
-1
-2
NMDS Axis 2
-3
-2
-1
0
1
2
NMDS Axis 1
□ SG study-'07
□ SG reference-'07

b)


2
1
0
-1
-2
NMDS Axis 2
-3
-2
-1
0
1
2
NMDS Axis 1
+ SG study-'11
+ SG reference-'11

c)

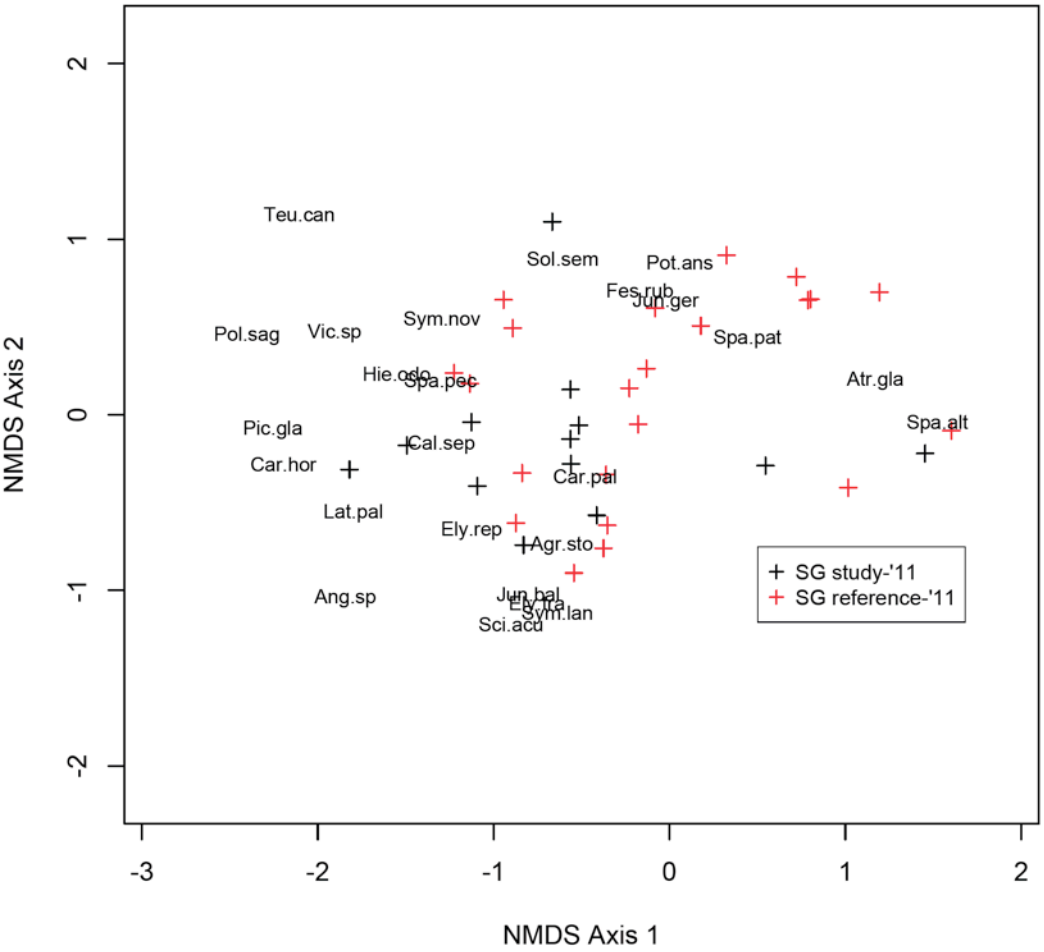


Figure 35 Non-metric multidimensional scaling ordination of plots at SG and SG-R (stress=0.13), showing results from 2007 (a) and 2011 (b) separately; (c) is 2011 data with species labeled within ordination space.

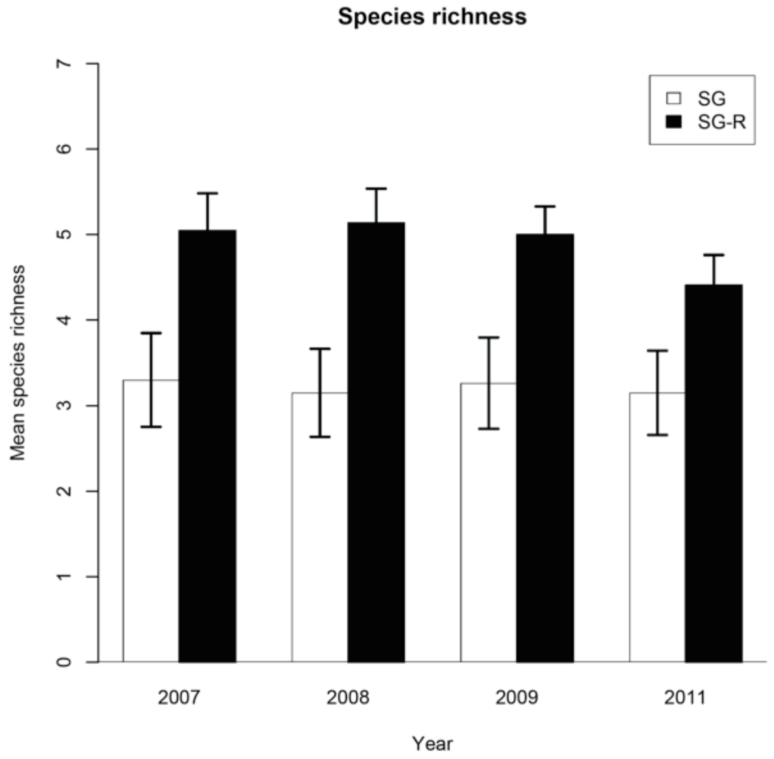


Figure 36 Mean plot species richness (# species/m^2) at SG and SG-R.

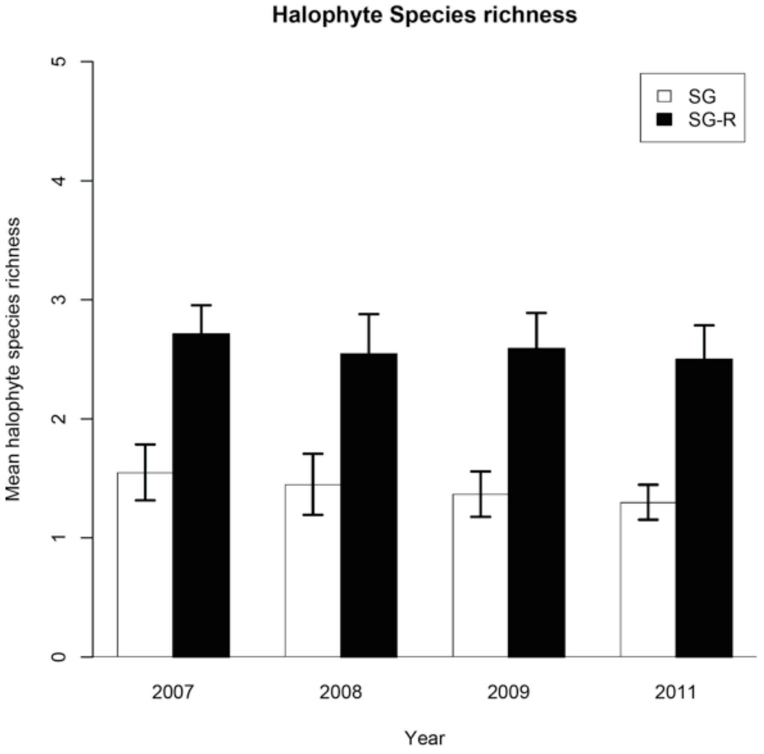


Figure 37 Mean plot halophyte species richness (# species/m^2) at SG and SG-R.

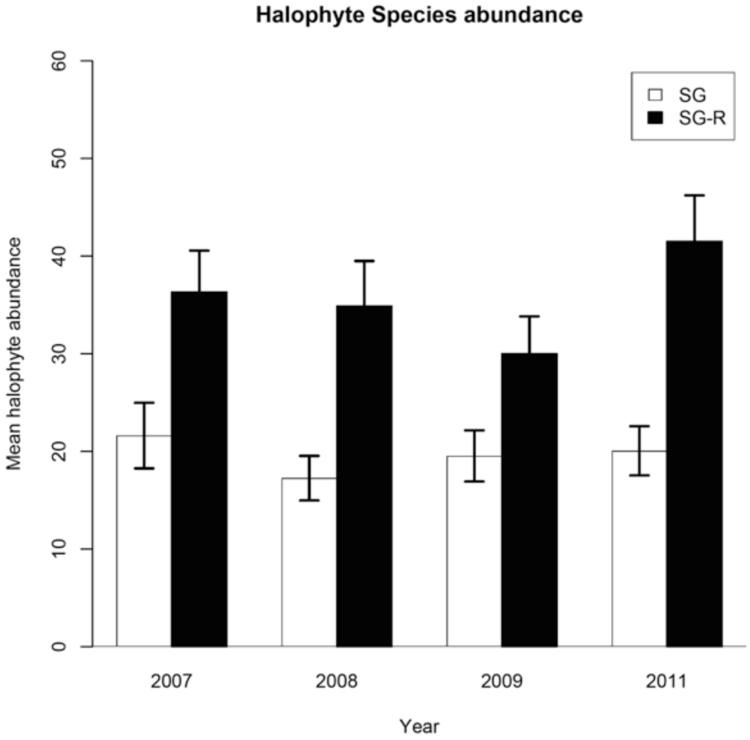


Figure 38 Mean plot halophyte species abundance (# species/m^2) at SG and SG-R.

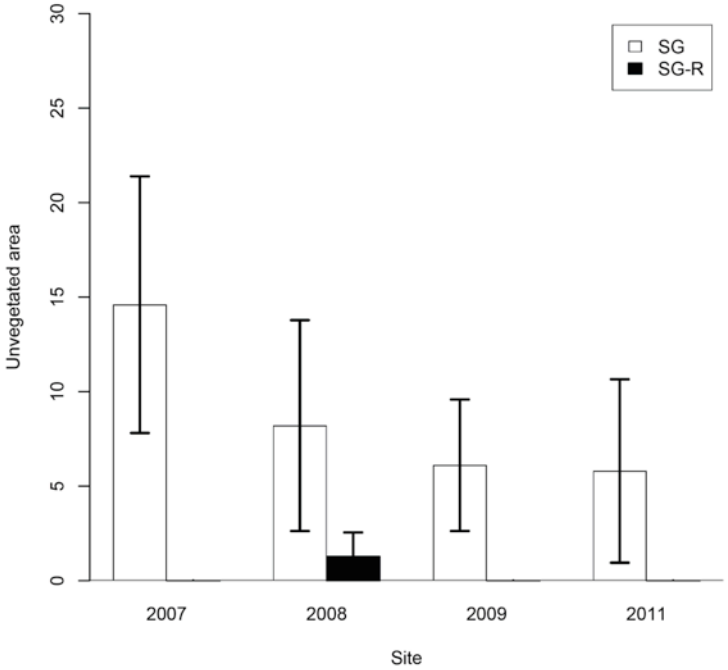


Figure 39 Mean plot unvegetated area (# contacts/m^2) at SG and SG-R.

Figure 40 Change in vegetation cover at Line 5 showing August a) 2008, b) 2009 and c) 2011. Photographs taken by N. Neatt.

4.5 Nekton

Ten fish species and two crustaceans were collected in the channel at SG over the course of the five years of sampling (Table 20). Focusing on the fish species, species richness upstream was equal to or greater than downstream for all years except for 2008 (second year post) (Table 20). Species abundance (number of individuals) was greatest the first year following restoration (2007), with the lowest abundance observed before restoration (Table 19). This is misleading as the sampling methodology (equipment type and number of sampling events) used by Hulbert (2007) was different. Considering only the post-restoration data, the increased density over the first one to three years following restoration is consistent with findings of other culvert replacement projects (Bowron et al. 2011; Konisky et al. 2006). The higher number of species and density of fish upstream of the causeway for most years, may, in part, be due to the concentration of fish in the more confined (narrow, shallower channel) area upstream of the causeway and thus more readily captured. As has been observed at other culvert replacement projects, the decline in density over the five years following restoration both upstream and downstream of the causeway may be connected to the changes in habitat conditions; i.e., increased density, height and extent of coverage by halophytic vegetation (Neatt et al. 2010).

Of the two larger charismatic species captured by Hulbert (2007) prior to restoration, American Eel (*Anquilla rostrata*) and White Perch (*Morone Americana*), only the American Eel was encountered following restoration. A single individual was observed downstream of the causeway during one of the summer fish sampling events in 2008. A juvenile flounder (*Pleuronectidae*) was captured upstream in 2009.

Table 18 Nektonic species captured downstream (D) and upstream (U) at SG during the pre- and post-restoration sampling programs.

Common Name	Species Name	2006*	2007	2008	2009	2011
Atlantic silverside	*Menidia menidia*		D/U	D	U	D/U
Black spotted stickleback	*Gasterosteus wheatlandi*	D/U				
3-spine stickleback	*Gasterosteus aculeatus*	U	D/U	D/U	D/U	D/U
4-spine stickleback	*Apeltes quadracus*	D/U	D/U		U	D
9-spine stickleback	*Pungitius pungitius*		D/U	D	U	U
Mummichog	*Fundulus heteroclitus*	D/U	D/U	D/U	D/U	D/U
American eel	*Anquilla rostrata*	U				
White perch	*Morone americana*	D				
Flounder	*Pleuronectidae*				U	
Unknown juvenile fish			U			
Green crab	*Carcinus maenus*	D/U	D/U		D/U	D/U
Sand shrimp	*Crangon spp.*	U	D/U	D/U	D/U	D/U
Species Richness (D)		5	7	5	4	6
Species Richness (U)		7	8	3	8	6

*Hulbert 2007.

Fundulus heteroclitus (mummichog) was the dominant fish species encountered both upstream and downstream of the causeway (Table 19). This was a common trend for most of the tidal wetland restoration sites in the province, specifically sites in the Minas Basin (Bowron et al.

20011; Neatt et al. 2011). The mummichog occupied >50% of the catch in all years, and was higher downstream for most years. The Three-spine stickleback (*Gasterosteus aculeatus*) and four-spine stickleback (*Apeltes quadracus*) were the next dominant species (Table 19).

For fish length class frequency (all fish species measured), the majority of individuals sampled in 2007 (one year post) were in the 10 – 40 mm range (Figure 41). In subsequent years (2008, 2009, 2011), the majority of individuals were in the 41 – 70 mm range. In fish, size can be used as an indicator of sexual maturity, which in the case of the species encountered in this study (excluding American Eel, flounder, White Perch), the 41 – 70 mm (and greater) represents the size, or age, of maturity. There did not appear to be a trend of size class to location, with similar numbers and sizes present on either side of the causeway.

Fish are a challenging indicator to sample. Factors such as mobility, seasonal variability, time of day, part of the tidal cycle, sampling method/equipment, location on the marsh, and the vegetation community can dictate what species are caught and may cause considerable variability in sampling results. Despite the challenges inherent in fish sampling, efforts were sufficient to indicate the presence of key species within the restoration site and that the three culverts were allowing for the passage of fish into and out of the restoration site. The absence of representatives of larger species may be the result of the sampling technique (three to four hour sampling period over a single daytime spring tide) rather than the absence of these species. The inclusion of a longer sampling period, or a nighttime sample might yield a broader range of species. However, the risk of fish morality associated with a longer or nighttime sample would be significantly higher. Also, these larger, faster, and more elusive species, in a site like SG, are simply much more difficult to catch. The presence of the range and density of smaller (prey) species, such as mummichog, would suggest that it is likely that the larger (predatory) species are also present in the system.

Two fish species were also captured in the IATs during the invertebrate sampling, with a large abundance of mummichog in the SG-R samples (Table 23). The non-resident nine-spine stickleback was present in small numbers in the SG samples (Table 24).

Table 19 Total number of individuals and percent composition of total catch for SG and SG-downstream, all years.

Species	**Pre 2006***		**Post 2007**		**Post 2008**		**Post 2009**		**Post 2011**	
	SG 2006	**DS 2006**	**SG (n=2)**	**DS (n=2)**	**SG (n=2)**	**DS (n=2)**	**SG (n=2)**	**DS (n=2)**	**SG (n=2)**	**DS (n=2)**
	%	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
Atlantic silverside			4	1		11.4	0.7		1.7	10.2
Three-spine stickleback	8.6		24	17	0.7	17.1	18.1	1.7	12.7	22
Four-spine stickleback	22.9	3.9					16.1			2.8
Black-spotted stickleback	5.7	2.0								
Nine-spine stickleback			8	2		14.3	16.2		0.6	

Species	Pre 2006*		Post 2007		Post 2008		Post 2009		Post 2011	
	SG 2006	DS 2006	SG (n=2)	DS (n=2)	SG (n=2)	DS (n=2)	SG (n=2)	DS (n=2)	SG (n=2)	DS (n=2)
	%	%	%	%	%	%	%	%	%	%
Mummichog	54.3	82.4	64	80	99.3	57.2	48.7	98.3	85	65
American Eel	8.6									
Flounder							0.2			
White perch		3.9								
Total individuals	35	51	1294	3270	428	35	1863	536	300	177
Total species	5	5	4	4	2	2	6	2	4	4

*Hulbert 2007

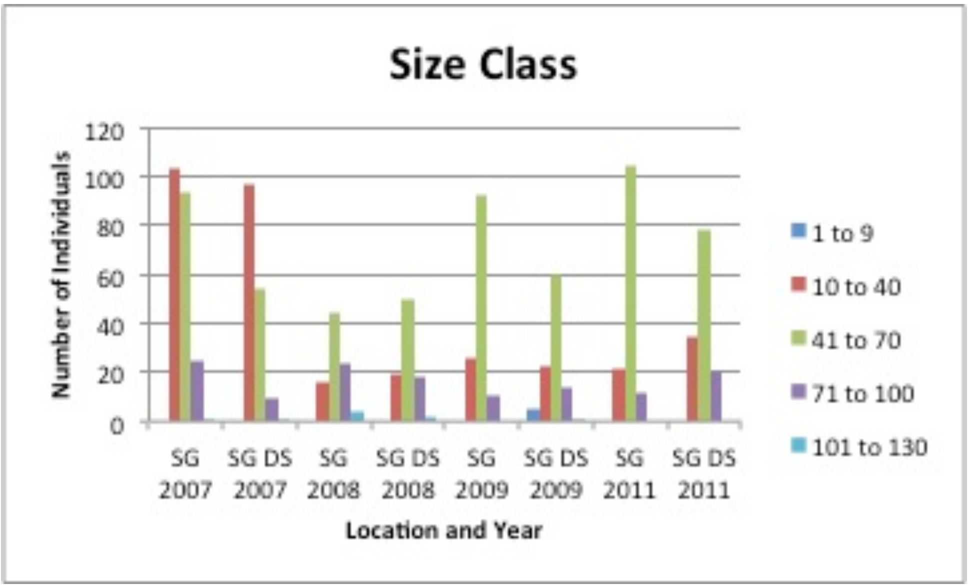


Figure 41 Number of individuals per length class for fish captured, all years and gear type (upstream –SG; downstream – SG DS).

4.6 Benthic and Other Aquatic Invertebrates

Species identifications, abundance, and biomass measures are presented in Table 20 to **Error! Reference source not found.**. Since Ekman samples represent an area of 0.023 m^2, the number of individuals and biomass were multiplied by a factor of 43.5 to give estimates per square metre). Abundance in IAT samples were expressed on a per sample basis. All organisms present (including nektonic species) were included in estimates. It was not possible to do a before and after comparison of invertebrate populations due the absence of pre-restoration invertebrate data.

Benthic Invertebrates

Ekman grab samples from the reference site had low to moderate diversity, abundance and biomass, dominated by the estuarine snail *Hydrobia totteni* at both the panne and river locations. Hemiptera (Corixidae, water boatmen) were also dominant along with *H. totteni*, at the panne site. The river sample (L3 channel) included the polychaete *Nereis diversicolor,* oligochaetes (worms), and the clam *Macoma balthica* (Table 20).

Samples downstream of the restoration site (SGDS) had moderate to high abundance and diversity as well as high biomass of predominantly marine/ estuarine species, dominated by snails, *Hydrobia totteni,* clams *Macoma balthica* and *Mya arenaria,* and oligochaetes (worms). Polychaete worms (*Heteromastus filiformis*, *Nereis diversicolor, Nereis* sp., and *Spio filicornis*), were also among the dominants at the furthest downstream sample (L3S2) (Table 21). A ribbed mussel (*Geukensia demissus*) accounted for the majority of the biomass in the L3S2 sample.

Ekman grab samples from the restoration site had moderate to high abundance and diversity and moderate to high biomass, with the high biomass due to the presence of clams (*Macoma balthica)* at the L3S2 site (Table 22). Dominant species included the gastropod *Hydrobia totteni*, clams (*Macoma balthica* and *Mya arenaria),* polychaete worms, in particular *Nereis diversicolor,* oligochaete worms (mainly at L3S2), the amphipod *Corophium insidiosum,* and Tanaids (the latter two both at site L1S2), and chironomid (midge) larvae. The SGL5 (Panne) sample had high abundance of organisms and a moderate diversity and biomass, and was dominated by the gastropod *Hydrobia totteni*, the polychaete *Heteromastus filformis*, the amphipod *Gammarus tigrinus*, and biting midge larvae (Ceratopogonidae). The sample from the SGL5 Creek site had a low biomass and diversity, and moderate abundance, dominated by Chironomid (midge) larvae, oligochaetes, and amphipods (*Gammarus mucronatus* and *G. tigrinus*?).

Across all post-restoration sampling years, species richness and abundance was highest in the SGDS samples and lowest in the SG-R. This is not unexpected when you consider the differences between the three sites: SGDS being the most estuarine/marine habitat type of the three and SG being the most transitional (salt, brackish, to tidal freshwater) wetland. All three sites had a host of marine/estuarine species, but it was SG that consistently had strong representation by the larval stages of brackish/freshwater insects (diptera - chironomidae).

Aquatic Invertebrates

IAT samples for both sites typically contained a mix of estuarine, freshwater, planktonic, and small (meiofaunal) and macrofaunal invertebrate animals and fish. Dominant species included freshwater insects (water boatmen, Corixidae), estuarine amphipods (*Gammarus tigrinus* and *Gammarus mucronatus*)*,* with meiofaunal and planktonic types (ostracods and copepods: principally cyclopoid) (Table 23). The two sites differed in terms of overall abundance and diversity (generally lower at the SG site; Table 23; Table 24**)** SG-R samples were dominated by the gastropod (*Hydrobia totteni*); juvenile and adult water boatmen (Corixidae); and amphipods (*Gammarus mucronatus* and *Gammarus tigrinus*). Mummichog were also present in the SG-R samples. The SG samples were dominated by the estuarine amphipod *Gammarus tigrinus,* with meiofaunal (ostracods) and planktonic organisms (copepods, principally cyclopoids) important along with juvenile and adult water boatmen (Corixidae) (Table 23).

The trends for species richness and abundance in IAT samples were the opposite of the Ekman dredge samples, with numbers generally being higher for both at the reference site. The presence of a large number of individuals of fish in the 2011 SG-R samples does alter the results for invertebrates, but even with them removed, richness and abundance levels were still higher for SG-R. The greater influence of freshwater on panne conditions at SG (closer to the head of tide) would result in a difference in habitat conditions at the restoration site compared to that of the reference.

Table 20 Abundance of aquatic benthic organisms in sediments from Ekman Dredge samples from SG-R, all years.

	Year 1 Post-Restoration (2007)		**Year 2 Post-Restoration (2008)**		**Year 3 Post-Restoration (2009)**		**Year 5 Post-Restoration (2011)**	
	SGR L3	**SGR L3**	**SGR L3**	**SGR L3**	**SGR L3**	**SGR L3**	**SGR L3**	**SGR L3**
	Panne	**Channel**	**Panne**	**Channel**	**Panne**	**Channel**	**Panne**	**Channel**
GASTROPODA								
Hydrobia totteni	913	-	1784	-	3219	218	870	1044
Oldostomia bisuturalis?	-	-	-	-	-	-	-	-
Aclis? sp.	-	-	-	-	-	-	-	-
Unidentified Gastropod	-	-	-	-	-	-	-	174
BIVALVIA								
Geukensia demissa	-	-	-	-	-	-	-	-
Macoma balthica	-	-	-	-	-	87	-	696
Mya arenaria	-	-	-	-	-	-	-	-
Mytilus sp.	-	-	-	-	-	-	-	-
Nassarius trivittatus	-	-	-	-	-	-	-	-
Unid.	-	-	-	-	-	-	-	-
POLYCHAETA								
Etone longa	-	-	-	-	-	-	-	-
Etone sp. A	-	-	-	-	-	-	-	-
Heteromastus filiformi	-	-	-	-	-	-	-	-
Nereis diversicolor	-	739	-	1392	-	4089		3480
Nereis sp.	-	-	-	-	-	-	-	-
Nereis succinea	-	-	-	-	-	-	-	-
Polychaete unid.	-	-	-	-	-	-	-	-
Polydora cornuta	-	-	-	-	-	-	-	-
Pygospio elegans	-	-	-	-	-	-	-	-
Scoloplos sp.	-	-	-	-	-	-	-	-
Spionidae	-	-	-	-	-	-	-	-
Spio filicornis								
OLIGOCHAETA	-	-	-	305	-	87	-	1740
CRUSTACEA								
Amphipoda								
Corophium insidiosum	-	-	-	-	-	-	-	-
Gammarus sp.	-	87	-	-	-	-	-	-
Gammarus mucronatus	-	-	-	-	-	1131	-	-

	Year 1 Post-Restoration (2007)		Year 2 Post-Restoration (2008)		Year 3 Post-Restoration (2009)		Year 5 Post-Restoration (2011)	
	SGR L3	SGR L3	SGR L3	SGR L3	SGR L3	SGR L3	SGR L3	SGR L3
	Panne	Channel	Panne	Channel	Panne	Channel	Panne	Channel
Gammarus palustris?	-	-	-	522	-	-	-	-
Decapoda								
Crangon septemspinsosa	-	87	-	-	-	-	-	-
Ostracoda	-	87	-	-	-	-	-	-
Tanaidacea	-	-	-	-	-	44	-	-
Turbellaria	-	-	-	-	-	-	-	-
Nemertea	-	-	-	-	-	-	-	-
CIRREPIDA								
Balanus imporvisus								
INSECTA								
Coleoptera-Corixidae	-	-	-	-	392	-	-	-
Diptera-Chironomidae	-	-	-	-	-	-	-	-
Diptera-Ceratopogonidae Culicoides?								
Diptera-Chironomidae larvae	-	-	-	-	-	-	-	-
Diptera larvae (unidentified)	-	-	-	-	-	-	174	-
Hemiptera – Corixidae (adult)	-	-	-	-	-	-	348	-
Hemiptera – Corixidae (juvenile)	-	-	-	-	-	-	174	-
MEIOFAUNA & PLANKTON								
Ostracoda	-	-	-	-	-	-	-	348
ABUNDANCE (#/m^2)	**913**	**1000**	**1784**	**2219**	**3611**	**5656**	**1566**	**7482**
SPECIES/sample	**1**	**4**	**1**	**3**	**2**	**6**	**4**	**6**
BIOMASS (g. wet weight/m^2)	**15.4**	**90.8**	**12.8**	**52**	**31.5**	**39.6**	**3.9**	**28.3**

Table 21 Abundance of aquatic benthic organisms in sediments from Ekman Dredge samples from SG-DS, all years.

	Year 1 Post-Restoration (2007)		Year 2 Post-Restoration (2008)		Year 3 Post-Restoration (2009)		Year 5 Post-Restoration (2011)	
	SGDS L2	SGDS L3	SGDS L2	SGDS L3	SGDS L2	SGDS L3	SGDS L2	SGDS L3
	Creek	Creek	Creek	Creek	Creek	Creek	Creek	Creek
GASTROPODA								
Hydrobia totteni	3828	783	696	6960	20619	19967	1914	3306
Oldostomia bisuturalis?	-	-	-	-	1958	2132	-	348

	Year 1 Post-Restoration (2007)		Year 2 Post-Restoration (2008)		Year 3 Post-Restoration (2009)		Year 5 Post-Restoration (2011)	
	SGDS L2	SGDS L3	SGDS L2	SGDS L3	SGDS L2	SGDS L3	SGDS L2	SGDS L3
	Creek	Creek	Creek	Creek	Creek	Creek	Creek	Creek
Aclis? sp.	-	43	-	-	-	-		
Unidentified Gastropod	-	-	-	-	-	-	-	-
BIVALVIA								
Geukensia demissa	-	-	87	-	-	-	-	44
Macoma balthica	261	739	783	827	1218	740	522	522
Mya arenaria	-	43	-	-	131	87	348	174
Mytilus sp.	-	-	-	-	44	-	-	-
Nassarius trivittatus	-	-	-	-	218	174	-	-
Unid.	-	-	44	-	-	-	-	-
POLYCHAETA								
Etone longa	-	87	-	-	-	783	-	-
Etone sp. A	-	-	-	-	479	-	-	-
Heteromastus filiformi	-	-	-	305	-	44	-	1044
Nereis diversicolor	174	87	261	-	783	435	174	-
Nereis sp.	43	87	-	87	-	-	-	522
Nereis succinea	-	-	-	131	-	-	-	-
Polychaete unid.	-	43	-	-	-	-	-	-
Polydora cornuta	-	-	-	-	87	131	-	-
Pygospio elegans	-	-	-	-	87	87	-	-
Scoloplos sp.	-	-	-	-	-	44	-	-
Spionidae	-	-	-	261	-	-	-	-
Spio filicornis	-	-	-	-	-	-	-	1044
OLIGOCHAETA	-	43	44	1958	261	131		3654
CRUSTACEA								
Amphipoda								
Corophium insidiosum	43	-	-	-	-	-	-	-
Gammarus sp.	-	-	-	-	-	-	-	-
Gammarus mucronatus	-	-	-	-	2001	44	-	-
Gammarus palustris?	-	-	44	-	-	-	-	-
Decapoda								
Crangon septemspinsosa	-	-	87	131	-	-	-	-
Ostracoda	5872	130	131	261	-	218	-	-
Tanaidacea	87	-	696	305	435	44	-	174
Turbellaria	-	-	-	-	87	-	-	-
Nemertea	-	-	-	44	-	44	-	-
CIRREPIDA								
Balanus imporvisus								
INSECTA							-	-
Coleoptera-Corixidae	-	-	-	-	-	-	-	-
Diptera-Chironomidae	609	261	218	4133	-	-	-	-
Diptera-Chironomidae larvae	-	-	-	-	392	-	-	-

	Year 1 Post-Restoration (2007)		**Year 2 Post-Restoration (2008)**		**Year 3 Post-Restoration (2009)**		**Year 5 Post-Restoration (2011)**	
	SGDS L2	**SGDS L3**	**SGDS L2**	**SGDS L3**	**SGDS L2**	**SGDS L3**	**SGDS L2**	**SGDS L3**
	Creek	**Creek**	**Creek**	**Creek**	**Creek**	**Creek**	**Creek**	**Creek**
Diptera larvae (unidentified)	-	-	-	-	-	-	-	-
Hemiptera – Corixidae (adult)	-	-	-	-	-	-	-	-
Hemiptera – Corixidae (juvenile)	-	-	-	-	-	-	-	174
Hemiptera?	-	-	-	44	-	-	-	-
MEIOFAUNA & PLANKTON								
Ostracoda	-	-	-	-	-	-	522	348
ABUNDANCE (#/m^2)	**10918**	**2349**	**3091**	**15447**	**28887**	**25105**	**14268**	**11354**
SPECIES/sample	**8**	**11**	**11**	**13**	**15**	**16**	**6**	**12**
BIOMASS (g. wet weight/m^2)	**56**	**273**	**1075.7**	**407.2**	**1065.5**	**844.3**	**704.0**	**762.1**

Table 22 Abundance of aquatic benthic organisms in sediments from Ekman Dredge samples from SG 2007, 2009 and 2011.

	Year 1 Post-Restoration (2007)				**Year 3e Post-Restoration**				**Year 5 Post-Restoration**			
	SGL1	**SGL3**	**SGL5**	**SGL5**	**SGL1**	**SGL3**	**SGL5**	**SGL5**	**SGL1**	**SGL3**	**SGL5**	**SGL5**
	Creek	**Creek**	**Panne**	**Creek**	**Creek**	**Creek**	**Panne**	**Creek**	**Creek**	**Creek**	**Panne**	**Creek**
GASTROPODA												
Hydrobia totteni	43	130	435	435	5742	34800	8439	2480	2958	25230	1740	
Odostomia bisuturalis ?	-	-	-	-	696	-	-	-				
Aclis? sp.												
Unidentified Gastropod												
BIVALVIA												
Geukensia demissa												
Macoma balthica	261	-	-	-	-	131	-	-		348		
Mya arenaria	-	-	-	-	1305	-	-	-	696			
Mytilus sp.	-	-	-	-	87	-	-	-				
Nassarius trivittatus												
unidentified												
POLYCHAETA												
Capitellidae unidentified									348			
Etone longa	-	-	-	-	87	131	-	-				
Etone sp. A	-	-	-	-		44	-	-				
Heteromastus filiformi											10092	
Nereis diversicolor	174	435	-	348	2175	653	-	218	1740	1044		
Nereis sp.	-	-	-	43	-	-	-	-				
Nereis succinea												
Polychaete unid.												

	Year 1 Post-Restoration (2007)				**Year 3e Post-Restoration**				**Year 5 Post-Restoration**			
	SGL1	**SGL3**	**SGL5**	**SGL5**	**SGL1**	**SGL3**	**SGL5**	**SGL5**	**SGL1**	**SGL3**	**SGL5**	**SGL5**
	Creek	**Creek**	**Panne**	**Creek**	**Creek**	**Creek**	**Panne**	**Creek**	**Creek**	**Creek**	**Panne**	**Creek**
Polydora cornuta												
Pygospio elegans												
Scoloplos sp.												
Spionidae									348			
Spio filicornis												
OLIGOCHAETA	-	43	22011	-	-	-	44	609	174	8178	1044	870
CRUSTACEA												
Amphipoda									696			
Corophium insidiosum	-	-	-	-	2088	-	-	87				
Gammarus tigrinus	-	-	8265	478	-	-	-	-			22098	348
Gammarus sp.	-	-	-	217	-	-	-	-				
Gammarus mucronatus	-	-	-	-	-	131	174	16226				348
Gammarus palustris?	-	-	-	-	-	-	-	-				
Ostracoda	87	304	4176	43	-	609	1958	87				
Tanaidacea	-	-	-	-	15138	-	-	-	5568			
Turbellaria												
Nemertea	-	-	-	-	-	44	-	-				
Hydrachnidia sp.											174	
CIRREPIDA												
Balanus imporvisus	-	-	-	-	87	-	-	-				
INSECTA												
Coleoptera-Corixidae	-	-	-	-	-	131	1001	-				
Diptera-Chironomidae	43	1087	565	435	-	-	-	-				
Diptera-Ceratopogonidae Culicoides?	-	-	-	-	-	-	44	-				
Diptera-Ceratopogonidae	-	-	217	-	-	-	-	-	174		6438	
Diptera-Chironomidae larvae	-	-	-	-	-	2001	3567	23664	1392	1044		4176
Diptera-Chironomidae pupae	-	-	-	-	-	-	44	174				
Diptera-Empididae	-	-	-	-	-	-	218	-				
Diptera-Psychodidae	-	-	43	-	-	-	-	-				
Odonata-Coenagriondae	-	-	-	-	-	44	-	44				
Trichoptera-Limnephilidae	-	-	-	-	-	-	-	-				
Tabanidae	-	-	130	-	-	-	-	-				
Hemiptera?	-	-	87	-	-	-	-	-				

	Year 1 Post-Restoration (2007)				**Year 3e Post-Restoration**				**Year 5 Post-Restoration**			
	SGL1	**SGL3**	**SGL5**	**SGL5**	**SGL1**	**SGL3**	**SGL5**	**SGL5**	**SGL1**	**SGL3**	**SGL5**	**SGL5**
	Creek	**Creek**	**Panne**	**Creek**	**Creek**	**Creek**	**Panne**	**Creek**	**Creek**	**Creek**	**Panne**	**Creek**
Homoptera (juvenile)									174			
ABUNDANCE (#/m^2)	**608**	**1999**	**35929**	**1564**	**27405**	**38719**	**15489**	**43589**	**522**	**17748**	**1566**	**2262**
SPECIES/sample	**5**	**5**	**6**	**6**	**9**	**11**	**9**	**9**	**12**	**6**	**7**	**5**
BIOMASS (g. wet weight/m^2)	**120.2**	**50.1**	**50.4**	**50.4**	**117.9**	**260.2**	**69.8**	**24.3**	**18.6**	**885.4**	**35.5**	**1.7**

Table 23 Species composition in IAT samples for SG-R, 2009 and 2011.

		Post-restoration Year 3 (2009)				**Post-restoration Year 5 (2011)**			
	Station Number	**SGR L2**	**SGR L3**	**SGR L2**	**SGR L3**	**L2**	**L3**	**L2**	**L3**
	Type Organism	**July**		**August**		**July**		**August**	
INSECTS									
Coleoptera	Haliplidae-adult								
	Hydrophilidae?								
	Diptera-Chironomid sp A		1						
	Diptera-Chironomid sp B	12	1						
	Diptera – Chironomidae larvae								2
	Diptera-adult		1		3				
	Diptera-pupae		1						
Hemiptera	Corixidae-adult		46	228	421	1	33	2	132
	Corixidae - juvenile					1	31		147
	Corixidae-larvae	6	163	228	61				
Homoptera	Unidentified adult								
	Mesoveliidae								
Hymenoptera	Hymenoptera-unid			1					
Odonata	Odonata-nymph								
POLYCHAETA	Flabelligeridae?						1	1	
MOLLUSCS	*Hydrobia totteni*	3	12	27	3	128	36	292	2
	Macoma balthica					1			
CRUSTACEANS									
Amphipoda	*Gammarus lawrencianus*		4						
	Gammarus mucronatus		2	1	21	1	9	3	6
	Gammarus setosus								
	Gammarus sp.				3	1	9		1
	Gammarus tigrinus						2	4	1
MYSIDACEAE	*Neomysis Americana*								1
TANAIDACEA						1			
HYDRACHNIDIA sp.						1			

A									
MEIOFAUNA & PLANKTON	Ostracoda		6	3		18	19	7	
	Copepoda-Calanoid					1	41	65	11
OLIGOCHAETA				1					
NEKTON (fish)	*Pungitius pungitius*			1					
	Fundulus diaphanus					89	13	7	11
OTHER	Argulidae, *Argulus* sp.	1				17	1	2	2
	Abundance (#/sample)	21	237	490	512	260	195	383	316
	Species/sample	4	10	8	6	12	11	9	11

Table 24 Species composition in IAT samples for SG (2009, 2011).

		Post –restoration Year 3 (2009)			**Post-restoration Year 5 (2011)**			
	Station Number	**L5**	**L4-1**	**SGL4-2**	**L4**	**L5**	**L4**	**L5**
	Type Organism	**July**	**August**		**July**		**August**	
INSECTS								
Coleoptera	Haliplidae-adult			1				
	Hydrophilidae?			1				
	Diptera-Chironomid sp A	1		1				
	Diptera-Chironomid sp B							
	Diptera – Chironomidae larvae				1			
	Diptera-adult		1					
	Diptera-pupae							
Hemiptera	Corixidae-adult	4		102	5		6	
	Corixidae - juvenile				1	2	4	2
	Corixidae-larvae	8	8	37				
Homoptera	Unidentified adult						1	
	Mesoveliidae	1						
Hymenoptera	Hymenoptera-unid							
Odonata	Odonata-nymph		1				1	
POLYCHAETA	Flabelligeridae?							
MOLLUSCS	*Hydrobia totteni*	39	1	134			6	
	Macoma balthica							
CRUSTACEANS								
Amphipoda	*Gammarus lawrencianus*			3				
	Gammarus mucronatus		1	28		2		
	Gammarus setosus	73						
	Gammarus sp.				14		9	2
	Gammarus tigrinus				121	67		8
MYSIDACEAE	*Neomysis Americana*							
TANAIDACEA								
HYDRACHNIDIA sp. A								
MEIOFAUNA &	Ostracoda	16	2	12	4	122	14	3

PLANKTON								
	Copepoda-Calanoid			15	23	93	11	9
OLIGOCHAETA			1					
NEKTON (fish)	*Pungitius pungitius*					2	2	
OTHER	Argulidae, *Argulus* sp.							
Abundance (#/sample)		**142**	**16**	**334**	**173**	**286**	**52**	**24**
Species/sample		**7**	**7**	**10**	**9**	**5**	**8**	**5**

4.7 Structured Winter Walk

Nova Scotia, as with much of southern Canada, experienced a warmer-than-normal winter in 2012. Cold temperatures and heavy snowfall were limited to only a few events in early January. Snow and ice conditions on the marshes were low to non-existent for much of the winter.

Despite the lack of snow and ice cover for protection, no significant change (erosion, deposition) in habitat conditions was evident at either SG or SG-R. Upstream hydrology continues to be affected by two beaver dams across the main river channel, one near Line 4 and a larger one between Line 5 and 6 (Figure 42). The dams, first observed in the fall of 2009, have altered the upstream hydrology of the system, maintaining a higher water level within the river channel and the retention of water on the marsh surface (more standing water).

A selection of landscape photographs from the SG and SG-R winter walk are provided in Appendix B.

Figure 42 Beaver dams and resulting altered hydrology at SG.

5.0 Summary and Area Restored

The results of the fifth (final) year of post-restoration monitoring of the SG salt marsh and tidal river restoration project were presented in this report. This was the fifth year of the six-year formal monitoring program that was developed for this project (baseline, and post-restoration at Years 1, 2, 3 and 5). It was the intent of this monitoring program to provide a record of habitat conditions at both the restoration and reference sites, as well as to document the change in conditions at SG as a result of intervention. The greatest change in habitat conditions occurred within the first two years following culvert replacement, with slower more subtle changes over the longer period.

The DEM for each site was updated in 2011 and improved survey/mapping techniques combined with a larger hydrological data set and geo-referenced low-altitude aerial photography enabled the refinement of the estimate of restored area. The project was originally approved on the estimate of 2.3 ha of restorable area. Based on the hydrology and elevation data collected during the third year (2009) of post-restoration that number was increased to 2.8 ha. However, with the inclusion of the high-resolution aerial photography from 2010 and 2011, the revised restored area was determined to be 2.47 ha (Figure 43). The difference in area was the result of the inclusion of higher resolution data rather than an expansion or contraction of marsh area.

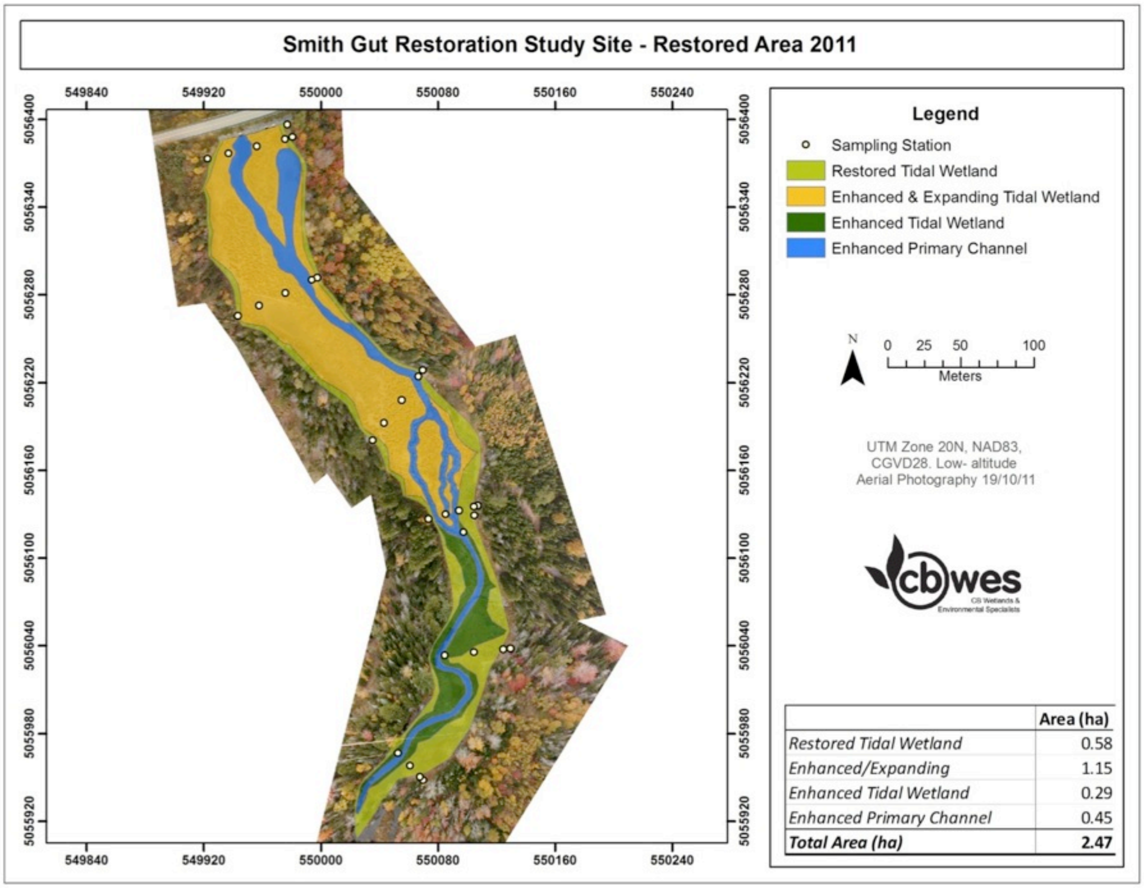
Sediment accretion and consolidation of the marsh surface continued to be greatest in the front portion of the Smith Gut site, the area that is largely comprised of a series of vegetated salt marsh “islands” and a non-distinct tidal channel (Figure 24). The 2009 and 2011 DEMs showed an increased elevation in this area, suggesting the development of a more contiguous marsh surface. This was the same area where fish sampling (beach seine and fyke net) was conducted and over the course of the post-restoration monitoring period, it became increasingly difficult to conduct sampling with the beach seine due to the increased vegetation cover. A greater sediment supply, consolidation of soils and an increase in marsh surface elevation, as seen in this part of the marsh, would make the area better suited for colonization by halophytic vegetation. On the whole, there was an increase in the amount of vegetated area and a decline in unvegetated surfaces, however, halophytic species richness continued to be lower at the restoration site as compared to the Huggans Brook reference marsh.

Assessment of restoration success relied heavily on vegetation, soils and hydrology, and the changes in these conditions were trending towards those of the reference site. While it is difficult to predict how successful this restoration project will be in the long term, it is clear, based on the five years of post-restoration monitoring, that the major objectives (reduce/eliminate the tidal restriction, increased and regular flooding by tidal waters, increase wetland vegetation, and improve fish passage and access to marsh surface) were achieved.

Restored Area

The results of the post-restoration monitoring, as discussed in this report, indicate that the system has responded in a positive and acceptable manner to the original intervention, and that no unanticipated or undesirable conditions have emerged during this period.

Based on the 2011 DEM, hydrology, and geo-referenced low-altitude aerial photography, the total area of restored tidal wetland at SG was 2.47 ha (Figure 43). This area includes both open water habitat (main river channel, pannes) and halophytic vegetation dominated habitat. The three culverts installed in 2006 do not represent a significant barrier to tidal flow.



	Area (ha)
Restored Tidal Wetland	0.58
Enhanced/Expanding	1.15
Enhanced Tidal Wetland	0.29
Enhanced Primary Channel	0.45
Total Area (ha)	**2.47**

Figure 43 Restored area at SG based on 2011 hydrology, elevation and vegetation data.

6.0 Recommendations for Post-Restoration Monitoring

The original monitoring program for SG, based on the GPAC Regional Monitoring Protocol, was a six-year program with post-restoration data collection scheduled over the first five years following restoration. Annual monitoring during the first three years following restoration are critical because it is during these initial years following restoration that the greatest and most rapid changes are likely to occur. The additional years of post-restoration monitoring allow a greater period of time for change to occur and to document these longer term and more gradual changes in response to restoration.

Although no further monitoring is formally planned for this project, it is recommended that in order to ensure that the project (the restored site) is both persistent and resilient over time, that site visits and rapid assessments of wetland habitat conditions be conducted by qualified personnel at regular intervals (every two to three years) for an additional five year period. There may also be value in supporting a university student to replicate the key components of the monitoring program (vegetation, hydrology, soils) at the 10 to 12 year post-restoration point in order to insure the long-term viability of the restoration/compensation site. The inclusion of low-altitude aerial photography at that time would be a considerable asset in documenting any landscape changes in the vegetation community structure and the consolidation of salt marsh "islands".

Based on the experience with this project site, as well as others in the province, the following general recommendations are made for monitoring tidal wetland restoration projects:

- It is recommended that measuring redox potential be included in the monitoring programs for all new projects, particularly those that were completely restricted prior to restoration, and, or experience rapid sedimentation (e.g., Fundy marshes). Measuring redox potential is important because it affects biogeochemical cycles of nitrogen, sulfur, iron and other redox-sensitive elements and is basically a measure of how the soil is affecting other biological communities within the marsh framework (Callaway 2001). The St. Croix River restoration site, for example, is located where fresh and salt water mix, inducing flocculation, where very high values of suspended sediment concentration may be recorded and deposited along adjacent lands. It is important that re-colonization rates and vegetation conditions be closely observed. Rapid sedimentation has the potential to lead to phytotoxic conditions at the interface between the new estuarine sediments and old agricultural soils, which may induce plant die-back (Portnoy 1999). Measuring redox potential would give insights into how the newly deposited estuarine soils and original marsh/upland soils are biochemically responding to restoration and potentially provide early warning of a potential for the collapse of the recovering vegetation community). Redox potential should be sampled at the same locations and frequency as interstitial pore water salinity.

- In connection with the inclusion of monitoring redox potential, it is recommended that sediment core sampling be decreased from four years (baseline, post-restoration at Years 1, 3 and 5) to three years (baseline, post-restoration at Years 1 and 5). The reduction of the post-restoration sediment sampling to Years 1 and 5, combined with the inclusion of sampling redox potential should provide sufficient information on developing soil conditions. An exception would be sites where rapid sediment deposition was anticipated (i.e., St. Croix River Restoration Project). For these sites, the frequency of soil sampling should remain at baseline and post-restoration years 1, 3 and 5.

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Appendix A – CBWES Supported Student Research: Project Descriptions

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 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; Bowron et al. 2009).
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

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Undergraduate Honours

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

Changes in grain size spectra and floc content over time in a macrotidal salt marsh restoration site

One of the indicators of success of a salt marsh restoration project is if the site is trending towards conditions present at a reference site. Several factors influence the soil characteristics at each sample location. These factors include source material, the elevation of the site within the tidal frame, distance from the estuary's mouth, distance from the creek bank and flow velocity. The grain size spectrum of a sample location is influenced by source material and velocity of current. The purpose of this project is to explore changes in source material and hydrodynamic processes in a restoration site over time with the use of disaggregated grain size (DIGS) analysis. It is hypothesized that over time the differences in source material and hydrodynamic processes at the restoration site will become minimal. The research was conducted within a newly restored salt marsh (and associated reference site) in the upper Bay of Fundy currently being monitored as a compensation project. Cores were taken from the restoration site and the reference site in 2008 and 2010. Samples taken from the cores were processed with hydrogen peroxide to remove organic material. The samples were processed through a Coulter Counter Multisizer 3 and using DIGS analysis a grain size spectrum and floc composition was produced for each sample. The shape of the resulting grain size spectrum gives an indication of source material and hydrodynamic processes. Minimal differences were observed in the data collected from the reference marsh and most of the samples processed from the restoration marsh. This indicates a similar source of material and similar hydrodynamic processes were experienced at both reference and part of the restoration site. However approximately half of the samples at the restoration site suggested different processes and source material. DIGS analysis was found to be a useful to identify changes in hydrodynamic processes and source material over time.

Undergraduate Honours

Environmental Science
Saint Mary's University
Michelle Whidden
NSERC Industrial Undergraduate Student Research Awards
2012-2013

Development of a freshwater and estuarine water quality monitoring protocol for evaluating wetland restoration projects.

Wetlands in Nova Scotia (NS) are important fish, bird and 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 protection and restoration of wetlands in NS has been identified as an important step in enhancing the quality of the natural environment.

Wetland and fish habitat restoration activities have increased dramatically over the last decade; however, our knowledge of ecosystem dynamics within the various types of wetlands remains limited. The current science-based ecological monitoring program matches each restoration site with an undisturbed reference site. The idea is that reference wetlands will best represent the conditions expected to develop on the restoration site. Experience suggests that small differences in environmental conditions between the paired reference and restoration sites can lead to differences in the plant and animal communities, making it difficult to determine whether the restoration is successful. Water quality is a critical controlling factor for many wetland flora and fauna, and the monitoring of water quality conditions is an important component of restoration ecology. It is important that the water quality monitoring activities being completed be appropriate, accurate and consistent among projects. It is important to have data that is collected and analyzed with standard methods so that it may be compared with data from other areas, projects and by other organizations. This study will review how other organizations conduct water quality monitoring and work with CBWES to develop and implement a water quality monitoring protocol as part of their on-going tidal wetland restoration monitoring activities in NS. This project will greatly enhance our ability to scientifically evaluate the success of wetland restoration efforts and will make a significant contribution to restoration science within the region.

Completed Projects:

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 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 & Askins 2002, Shriver et al. 2004, Hanson & 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.

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

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Appendix B – Photographic Documentation of 2009/2010 Winter Conditions

SG Transect and Landscape Photographs:

Figure 1 Culverts from upstream side of causeway at high tide.

Figure 2 Downstream of Smith Gut causeway at high tide.

Figure 3 Upstream of causeway at high tide.

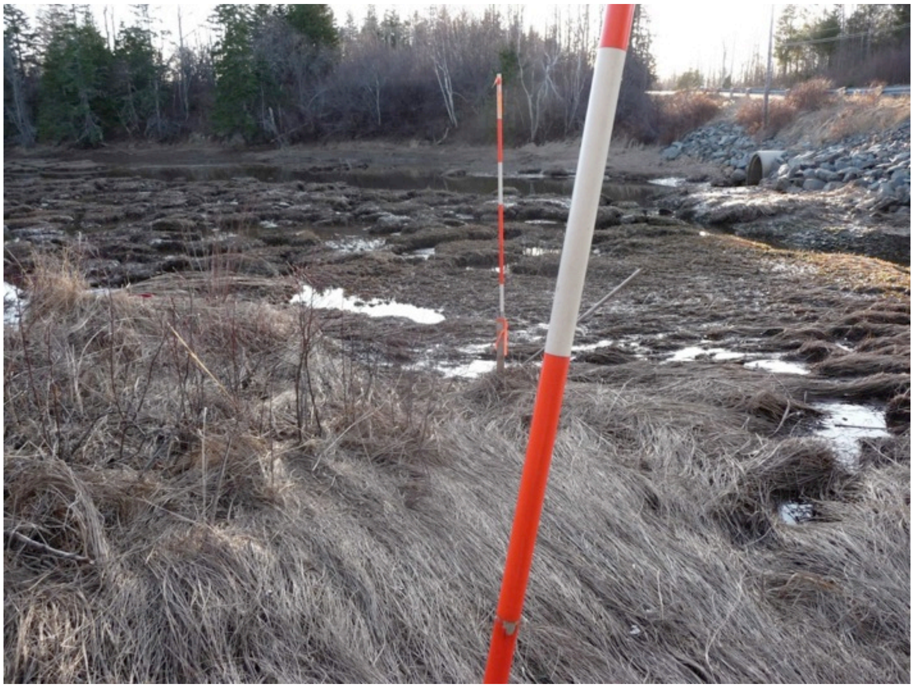

Figure 4 Line 1

Figure 5 Line 2

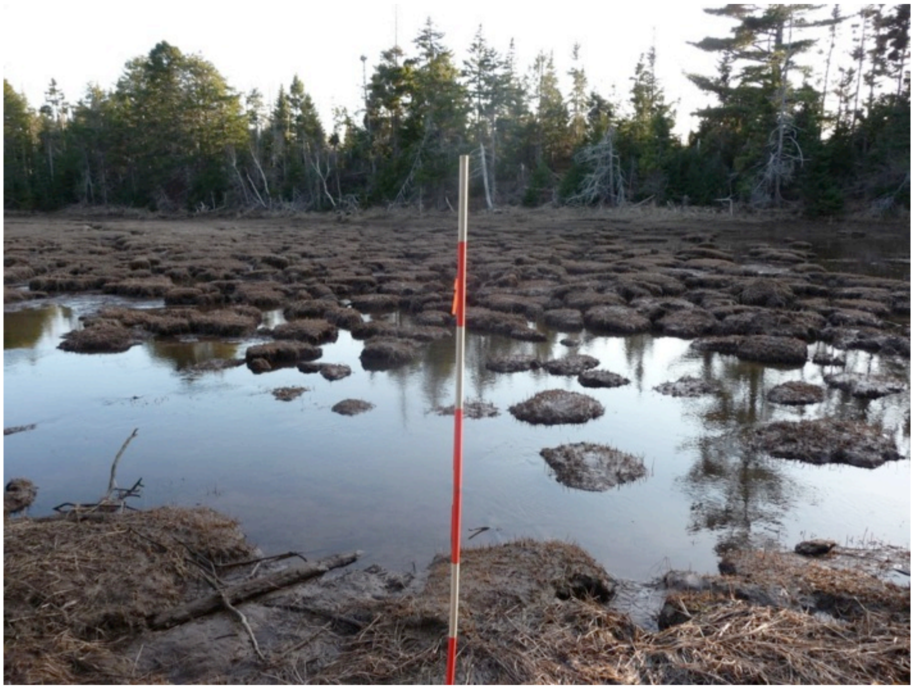

Figure 6 Line 3

Figure 7 Line 4

Figure 8 Line 5

Figure 9 Line 6

SG-R Transect and Landscape Photographs:

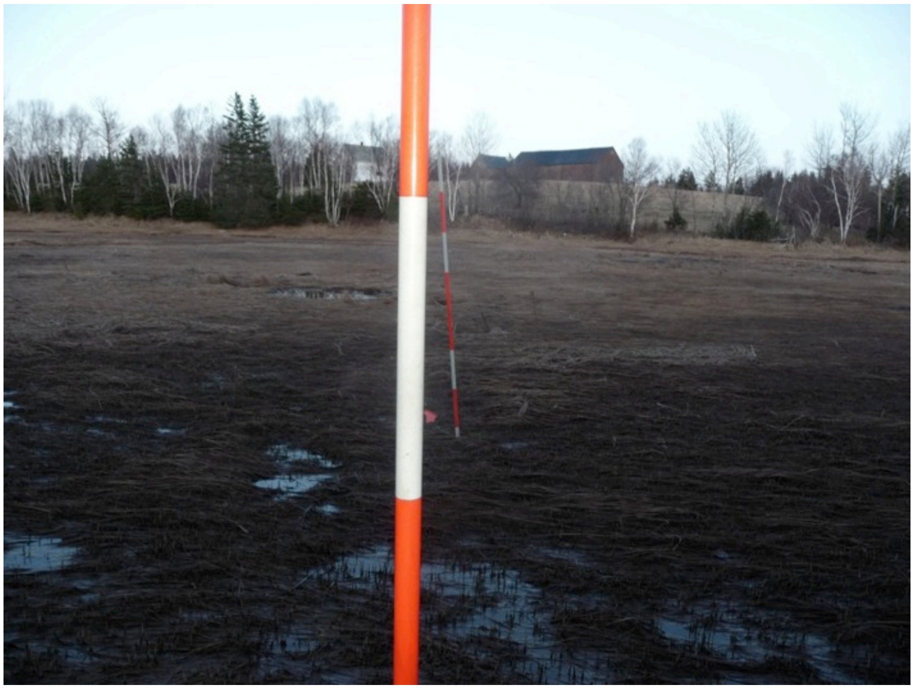

Figure 10 SG-R Line 1

Figure 11 SG-R Line 2

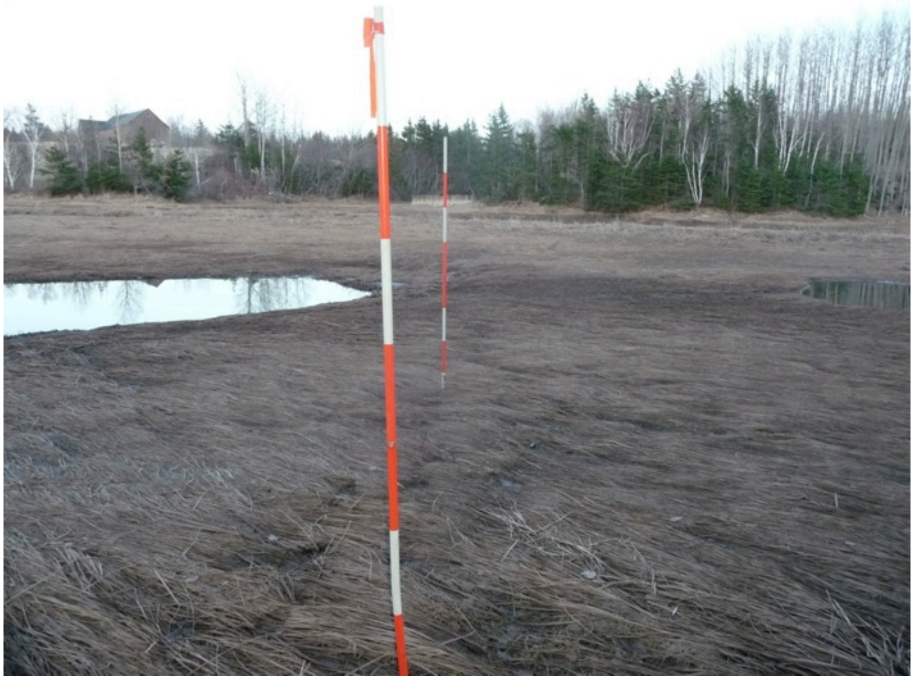

Figure 12 SG-R Line 3

Figure 13 SG-R Line 4

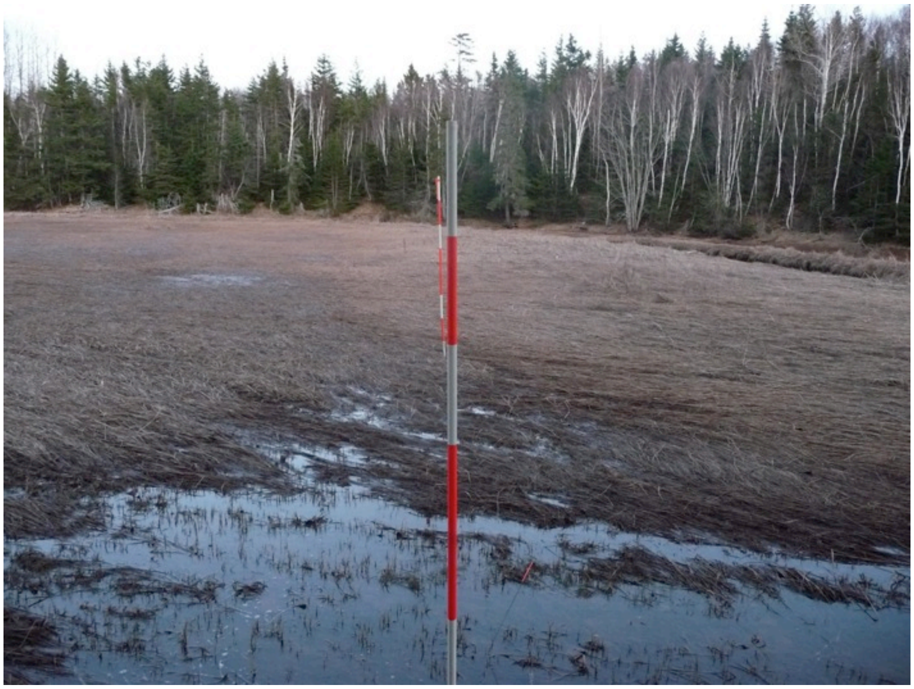

Figure 14 SG-R Line 5

Figure 15 Downstream of Huggans Brook bridge at high tide.

Figure 16 Upstream of the Huggans Brook bridge at high tide.