Testing of Temporal Monitoring Techniques for Benthic Habitat Impacts of Tidal Energy Developments

Final Report: November 30, 2011 - November 19, 2014

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Disclaimer
The timelines presented herein are subject to change due to the uncertain nature of offshore survey work and the extreme environmental conditions encountered offshore Nova Scotia. Survey methods and equipment are also subject to change to best ensure all survey objectives are meet.

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1 EXECUTIVE SUMMARY

The overall aim of this study was to test and develop monitoring procedures for assessing the impact of the placement of tidal in-steam energy conversion (TISEC) devices (*e.g.* turbines, cables and other seafloor hardware) on the seafloor environment in terms of the physical habitat structure and associated benthic assemblages resulting from bed-form movement and scour formation.

Traditionally, in situ sampling methods, such as sediment grabs, quadrats and scuba divers, have been used to monitor marine habitats and communities from unconsolidated and consolidated substrata (van Rein *et al*., 2009). However, across broad- (> 1 km²) and meso- scales (10 m² - 1 km²), these methods typically lack the necessary data density and spatial coverage to accurately determine habitat heterogeneity. In addition, community variability measured using in situ monitoring techniques does not always reflect the variability of broad-scale processes. To effectively monitor marine benthic habitats across meso- and broad-scales, standard methods that address the issues of spatial coverage and data density need to be developed. This is of particular relevance to the assessment of, including alteration to, benthic habitat as it relates to cable sitting, bed-form movement and scours in connection with TISEC devices.

Acoustic mapping equipment, such as multibeam echosounders (MBES) and side-scan sonars (SSS), can ensonify areas of seabed > 100 km² with 100 % spatial coverage at a resolution finer than 1 m² (Anderson *et al*., 2007; Anderson *et al*., 2008). Acoustic backscatter data generated by these systems can be used to derive roughness characteristics, material properties and morphological maps, greatly facilitating the mapping of seabed sediments, bedforms and rocky outcrops over broad-scales (Lurton, 2002). These features are usually verified by the collection of "ground-truth" samples, from which additional biological data can be linked to the seabed features. Commonly referred to as acoustic seabed classification (ASC) (Anderson *et al*., 2007; Anderson *et al*., 2008), this approach holds great potential for use in the broad-scale monitoring of marine benthic habitats (Pickrill and Todd, 2003), with potential application to monitoring the impact of TISEC devises.

However, despite widespread application there has been little or no standardisation of ASC methods for the purposes of monitoring marine benthic habitats (Davies *et al*., 2001; Coggan *et al*., 2007). Many studies have focused on the mapping of marine benthic habitats (*e.g.* scallop grounds - Kostylev *et al*., 2003; Lophelia spp. reefs - Roberts *et al*., 2005; Modiolus spp. reefs - Wildish *et al*., 1998; unconsolidated sediment habitats - Brown *et al*., 2004a and b). Only a few studies have conducted repeat surveys over the same habitat for the purposes of assessing benthic habitat change, *e.g.*, kelp forest (Grove *et al*., 2002), seagrass meadow (Ardizzone *et al*., 2006), and coral reef (Collier and Humber, 2007). Deployment of TISEC devices, including turbines and cables, could potentially impact benthic habitats through the alteration of environmental conditions (*i.e.* changes in physical processes, scour etc.) with subsequent impacts on benthic assemblages. This highlights the need to develop marine monitoring methods across all spatial scales, monitoring both physical and biological characteristics of the seafloor environment. The overall aim of this study is to assess the extent to which ASC can be employed for monitoring marine benthic habitats over meso- and broad- scales in connection with deployment of TISEC devices.

Before testing any ASC-based monitoring method, several issues must first be addressed. Problems can arise when time-lapse acoustic data are acquired by different sonar systems, under different data acquisition settings, meteorological conditions, or at different vessel speeds. This can introduce additional variability in backscatter responses irrespective of real environmental variability (McGonigle *et al*., 2010). Any monitoring method using acoustic mapping techniques therefore needs to take these factors into careful consideration, and potentially devise ways to counteract resulting variability (Diesing *et al*., 2006; Kubicki and Diesing, 2006). The defining biological features of targeted habitats must also be detectable by either the acoustic mapping technique or by ground-truth methods employed.

This project collected test data in 2012 and 2013 over selected case study sites in the Bay of Fundy using high-resolution acoustic survey techniques (multibeam sonar and sidescan sonar) and benthic biological sampling methods (underwater grabs, video, photographs). The goal was to evaluate and determine the most appropriate temporal monitoring strategy for assessing the effects of deployment of TISEC devices on benthic habitats, providing guidance for future tidal power developments.

The project was formally awarded to McGregor GeoScience Ltd (McGregor) from OERA in Q4 of 2011. This final report summarises the work conducted as part of this program of research, and presents the results, conclusions and recommendations over the period from November 30, 2011 through to June 15, 2014.

Field surveys were conducted in 2012 and 2013. Multibeam sonar and sidescan sonar surveys were conducted over four test sites in the Annapolis Basin to evaluate and test the utility of multibeam bathymetry and backscatter for detecting change in the seafloor environment. The sites were chosen to provide a range of environmental conditions (*i.e.* substrate, energy, geomorphology etc.) over which to test the proposed monitoring methodology. Upon commencement of field surveys, it was necessary to make a number of modifications to site selection due to evolving tidal energy developments in the region at the FORCE test area, and due to unforeseen logistical challenges.

At the time of planning, it was anticipated that TISEC hardware would likely be in-place on the seafloor at the Fundy Ocean Research Center for Energy (FORCE) test area in the Minas Passage prior to, or around the time of the field surveys taking place. Evaluation of the proposed methodology over a working tidal energy site would have been beneficial to evaluate the monitoring techniques directly against the effects of a TISEC device (*i.e.* assessment of scour features, changes in seafloor communities etc.). Unfortunately, scheduling for cable laying at the FORCE test area was postponed until 2012/2013, with subsequent TISEC deployment to be confirmed beyond this time frame. With no TISEC devices or hardware in place against which to test the proposed monitoring techniques in the Minas Passage, alternative sites were selected in the Annapolis Basin and Digby Gut which are geographically closer together. This alteration to the survey plan offered logistically easier sites to survey and provided a cost-effective manner to develop the monitoring methodology without compromising the scientific objectives.

Inter-tidal and inter-annual multibeam sonar and sidescan sonar data sets were collected over the four sites in 2012 and 2013. The temporal data sets were compared using a range of different methods (*i.e.* comparison of bathymetric data; comparison of conventional "by-eye" interpretation of backscatter mosaic; evaluation of two novel backscatter classification software packages – *QTC Swathview* and *Geocoder*). Results revealed close agreement in bathymetric surfaces between surveys, with only very small differences detected around seafloor objects as a result of small surface artefacts caused in the process of generating the seafloor surfaces for each data set. Absolute differences in backscatter values were apparent between surveys due to the uncalibrated nature of backscatter measurements from Reson multibeam sonar systems. Calibration of MBES backscatter is a significant challenge, and there are very poorly defined routines to achieve this goal. Further research is required in this area before absolute backscatter values can be compared on a site-by-site basis.

Comparison between the 2012 and 2013 infaunal data sets revealed interesting inter-annual differences in community composition at all stations, especially stations at Site 1. Comparison of univariate diversity measures between 2012 and 2013 revealed higher species abundance and diversity in 2013 compared with 2012, which was particularly evident at Site 1. Additionally, epifaunal data from photographs were pooled by station and presence/absence data were used in statistical analyses. Multivariate statistical analysis techniques were used to compare the benthic epifaunal assemblage data between the 2012 and 2013, and revealed some inter-annual differences in community composition. These differences may be due to the changes of sediment grain sizes between two years, with coarser sediments found in 2013. Moreover, as demonstrated in this study, passive drop camera systems can be used to assess benthic faunal characteristics from an area, and provide semi-quantitative or qualitative assessments of a site over as part of a monitoring program.

This project also aimed to test the feasibility of low-cost seafloor instrumentation that may prove beneficial for obtaining time-lapse footage in areas with extreme environmental conditions. Time-lapse footage may be useful for assessing changes and movement of biota (*i.e.* fish and meg-benthos) over various temporal timeframes. A system was designed around the GoPro Hero3 imaging engine and new technology LED lighting. A Time Lapse Intervalometer was integrated with the system which controls the camera directly and switches the LED lights with an external trigger circuit custom-made in-house by McGregor GeoScience personnel. Field testing demonstrated that movement of biota was clearly visible, and excellent quality images were acquired in both day time and night time conditions.

Overall conclusions and recommendations state that multibeam sonar and sidescan sonar offer very suitable methods for broad-scale mapping of sites for deployment of TISEC devices, providing baseline information on the seafloor conditions for site evaluation.

However, the use of backscatter data for monitoring change in seafloor conditions is currently limited due to the uncalibrated nature of the backscatter intensity values acquired from MBES systems. Automated backscatter classification tools show promise in monitoring change in temporal MBES data sets. However, due to the uncalibrated nature of the backscatter signal, the ability of these new analysis methods to detect changes in seafloor conditions are limited. It is likely that these methods will mature over the next few years as further research is conducted to develop and advance this analytical approach. Additionally, by-eye interpretation is still a valuable approach to assessing change in benthic systems from acoustic remote sensed data sets, and provide a method for assessing change in seafloor conditions around TISEC devices.

Repeat benthic infaunal sampling, following National Marine Biological Analytical Quality Control Scheme (NMBAQC) procedures were able to detect shifts in seafloor conditions over inter-annual time periods. Detectable changes in community demonstrate that this method is robust and well suited to monitoring impacts in benthic systems. Additionally, infaunal sub-sampling methods were tested against full sample analysis during this study. Findings demonstrate that no significant differences were found between the two sub-sampling methods and full-scale analysis. Thus, subsampling will allow faster, more cost effective sample processing to take place when collecting benthic infaunal samples as part of long term monitoring programs. Finally, results from the underwater video and photographic techniques demonstrate that these tools are highly suitable for site characterization, and can be used to link acoustic remote sensed data sets (*i.e.* multibeam and sidescan sonar data) with faunal characteristics for site evaluation baseline mapping of potential TISEC locations.

2 INTRODUCTION

The overall aim of this study was to test and develop monitoring procedures for assessing the impact of the placement of TISEC devices (*e.g.* turbines, cables and other seafloor hardware) on the seafloor environment in terms of the physical habitat structure and associated benthic assemblages resulting from bed-form movement and scour formation.

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3 SCIENTIFIC OBJECTIVES

The project addressed the following 5 scientific objectives (as stated in the original research proposal). These 5 objectives were addressed through 3 research activities (also as stated in the original research proposal), which are listed below.

<u>Objectives:</u>

1. Use a suite of acoustic survey techniques (multibeam sonar, sidescan sonar) to measure temporal changes in the physical seafloor characteristics over short (inter-tidal) and longer (inter-annual) time periods (***Research Activity 1***).

2. Test novel backscatter classification methods (using state-of-the-art software – *QTC Swathview* and *Geocoder*) for the objective measurement and detection of change in backscatter characteristics over these temporal time-frames at selected case study sites (***Research Activity 1***).

3. Determine and develop the most appropriate sampling methods for monitoring changes in benthic assemblage structure (both epifaunal and infaunal assemblages) (***Research Activity 2***).

4. Test cost-effective *in situ* monitoring of environmental conditions of short and longer-term movement of biota using multiple time-lapse cameras deployed from low-drag benthic landers (***Research Activity 3***).

5. Provide recommendations on the most appropriate monitoring techniques (physical and biological) for assessing change in benthic ecosystems in connection with deployment of TISEC devices.

<u>*Research Activities:*</u>

Activity 1: Inter-tidal and inter-annual repeat acoustic surveys of the case study areas.

Activity 2: Inter-annual repeat biological surveys (infauna and epifauna) of test study areas.

Activity 3: Time-lapse environmental monitoring.

3.1 DISCUSSION OF OBJECTIVES, METHODOLOGY AND RESULTS

3.1.1 Research Activity 1: Inter-tidal/ Inter-annual acoustic surveys – Summary of research conducted

<u>Study sites</u>

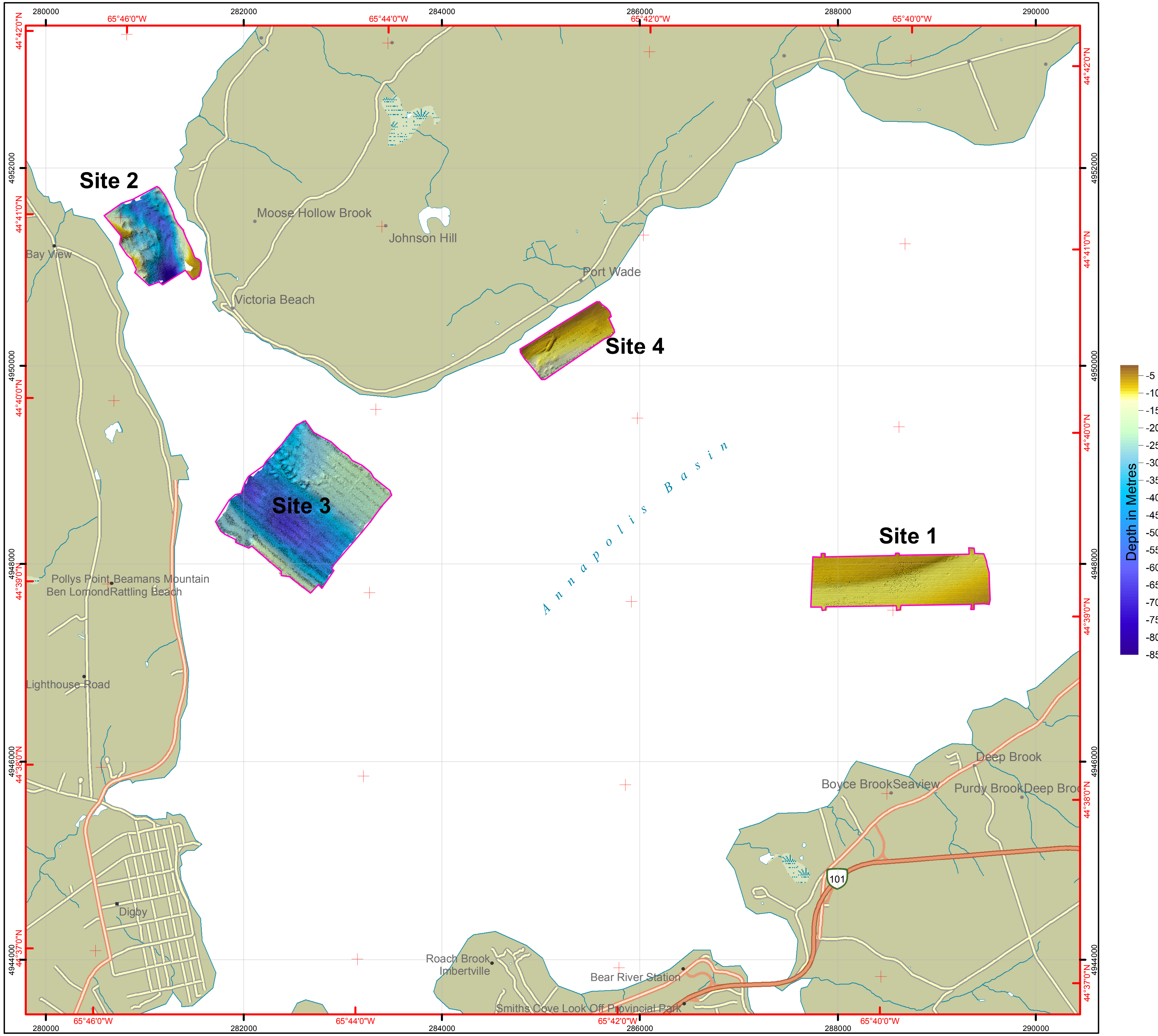
The test sites surveyed as part of this study are shown in **Figure 1**, and are described below. Four study areas were surveyed:

- Site 1: Cornwallis, Annapolis Basin.
- Site 2: Digby Gut, Annapolis Basin.
- Site 3: Approaches to Digby Gut, Annapolis Basin.
- Site 4: North Shore, Annapolis Basin.

Short-term (*i.e.* inter-tidal) repeat surveys were conducted at Site 1. Features on the seafloor at this site (*i.e.* oyster cages surrounded by tide-induced sediment scour features) provided an excellent test area to look for short-term and long-term variations in bottom characteristics (comparable to the types of features that may develop around TISEC devices placed on the seafloor). The site also offered gradational changes in sediment properties which provided a valuable feature against which to test the backscatter classification methods.

Site 2 (Digby Gut) was incorporated into the survey plan as it coincides with the area of interest for deployment of a TISEC device by Fundy Tidal Inc. (pers. com. Greg Trowse), and the site also provided an example of an area with high-tidal flow for testing the methodology. Completion of MBES and SSS at Site 2 revealed a hard, relatively uniform seafloor (high, relatively uniform backscatter assumed to be bedrock and boulder/cobbles). Following preliminary evaluation of these data in the field, it was decided that inter-tidal repeat surveys would offer little or no benefit in addressing the project objectives. It would be unlikely that any short-term changes would be detected over the site based on bottom characteristics. Inter-annual repeat surveys at Site 2 were judged to be sufficient to evaluate the monitoring methods over this area.

Data from Site 3 also indicated a hard, relatively uniform seafloor similar to that at Site 2. As for Site 2, it was decided that inter-tidal repeat surveys would offer little or no benefit in addressing the project objectives at this site. Due to the uniform seafloor at Sites 2 and 3 (indicated by the largely homogeneous backscatter return across these sites), it was also decided that an additional site with more heterogeneous backscatter features would help evaluate the backscatter classification tools in the context of monitoring temporal change. Site 4 was therefore surveyed, and was chosen to provide an area of varying topography and heterogeneous seafloor features (*i.e.* high-level of sediment "patchiness"). Scoping surveys and local knowledge of the area suggested that the North-shore of the Annapolis Basin may contain suitable features, and the bounds of the survey area were defined.



NAD 1983 CSRS UTM Zone 20N
Projection: Transverse Mercator
Datum: North American 1983 CSRS
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: -63.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Meter

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Metres

Coverage Area

Note:
Map scale 1:40,000 when printed on 11x17 size paper

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Overview of Survey Sites
2012 Data Collection

Survey Sites

Annapolis Basin
Bay of Fundy

McGregor GeoScience Limited

McGregor GeoScience Ltd.
Bedford, Nova Scotia, Canada

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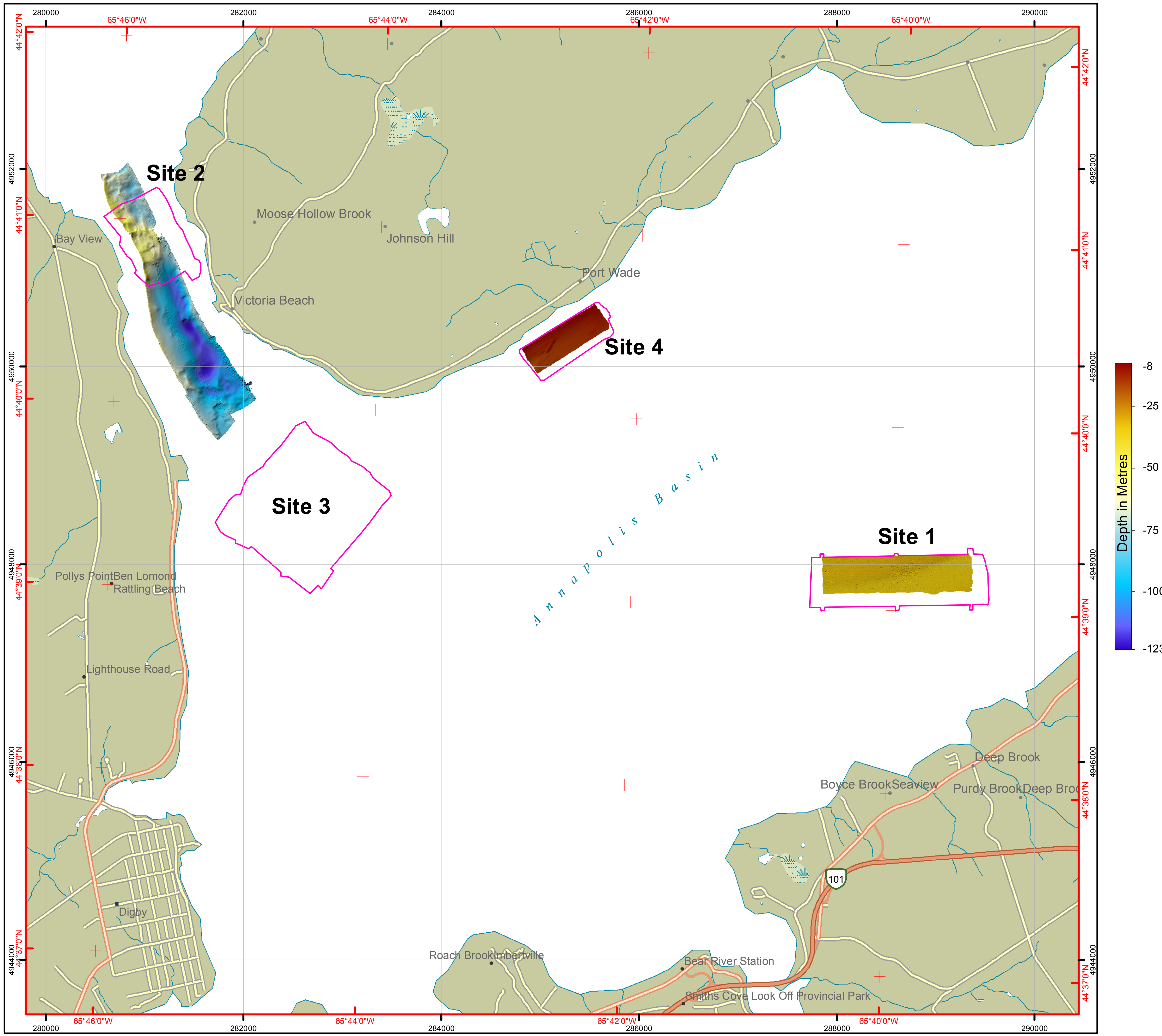

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N W E S

1,500 750 0 1,500
Metres

2012 Coverage Area

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Map scale 1:40,000 when printed on 11x17 size paper

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Overview of Survey Sites
2013 Data Collection

Survey Sites

Annapolis Basin
Bay of Fundy

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Data Acquisition

Multibeam sonar and sidescan sonar surveys were conducted at the four test sites in 2012 and 2013.

Mobilization for field surveys in Year 1 of the project took place on 9th and 10th May 2012, with field surveys of the four sites taking place between the 11th and 18th May, 2012. Acoustic systems were installed on the McGregor vessel the *Strait Surveyor*, a 6.7 m fibreglass vessel ideally suited for near-shore surveys. Powered by a 160 HP inboard/outboard, the vessel features two over-the-side mounts installed for the multibeam transducer and sidescan sonar fish, and sufficient deck space for the safe launch and recovery of all equipment.

All survey related data were collected and related to the CSRS NAD83 horizontal datum and collected relative to CHS Chart datum. RTK GPS was used for 3D positioning for the duration of the survey. RTK GPS involves a base station being setup over a known position. This base station transmits corrections to the receiver via a radio link, offering high accuracy 3D positioning in real-time. Primary horizontal positioning data was acquired using a Hemisphere RTK system with corrections coming from a base station set up by the Centre of Geographic Sciences (COGS) at Cornwallis, Base 1.

A Reson 8101 multibeam echo sounder (MBES) was mounted on the port side of the vessel. Patch tests were carried out on May 10th, 2012 in the Annapolis Basin, involving collection of five calibration survey lines to ensure correct alignment of the sonar transceiver array's pitch, roll, yaw and latency values. Variations in salinity, temperature and pressures affect sound velocity. To account for these variations, sound velocity casts were taken using an AML sound velocity sensor (SVS) at each site prior to the collection of MBES data. The instrument was lowered through the water column and recorded sound velocity measurements that were downloaded post recovery. Survey lines were run to ensure 100% bottom coverage of the seafloor within each study area was achieved. MBES data was recorded using the QINSy suite of acquisition software.

Following MBES data acquisition, sidescan sonar data was also collected over each study area in 2012. To collect sidescan imagery, survey lines were run using a Klein 3000 sidescan sonar system (SSS). The Klein 3000 is a 100-500 kHz dual frequency sidescan tow fish. The tow fish was pole-mounted from the starboard side of the vessel, which eliminated the need to calculate layback and depth of the SSS (as would have been the case if the SSS fish had been towed). Digitally recorded sidescan lines were recorded at range scales of 100-200 m. The SSS data was recorded using the QINSy suite of acquisition software.

Repeat year 2 acoustic surveys were originally scheduled to take place on the McGregor GeoScience survey launch, the *Strait Surveyor,* and coincide with the COGS field camp in May 2013. In April 2013 it became apparent that the *Strait Surveyor* would not be available to conduct the surveys due to timing conflicts with other ongoing, commercial survey work. Also in April 2013, the MBES sonar head from the Reson 8101 (the MBES system used for the 2012 OERA surveys), which at the time was mounted on the *RV Strait Hunter,* was lost at sea following mechanical failure of the mounting bracket (possibly following collision with debris in the water column during transit). A combination of these two issues prevented surveys taking place in the Annapolis Basin as planned.

McGregor immediately informed OERA of these issues, and it was agreed that the best solution would be to postpone the acoustic surveys until November 2013, and run them at the same time as the 2013 camera surveys. This would allow the same survey platform to be used (the *Strait Surveyor*), and give time for McGregor to source a replacement Reson 8101 sonar head. McGregor successfully sourced a rental Reson 8101 MBES system which was installed on the *Strait Surveyor*. Weather considerations and logistics regarding availability of survey personnel resulted in the repeat surveys successfully taking place in December 2013, only 3-4 weeks later than anticipated.

MBES surveys were conducted over three of the four test sites, with repeat inter-tidal data sets also collected at Site 1 (the primary test site). Data was not collected at Site 3 due to the presence of fixed fishing gear in the area restricting access to the site. Coverage at site 1 and 4 was slightly reduced in area due to time constraints at the time of survey caused by poor weather on some of the operational field days. Fixed fishing gear in Digby Gut also limited coverage of Site 2 close to shore, but coverage was extended to the north and south of the site. This extended coverage at Site 2 may benefit to other ongoing OERA projects in Digby Gut, and this data can be made available upon request.

Successful completion of surveys in 2012 and 2013 provided comprehensive data sets to address all project objectives through a combination of inter-tidal and inter-annual comparisons. Data from the test sites collected during 2012 and 2013 are shown in **Figure 1,** and details of the surveys are also provided in **Table 1**.

Table 1 - Summary of the acoustic surveys over the four sites

	2012		2013	
	Multibeam	**Sidescan**	**Multibeam**	**Sidescan**
Site 1	✓*	✓*	✓*	✓
Site 2	✓	✓	✓**	-
Site 3	✓	✓	-	-
Site 4	✓	✓	✓	-

* two repeat inter-tidal surveys conducted at this site
** partial coverage of site due to presence of fixed fishing gear

Data Processing

Multibeam data from each site was processed daily during the survey period to ensure data quality standards were achieved. Raw data files were copied from the acquisition computer onboard the *Strait Surveyor* to an external hard drive and were transferred to a data processing computer. The data was then converted and imported into CARIS HIPS

& SIPS for processing and cleaning. Attitude data (*i.e.* heading, heave, pitch and roll) was examined for each data set to ensure motion and heading values were applied correctly to the data set. Navigation data was also examined and cleaned for any outliers. The use of RTK GPS, which provides precise 3D positioning, removed the need to apply tidal corrections during the survey. The data collected by the sound velocity cast was compiled into a CARIS compatible *.svp file. The sound velocity correction process used a ray-tracing algorithm to apply the velocity profiles to the data from each site.

Data merging was conducted to combine the information from all of the sensors resulting in corrected geo-referenced depth values. Once merging was completed a processed depths file was created for each line containing the final computed geographic position for each depth record.

Grid surfaces were generated based on the corrected bathymetric data for each data set. The surface was examined and cleaned to remove any outliers, and the cleaned surfaces were exported from CARIS as Geotiffs and bathymetric ascii xyz files for further analysis.

MBES backscatter data was processed using *Fledermaus FMGT*. Raw .xtf and associated .gsf files for each survey line were imported into the software. The *Geocoder* mosaicing tools within the *Fledermaus* software were used to generate high-resolution backscatter mosaics for each data set using the snippets backscatter data and using default settings within the software. Backscatter mosaics were exported as Geotiffs and ascii xyz files for preliminary evaluation and QA.

SSS data was also processed using *Fledermaus FMGT*. Raw .xtf files for each survey line were imported into the software. The *Geocoder* mosaicing tools within the *Fledermaus* software were used to generate backscatter mosaics for each data set using default settings. Backscatter mosaics were exported as Geotiffs and ascii xyz files for preliminary evaluation and QA.

Multibeam sonar backscatter data was processed using the image-based classification methods within the *QTC Swathview* software suite of tools, on all sets. Analysis was done at a number of different spatial scales (*i.e.* patch dimensions within the software – see Brown *et al*. 2011 for details on how the software processing works). The patch dimension determines the scale at which seafloor classification is conducted, and thus has an important bearing on resolvability of seafloor features. Selecting too small a patch size can result in the introduction of noise from angular range artefacts within the backscatter, which are inherent within the data (McGonigle *et al*. 2010). In contrast, selecting a patch size that is too large may result in the inability to resolve small target features on the seafloor. Analysis was performed on all data sets using three different patch sizes (Small - 17 x 9 pixels equating to 0.8 x 1.7 m on the seafloor; Intermediate - 33 x 9 pixels equating to 1.6 x 1.7 m on the seafloor; Large - 129 x 33 pixels equating to 6.3 x 6.1 m on the seafloor).

Backscatter classification using the signal-based Angular Range Analysis within *Fledermaus FMGT (*Geocoder ARA) uses a modelling approach to predict seafloor properties (including sediment grain size, hardness and roughness). Analysis was attempted on all data sets using this approach.

A number of technical challenges were encountered throughout the course of the research program with the novel image-based (*i.e. QTC Swathview*) and signal-based (*i.e. Geocoder ARA*) approaches – and these were reported to OERA during the course of the research program. These methods are relatively new (particularly the *Geocoder ARA* methodology), and this program of research has facilitated the early testing of these methods in a monitoring context. Some, but not all, of these issues were resolved through close collaboration with the software developers. These problems, and some of the solutions, are outlined below.

The original intention was to evaluate the *QTC Swathview* classification methodology on both the MBES and SSS data sets from each of the sites. While the MBES analysis proceeded effectively, the SSS analysis ran into challenges. Upon award of the project, McGregor attempted to obtain a reader for the Klein 3000 SSS system (the reader is a software add-on that allows import of raw data from a specific acoustic system). This was needed to import the raw SSS data files into the software and conduct the classification (McGregor were already in possession of a reader for the MBES data files). Logistical issues were reported in several of the project interim reports concerning the announcement by the software manufacturer (*Quester Tangent*) that as of late 2012 they would no longer be developing and selling the *QTC Swathview* software. *Quester Tangent* provided reassurances at the time that support for the software would be available through the company for the foreseeable future, and that a Klein 3000 reader would be made available to McGregor in due course. However, a reader was never provided despite continued requests by McGregor.

The failure to secure the *QTC Swathview* reader for the SSS data sets was a disappointing outcome, but did not greatly impact the overall study (comparison of the time series MBES was still possible using the *QTC Swathview* software). As a contingency plan for the failure to acquire the *QTC Swathview* SSS reader, additional classification methods beyond those outlined in the original OERA proposal were explored for the SSS (and MBES) data sets. An evaluation of conventional (by-eye) interpretation methods was undertaken, and comparisons were made between the 2012 and 2013 data sets.

In addition, work is also continuing through an MSc project at Memorial University (Dimitri Tzekakis) to explore other approaches to classifying backscatter data (beyond the original scope of research activities outlined for the OERA funded research project). Object based classification tools will be explored as part of this MSc over the next 12 months, which will complement the analysis performed to date as part of this OERA project (not presented in this report).

Survey Sites - Description of collected data sets

Site 1: Cornwallis, Annapolis Basin.

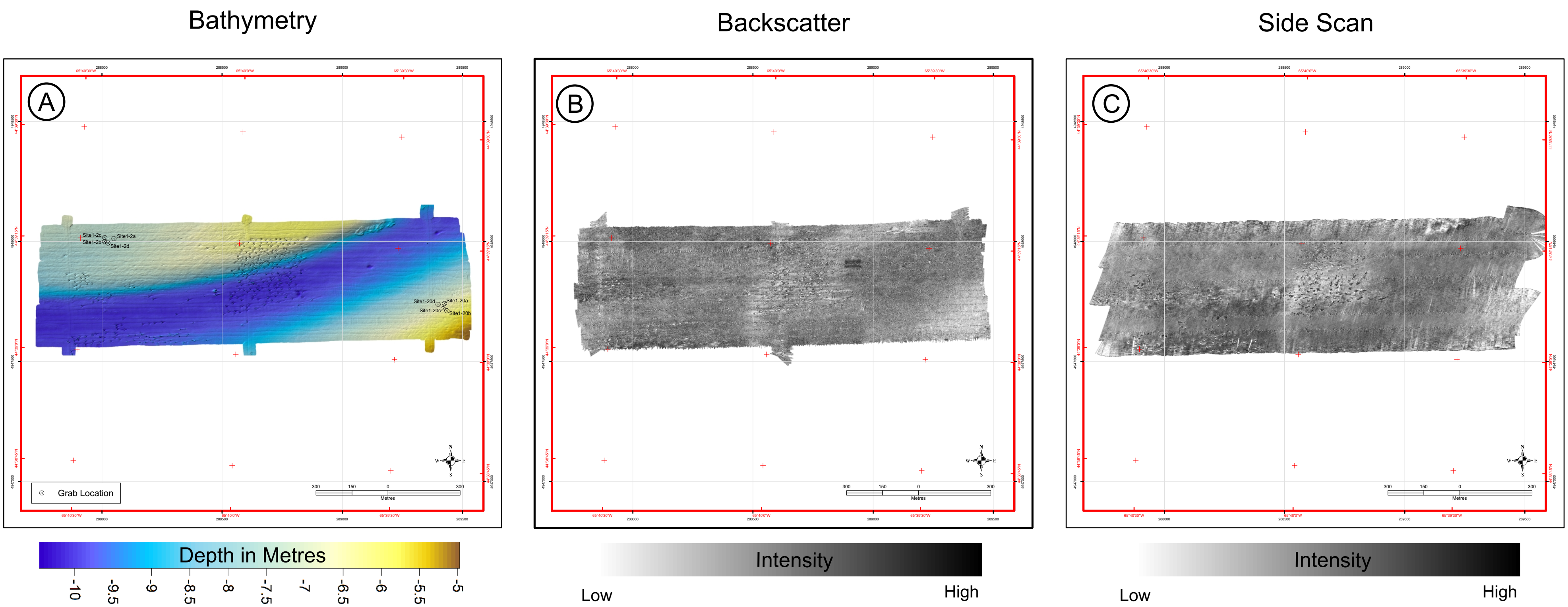
This site was selected as the primary study area over which to test the proposed monitoring methodology. The site is surveyed annually by the Centre of Geographical Sciences (COGS) at Nova Scotia Community College (NSCC) as part of the Marine Geomatics field camp, and this offered an opportunity for McGregor to collaborate with NSCC, share resources, and contribute to student training through involvement in the student field camp. Multibeam echo sounder (MBES) and Sidescan sonar (SSS) surveys of the site were conducted in 2012 and 2013, with inter-tidal surveys conducted in both years.

The survey site covered an area of ~0.9 km^2, consisting of a gently sloping seafloor ranging in depth from 5-11 m. A deeper water channel runs through the survey area from SW-NE. The MBES and SSS data revealed a large number of man-made structures in place on the seafloor (oyster cages) (**Figure 2**). These structures provided ideal features over which to develop and test the acoustic monitoring methods. Each seafloor object was surrounded by a scour feature, indicative of accelerated bottom currents caused by the strong tidal flows in the area. These scour features were similar in nature to the types of sediment transport features that may be expected to develop around TISEC devices placed on the seafloor in regions of unconsolidated sediments (typical in many parts of the Bay of Fundy). These features and seafloor objects provided targets over which to develop the monitoring methodology.

Backscatter data from both the MBES and SSS revealed a seafloor with gradational changes in backscatter intensity, suggesting shifts in sediment grain size characteristics over the site (**Figure 2**).

Site 2: Digby Gut

Site 2 was situated in the narrowest section of Digby Gut, covering the area of interest for tidal development/TISEC deployment by Fundy Tidal Inc. The survey area covered ~0.6 km^2 of seafloor (2012 data coverage), ranging in depth from 5 m close to each shore down to a maximum depth of 85 m in the deepest part of the channel (**Figure 3**). The bathymetry data revealed steep sides to the channel. Backscatter (MBES and SSS) revealed a relatively homogeneous backscatter return over most of the area, with slightly higher backscatter in the shallower water (**Figure 3**).



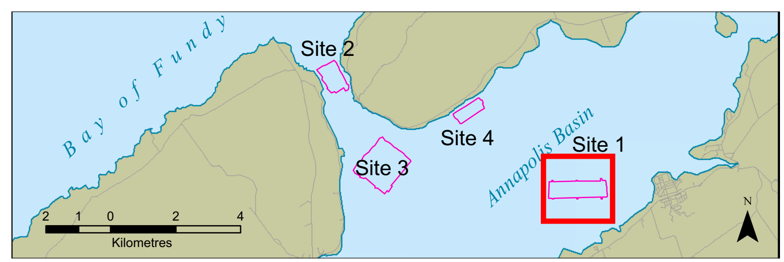


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Figure 2 Site 1 A -Bathymetry, B - Backscatter, C - Sidescan Sonar

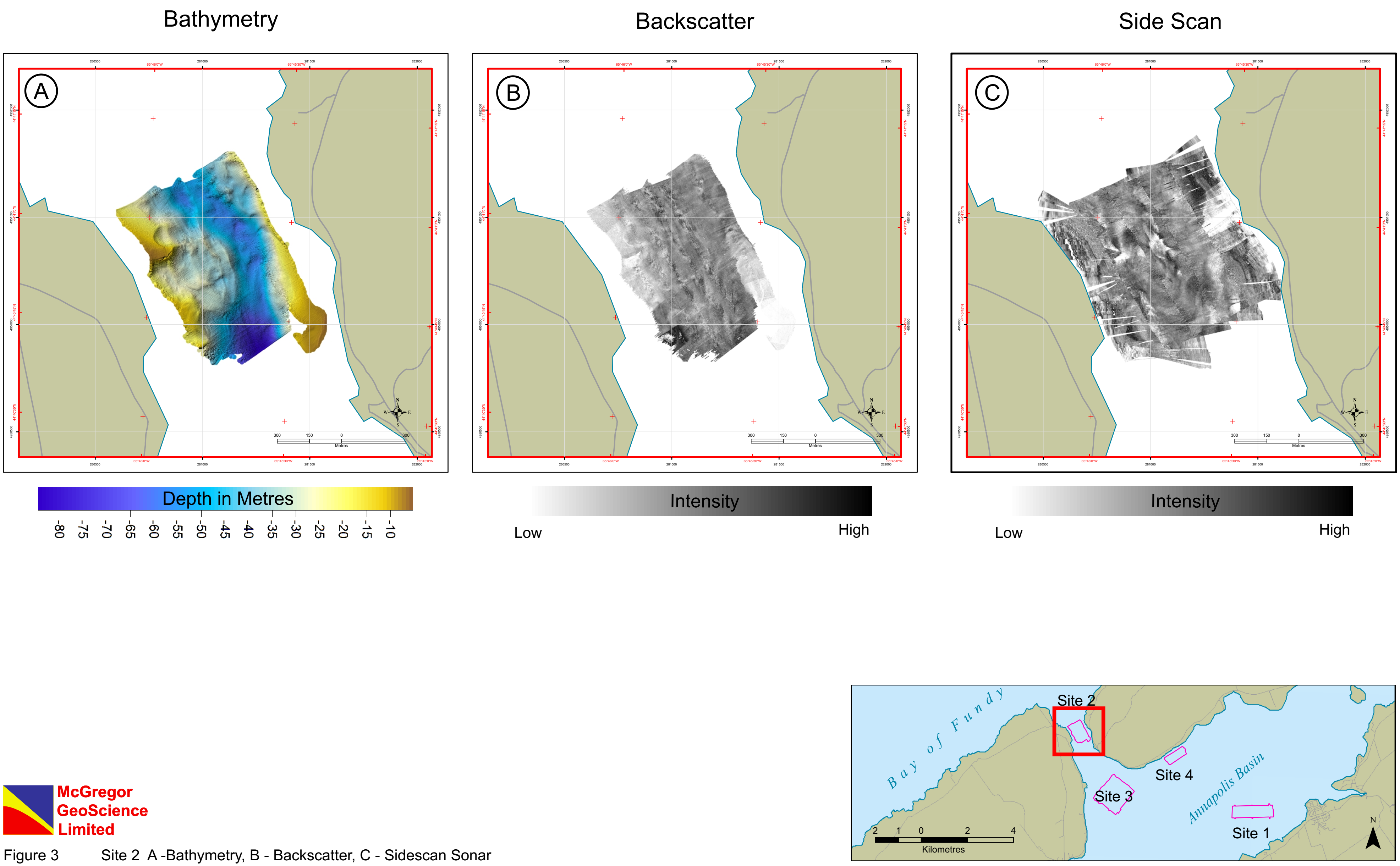

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Figure 3 Site 2 A -Bathymetry, B - Backscatter, C - Sidescan Sonar

Site 3: Approaches to Digby Gut, Annapolis Bain.

Site 3, situated in the Annapolis Basin at the mouth to Digby Gut, covered an area of ~1.75 km^2 seafloor in water depths ranging from 12 - 66 m (**Figure 4**). The deep-water channel extending from Digby Gut runs through the centre of the survey area, with bathymetric features on the northern flank of the channel. Backscatter strengths (MBES and SSS) were higher in the shallower-waters along the flanks of the channel feature, grading to lower backscatter in the deeper water (**Figure 4**).

Site 4: North Shore, Annapolis Basin.

Site 4 was selected to provide a study site representative of a region of heterogeneous seafloor features over which to test the acoustic monitoring methodology. The site covered an area of ~0.35 km^2, running parallel to the northern shore of the Annapolis Basin, in water depths ranging from 28 - 45 m (**Figure 5**). MBES and SSS backscatter was variable over the survey area, displaying fine-scale patchiness corresponding to visible bathymetric features and corresponding to differences in seafloor sediment characteristics (**Figure 5**).

Results

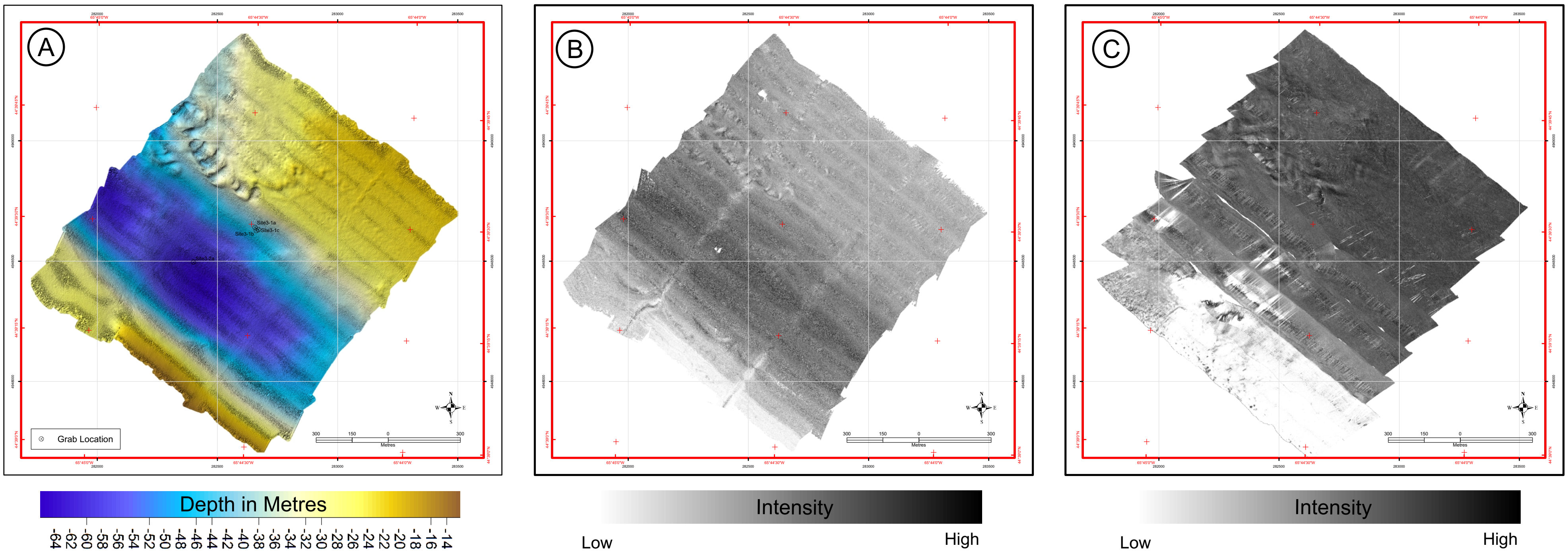
Bathymetric surfaces were generated for all four sites from data sets collected in both 2012 and 2013 (**Figure 1**). The large number of objects (oyster cages) on the seafloor at Site 1, within a strong tidal environment, offer physical man-made targets that may exert an effect on the seafloor environment comparable in nature to those potentially induced by TISEC devices and associated seafloor hardware when placed on sediment (as opposed to scoured bedrock - such as at the FORCE test area). As there are currently no TISEC devices/hardware in place within the Bay of Fundy over which to evaluate the monitoring methodology, this site was deemed a valuable compromise over softer sediment sites. Site 2-4 offer harder substrate test areas (in places, similar in nature to the FORCE test site *i.e.* Site 2). However, it should be noted that no anthropogenic structures are present at the hard substrate sites over which to test the methods.

Multibeam bathymetric surfaces (0.5 m grids) were generated and compared for the repeat inter-tidal survey data sets, and examples are shown from Site 1 (2012 surveys) (**Figure 6**). Tidally-induced sediment scour features are clearly visible surrounding each of the oyster cages (**Figure 6a**). Profiles over the cages clearly revealed the scour pits (**Figure 6b and 6c**). Comparison between the inter-tidal surveys revealed that differences between the surfaces were within normal, acceptable accuracy levels International Hydrographic Organization (IHO) Special Order - vertical 0.25m, horizontal 2 m). In this case, differences between the two surveys showed a difference that was no greater than that expected due to the inherent position inaccuracies of the multibeam system. These inherent positional accuracies determine the magnitude of "real" change in the seafloor (*i.e.* sediment movement) that can be detected using this approach. We can therefore conclude that any physical changes in seafloor features were below these accuracy limits over the time frame of the project

Bathymetry

Backscatter

Side Scan



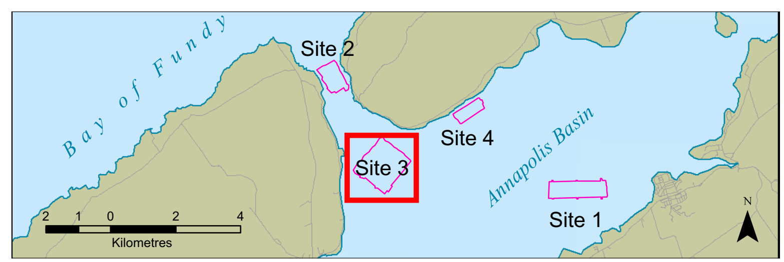


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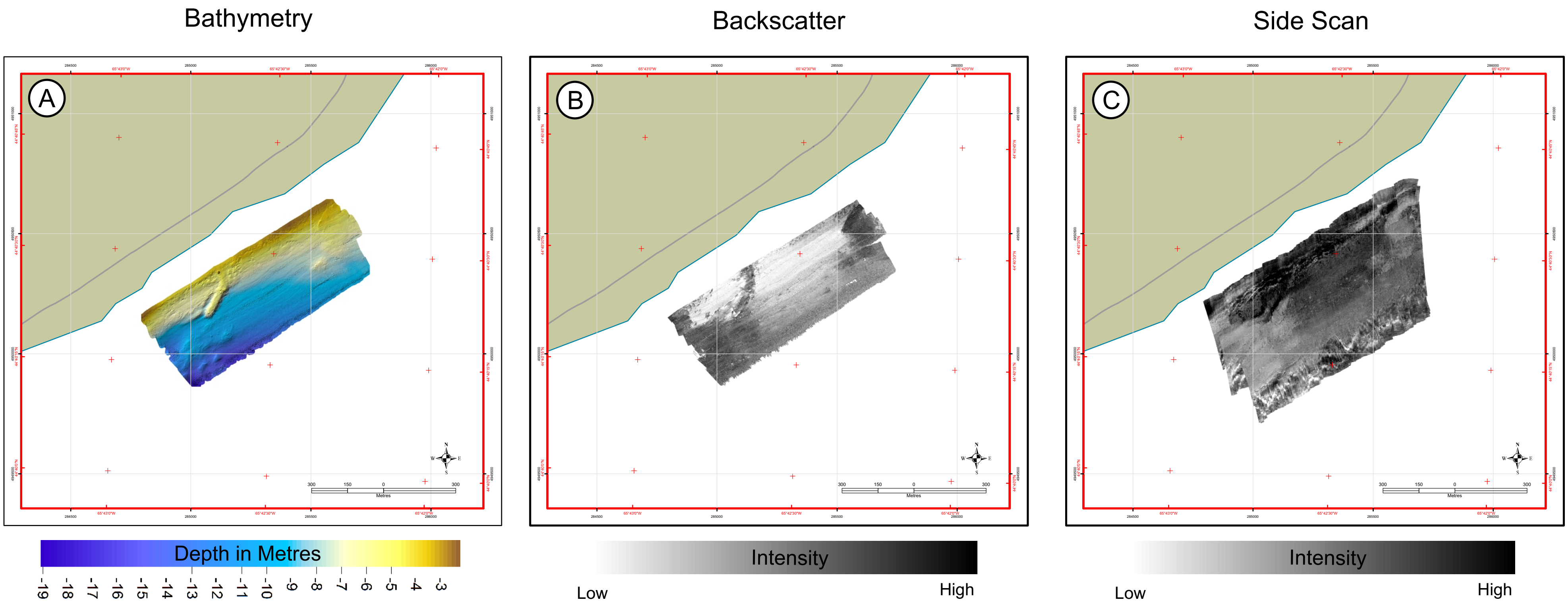
Figure 4 Site 3 A -Bathymetry, B - Backscatter, C - Sidescan Sonar



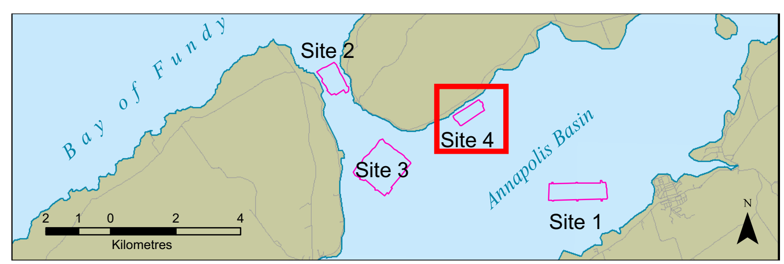


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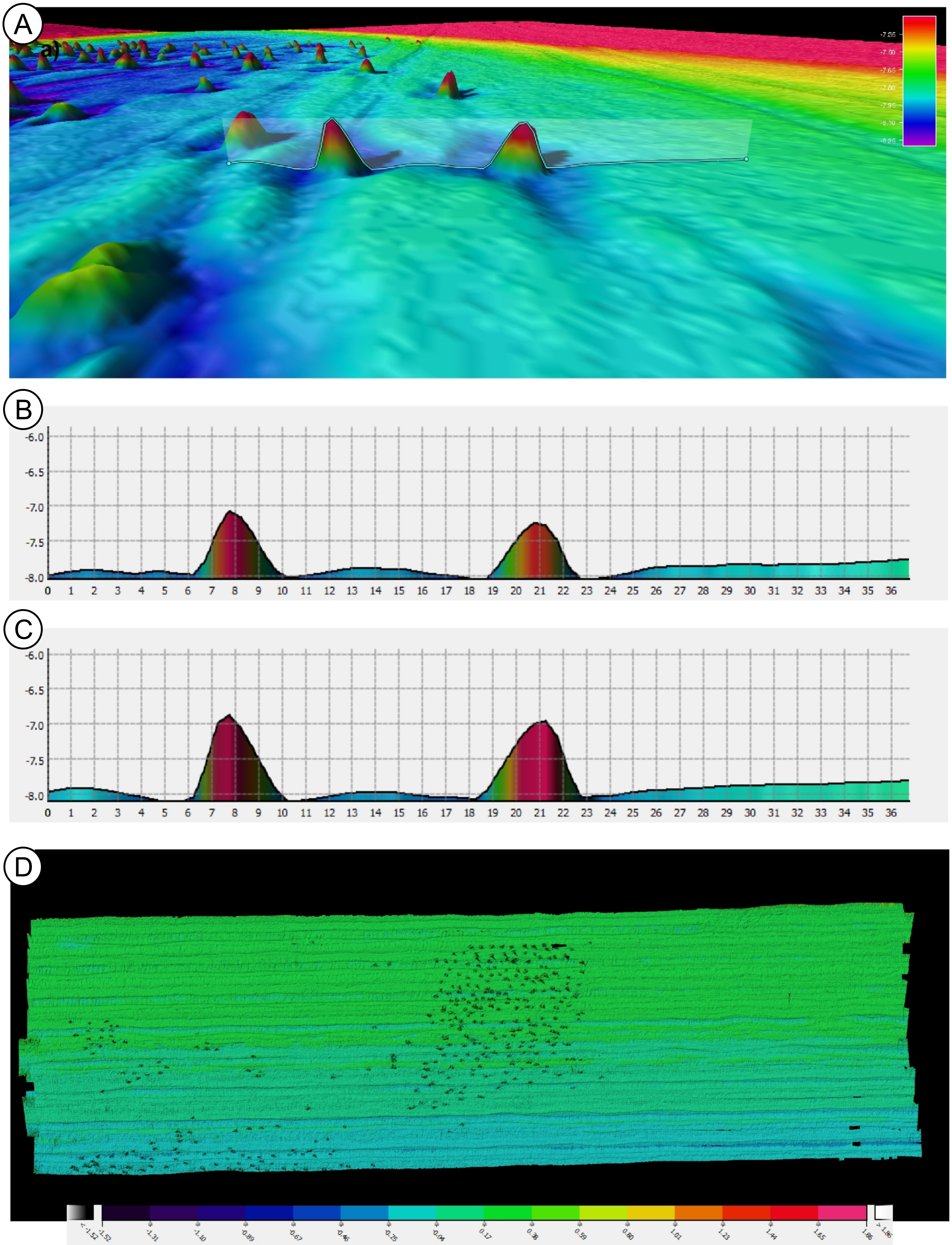
Figure 5 Site 4 A -Bathymetry, B - Backscatter, C - Sidescan Sonar



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Limited

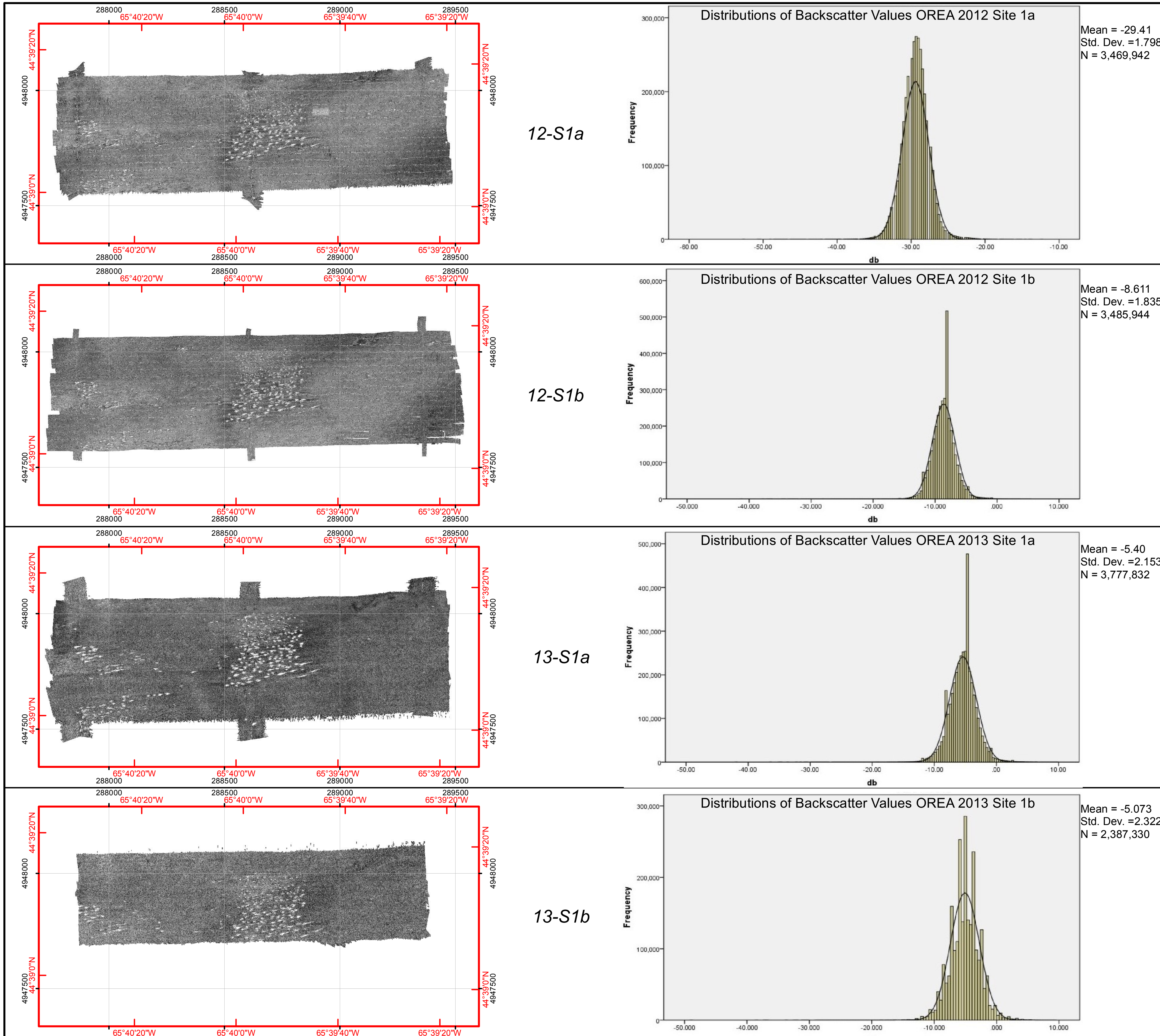
Figure 6 Bathymetry Comparison from Site 1

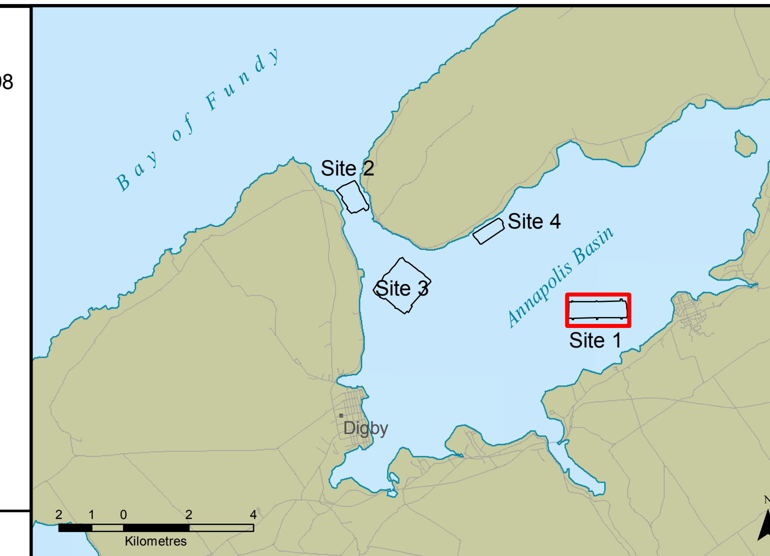
Figure 6

Multibeam sonar backscatter mosaics (0.5 m grids) were generated and compared for the repeat inter-tidal and inter-annual survey data sets. Examples are shown from Site 1 (2012 and 2013 surveys) (**Figure 7**). The mosaics reveal that overall patterns in relative backscatter intensity between the surveys were similar, allowing temporal comparison of features. However, spatially coincident, absolute backscatter values varied considerably between surveys (**Figure 7**) (*i.e.* backscatter intensity values from the same location were not identical between surveys, even inter-tidal surveys where sediment parameters would be expected to be very similar). This is due to the uncalibrated nature of backscatter measurements from Reson multibeam sonar systems. This inherent feature of the systems poses a significant problem when attempting to use backscatter for monitoring application when attempting to compare absolute backscatter values (*i.e.* decibel values).

A wide range of parameters can affect the backscatter measurements (*i.e.* system setting during acquisition, environmental parameters etc.). Acquisition settings were kept the same during this study, but there were still variations in absolute values between survey data set likely caused by a complex number of other interacting variables (*i.e.* ensonification angle, temporal changes in water column parameters, suspended material in the water column etc.). Calibration of MBES backscatter is a significant challenge, and there are very poorly defined routines to achieve this goal. Further research is required in this area before absolute backscatter values can be compared on a site-by-site basis. These issues are currently being documented through an International Backscatter Working Group (BSWG) operating through the GeoHab conference forum (www.geohab.org/BSWG). This group (of which Craig Brown is a Chairing member) aim to publish a recommendations and guidance document on backscatter at some stage in 2015. The results and findings from this OERA project will be used to facilitate the development of the BSWG recommendations document.

Nonetheless, backscatter mosaics were generated and compared between surveys to evaluate the degree of difference. Multibeam sonar backscatter data was processed using the image-based classification methods within the *QTC Swathview* software suite of tools, on data from all 4 survey sites. Results from Site 1 are illustrated in **Figure 8**, showing an example from this classification. The analysis resulted in a statistical optimum of 8 acoustic classes (**Figure 8c**). These have been interpolated using the categorical interpolation algorithm in *QTC Clams*. Comparison with the bathymetry (**Figure 8a**) and backscatter mosaic (**Figure 8b**) illustrates that the *QTC Swathview* software is detecting subtle seafloor differences in the shallower water in the north-west of the area (class 7 and 8), where backscatter intensity is slightly lower.





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Note:
Map scale 1:16,934 when printed on 11x17 size paper

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Multibeam Backscatter Mosaics & Histogram Distributions of Backscatter Intensities Between Intertidal & Interannual Dara

Site 1

Annapolis Basin
Bay of Fundy

McGregor GeoScience Limited
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Bedford, Nova Scotia, Canada

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Figure: 7

McGregor Project No.: 1111

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Results demonstrated that the approach has limited ability to detect fine scale change in seafloor conditions that may be associated with TISEC devices. Inspection of the *QTC Swathview* analysis revealed that the automated image-based analysis is capable of detecting difference in the backscatter signal associated with the tidally induced scour features (**Figure 9**). The scour pits around the cages were characterised by higher backscatter returns (**Figure 9b** - light grey tones). Examination of the classified analysis patches (**Figure 9d**) revealed that the higher backscatter associated with the pits was classified as a different acoustic class than the surrounding seafloor. The interpolated *QTC Swathview* classification using the categorical interpolation algorithm in *QTC Clams* also delineates the oyster cages and associated scour features (**Figure 9e**). However, limitations in the raster-based interpolation procedure do not provide clear resolvability of the edges of the features, which is a significant limitation of this approach within a monitoring context. The cessation of the software package is also a consideration when evaluating this approach as a broad-scale monitoring strategy for future applications.

Backscatter classification using the signal-based Angular Range Analysis within *Fledermaus FMGT (*Geocoder ARA) uses a modelling approach to predict seafloor properties (including sediment grain size, hardness and roughness). A number of technical challenges were encountered with the software when conducting the analysis (*i.e.* inconsistencies reading in raw files depending on the types of files imported, inconsistencies in the ARA performance with new software version releases). Some of these issues were resolved during the course of the project through close collaboration with the software developers. However, the ARA classification approach is still in the relative early stages of development and testing, and is at an early stage in the commercialization of the tools within the software package. The uncalibrated nature of the backscatter data poses significant challenges in developing a classification approach that is robust and repeatable, and the methodology would benefit from establishing protocols for acquiring calibrated backscatter (*i.e.* the subject of the GeoHab BSWG report described above). Nonetheless, results from the ARA classification were conducted on data from all sites, with example results from Site 1 included in **Figure 8**.

Predicted sediment grain size ranged from +2.2 phi (very fine sand) to -1 phi (gravel) from the 2012 data sets. These predicted values are coarser than measured values at the site from physical grab samples (see section 3.2.1 below), which revealed that the site consists predominantly of sandy silt. Reson multibeam systems log uncalibrated backscatter data, and this may explain the discrepancy between the predicted and measured grain size values. However, ARA predicted grain size was finer in the shallower water in the north-west of the area (+2 phi - red tones in **Figure 8c**), grading to predicted coarser sediments over the rest of the area (-1 phi - blue tones in **Figure 8c**). These relative geographical patterns correspond and agree with the *QTC Swathview* classification (**Figure 8c**), and with subtle patterns in backscatter intensity visible in the mosaic (**Figure 8b**). Predicted sediment grain size from the 2013 data sets ranged from +8.0 (very fine silt) to +3.2 phi (fine sand). These predicted values are similar to the 2012 data set and are slightly coarser than measured values at the site from physical grab samples collected in 2013. Sediment samples collected in 2013 were slightly coarser than those collected in 2012, although data indicates Site 1 is still predominately classified as sandy silt.

Closer examination of the *Geocoder* ARA classification approach from the 2012 data over the fine scale features at Site 1 is provided in **Figure 9.** This figure highlights some findings regarding the utility of this automated classification methods for monitoring broad-scale change in seafloor characteristics. The scale of analysis of the *Fledermaus Geocoder* ARA classification was too coarse to detect fine scale futures such as the oyster cages and associated tidal-scour pits. ARA classifies the port and starboard portion of the MBES swath based on the angular response characteristics of the MBES signal. Analysis of the data at this scale can not detect changes in seafloor properties at a resolution smaller than the footprint of the analysis patch (*i.e.* typically 30 stacked pings). The results of the classification can be seen in **Figure 9c**, illustrating that the features clearly visible in the underlying backscatter (**Figure 9b**) are not detect using the Geocoder ARA approach. This likely limits the scope of this classification approach for monitoring finer-scaled changes in seafloor conditions that may be associated with the placement of TISEC devises on the seafloor (*i.e.* formation of scour features, impact on benthic habitat conditions around turbines and cables etc.). Nonetheless, this approach may hold value in the future as these analysis methods are improved and refined. Work is ongoing in the development of the software (pers coms. with representatives from QPS), and this approach may hold potential in the near future as these methods mature.

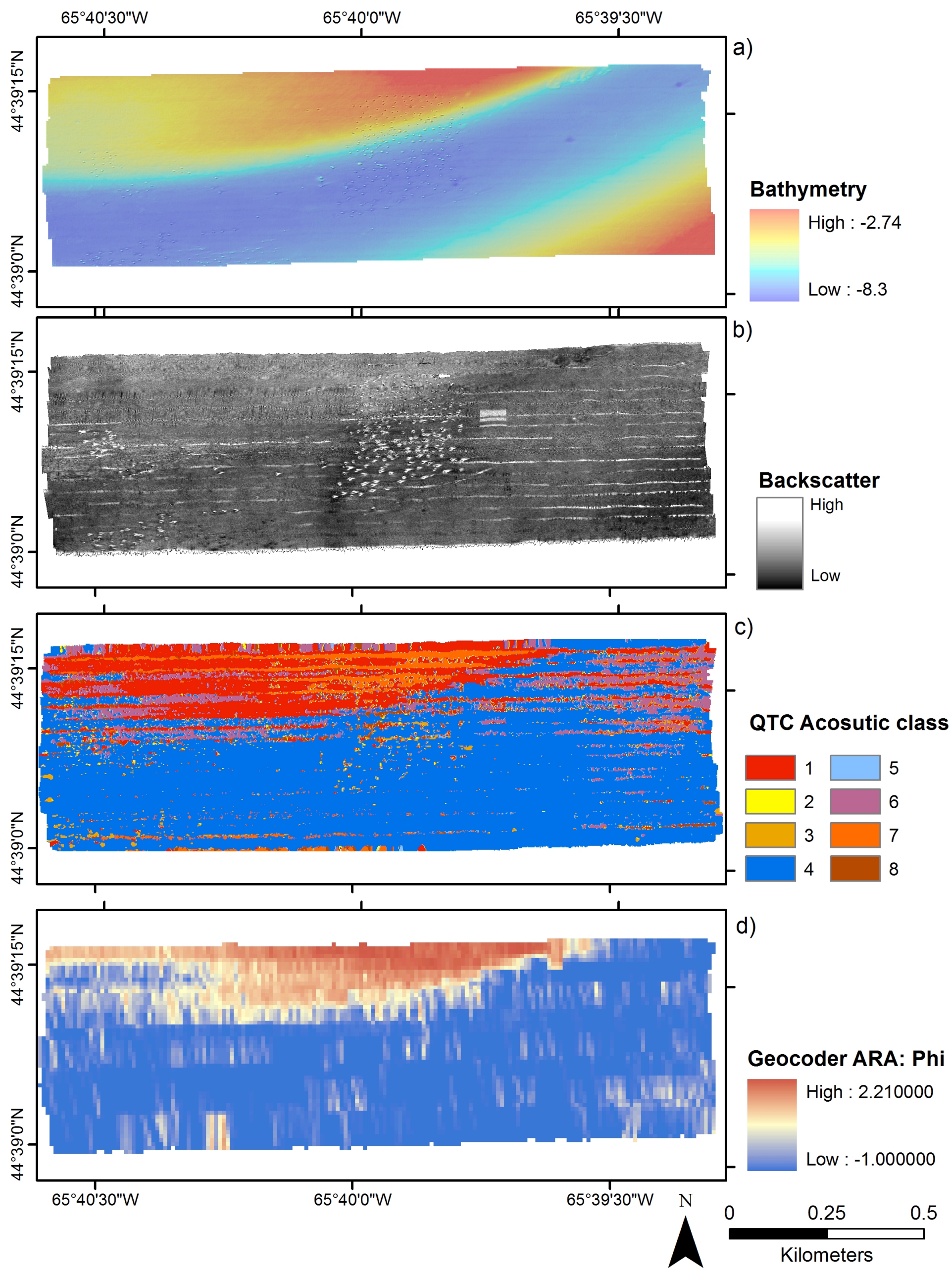


Figure 8 - Multibeam backscatter analysis - Site 1 preliminary results from first inter-tidal survey data set: a) Bathymetry of the site; b) Backscatter mosaic of the site. Light greyscale tones in the mosaic indicate weaker backscatter returns associated with softer sediments, and dark greyscale tones indicate stronger seabed returns indicative of coarser sediments; c) QTC Swathview classification. The classification uses an image-based approach to classify the seafloor into acoustic classes based on similarity in the backscatter image, in this case into 8 acoustic classes; d) Geocoder ARA classification. The classification uses a signal-based approach to predict sediment grain size of the seafloor based on changes in the backscatter signal across the multibeam swath. Grain size is predicted in phi, ranging from gravel (-1 phi) through to fine sand (+2 phi) at this site. These predictions do not agree with measured sediment grain size at the site. The Reson multibeam systems log uncalibrated backscatter data, and this may explain the discrepancy between the predicted and measured grain size values. Work is ongoing to investigate these issues.

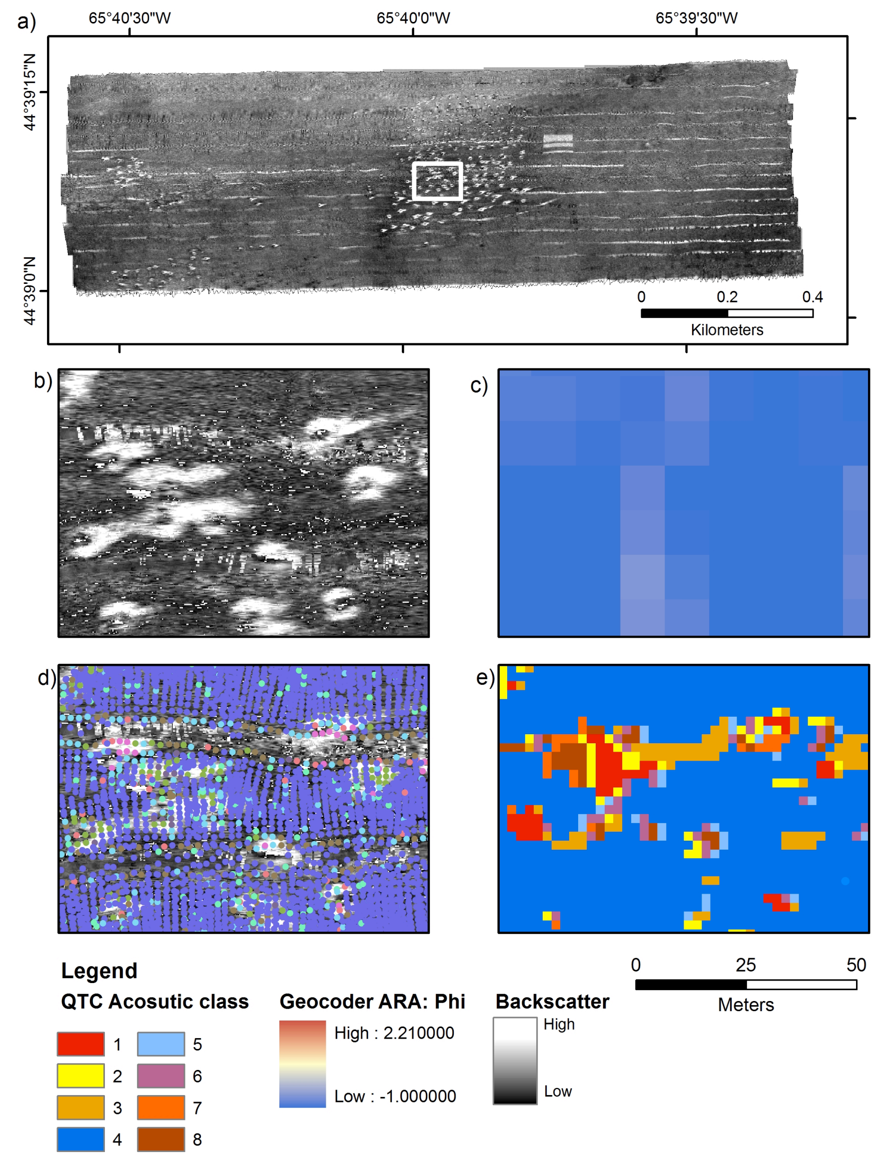
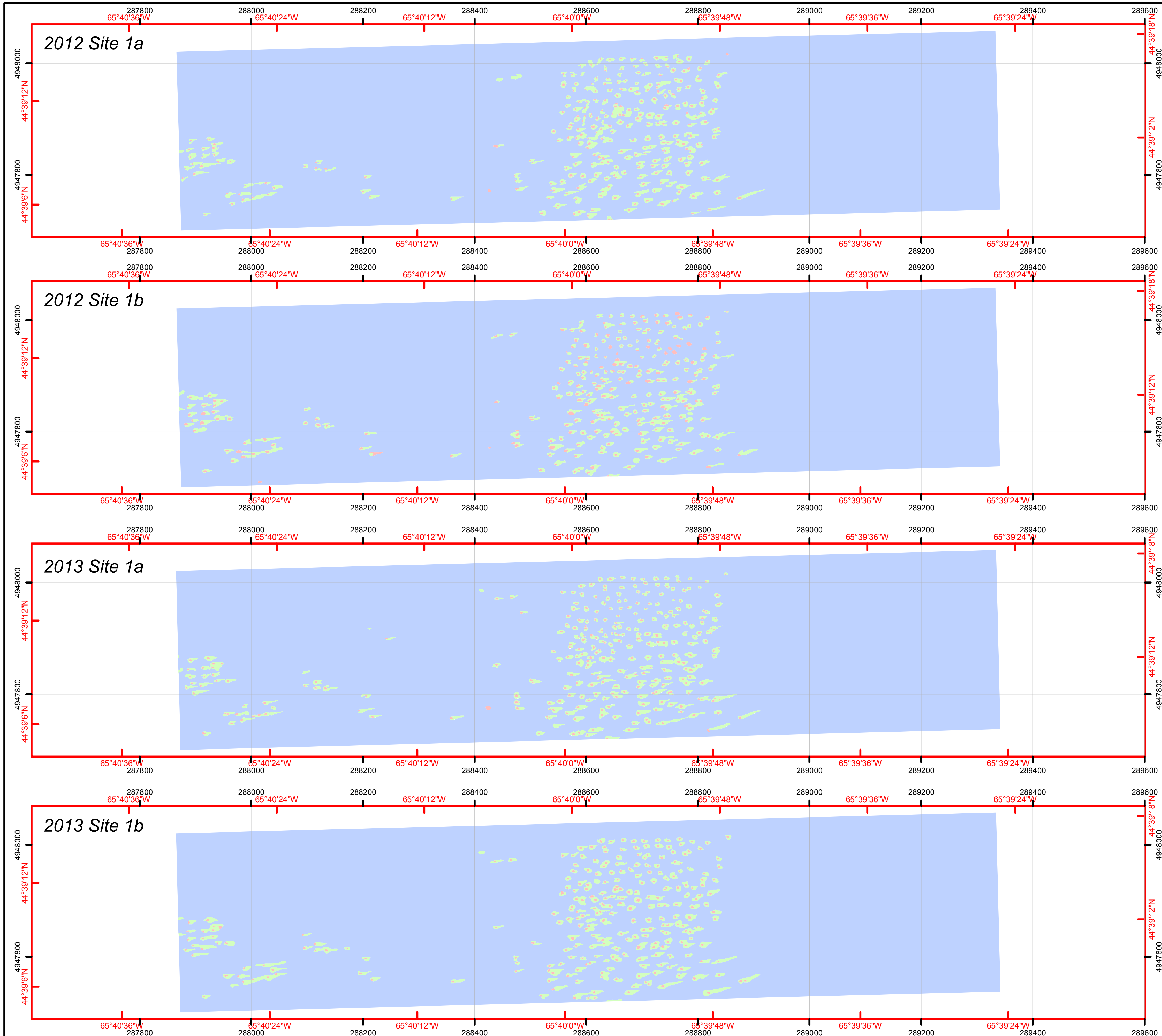
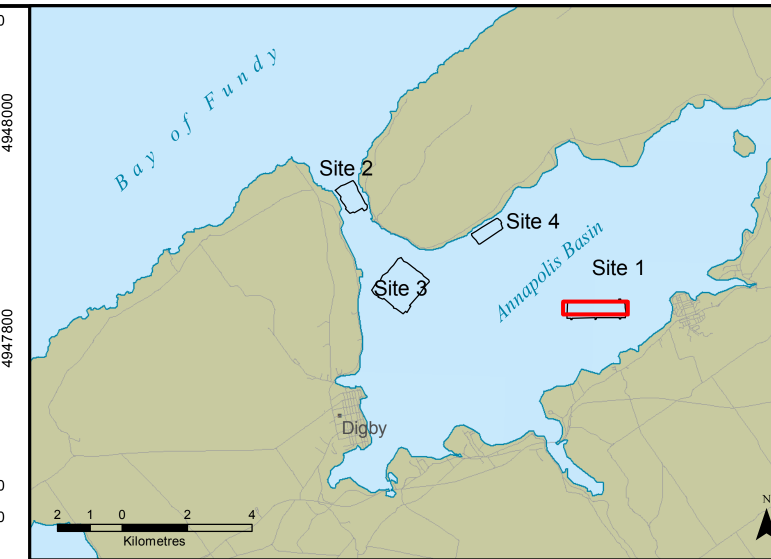


Figure 9 - Multibeam backscatter analysis: fine-scale assessment of performance. a) Site 1 multibeam backscatter mosaic. White polygon shows the area covered in panels b-e; b) Multibeam backscatter over seafloor objects (oyster cages) showing tidally induced scour features around the cages; c) Geocoder ARA classification. The scale of analysis is performed on a stacked number of multibeam sonar pings, representative of an area of seafloor. The ability of the approach to resolve fine scale features is limited, as illustrated by the homogeneous nature of the ARA classification which does not resolve the individual oyster cages ; d) QTC Swathview classification showing classified point data (patches). These points represent the analysis patches that the software uses to perform the classification (*i.e.* 9x17 backscatter pixels). Examination of the points reveals that the fine-scale features such as the scour pits and oyster cages are identified as discrete acoustic classes using the QTC methodology; e) QTC Swathview classification showing interpolated data (2m grid). Here the point data shown in image d have been interpolated to create a raster surface. Some of the fine-scale details are lost in the interpolation process, but the features are still mostly visible.

In addition backscatter mosaics were analysed using expert based “by-eye” interpretation for the inter-tidal and inter-annual surveys for Site 1 during 2012 and 2013. Polygons were created using *ArcMap 9.3.1* over visible features including both oyster cages and associated scours evident in the produced backscatter mosaics from inter-tidal and inter-annual surveys (**Figure 10**). Inter-tidal analysis was conducted from surveys collected in 2012 and 2013; these surveys are noted as 2012a, 2012b and 2013a, 2013b respectively. Additionally, inter-annual differences were calculated from 2012a and 2013a surveys (**Figure 11**). Once the polygons were created for each of the four surveys they were classified into three classes including: silty sand, scours, and oyster cages. The classified polygons were then converted to rasters and snapped to each other in order to allow pixel to pixel comparison between the data. Difference maps were created via raster math (subtraction) calculation tools within *ArcMap 9.3.1*. Percent differences were calculated from produced pixel values in order to evaluate the degree of change between the surveys. The 2012 inter-tidal data for Site 1 (surveys 2012a and 2012b) were compared resulting in 3.48% difference between classified polygons from 2012 inter-tidal surveys. The 2013 inter-tidal surveys showed similar results of 3.73% difference between the classified inter-tidal data polygons. Comparison of the inter-annual data between surveys from 2012 and 2013 show a 3.70% difference.

Differences between the inter-annual surveys can be attributed to survey errors including inherent position inaccuracies of the multibeam system and aforementioned environmental conditions between surveys. The inter-tidal difference maps highlight the outline of oyster cages and scours. Some of the oyster cages and scours are more visible in one mosaic than another. The backscatter mosaics created do not appear to have the resolution available for an expert to delineate small scale changes that may take place over short periods of time between tides. Changes between the inter-annual surveys show that scours over the survey area have either grown or shrank between 2012 and 2013. However, inter-annual differences can be attributed to the same inherent positional errors and environmental conditions apparent in the inter-tidal data. Additionally, by-eye interpretation can be relatively subjective as individual objects have to be traced and differentiated by eye and thus subject to human error.





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125 62.5 0 125 250 375 500
Metres

Seafloor Features

- Silty Sand
- Scour
- Oyster Cage

Note:
Map scale 1:7,000 when printed on 11x17 size paper

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Manual Interpretation of Backscatter Mosiacs

Site1

Annapolis Basin
Bay of Fundy

McGregor GeoScience Ltd.
Bedford, Nova Scotia, Canada

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Figure: 10

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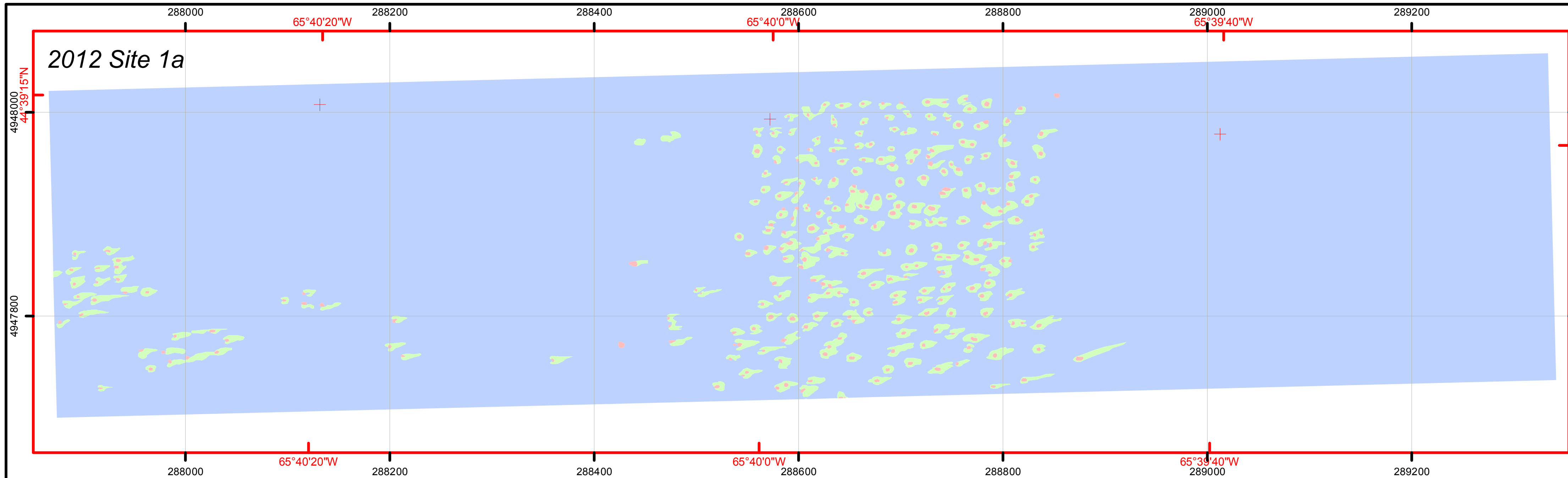

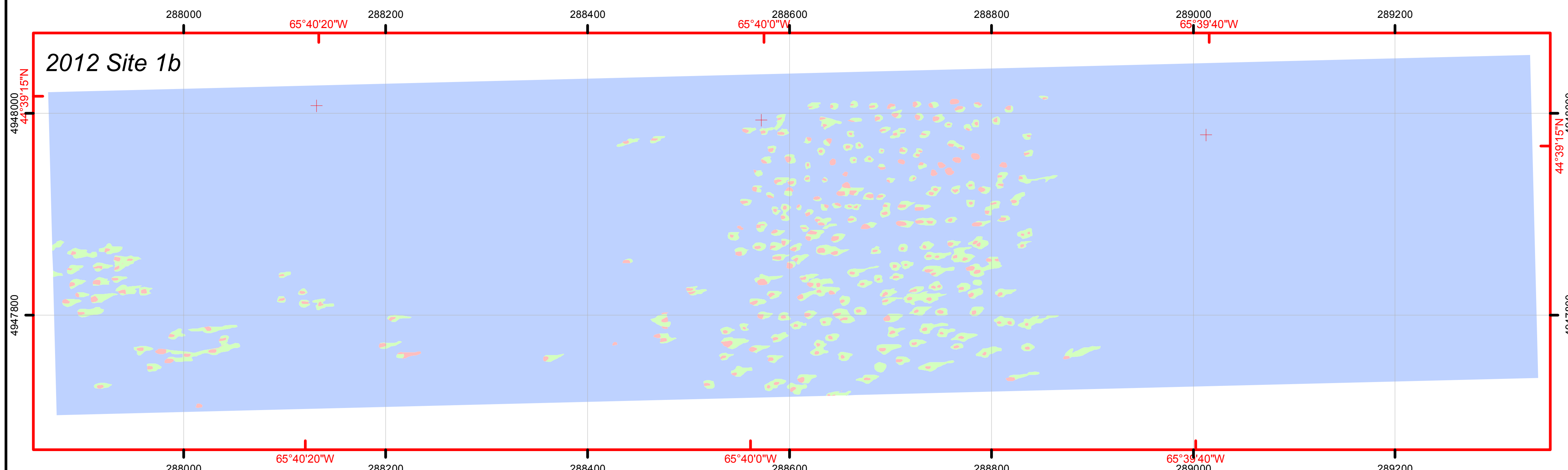

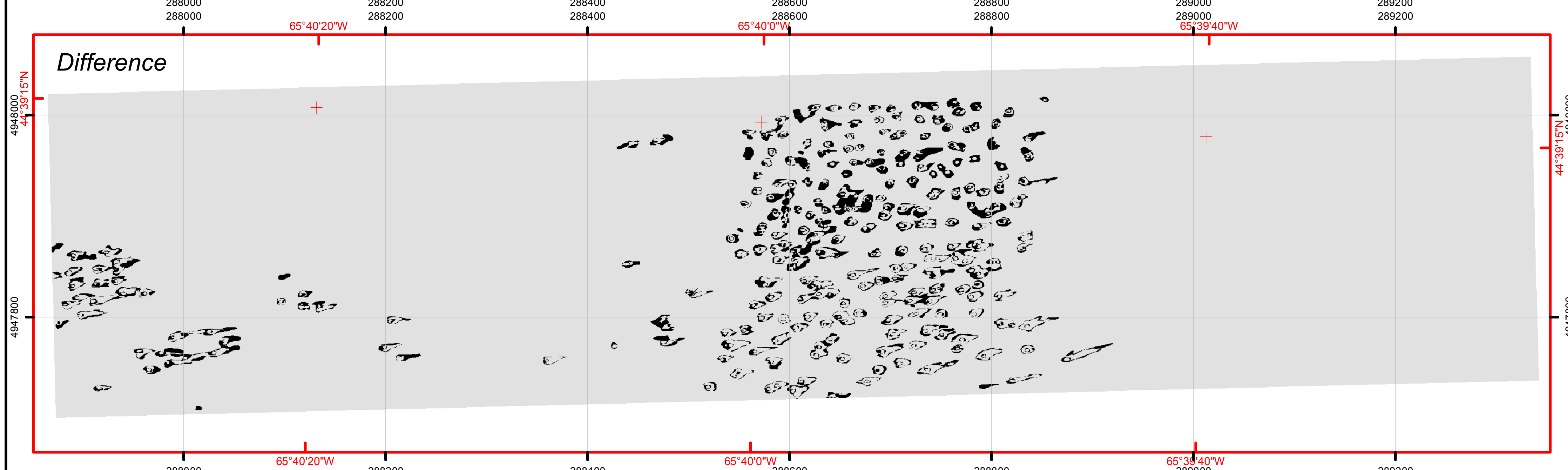

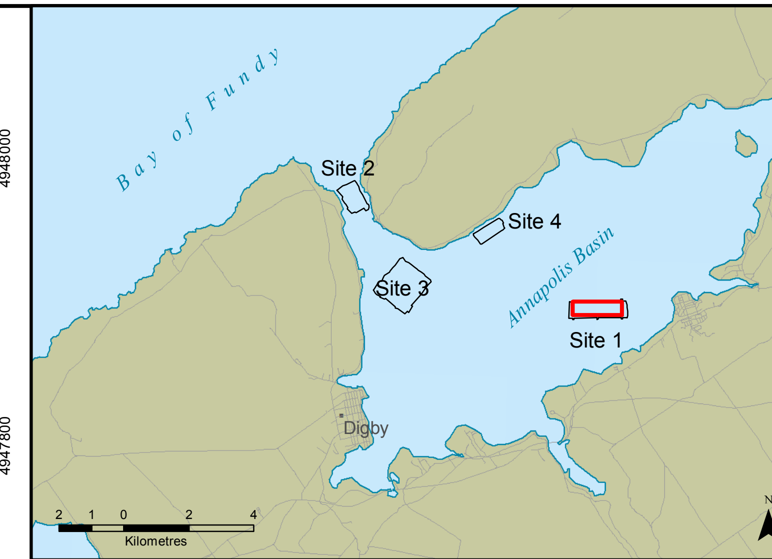

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N W E S

100 50 0 100 200 300 400
Metres

Seafloor Features	Difference
Silty Sand	Change
Scour	No Change
Oyster Cage	

Note:
Map scale 1:5,250 when printed on 11x17 size paper

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Difference Map of Manual Interpretation

2012 Site 1a & 2012 Site 1b

Annapolis Basin
Bay of Fundy

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Figure: 11a

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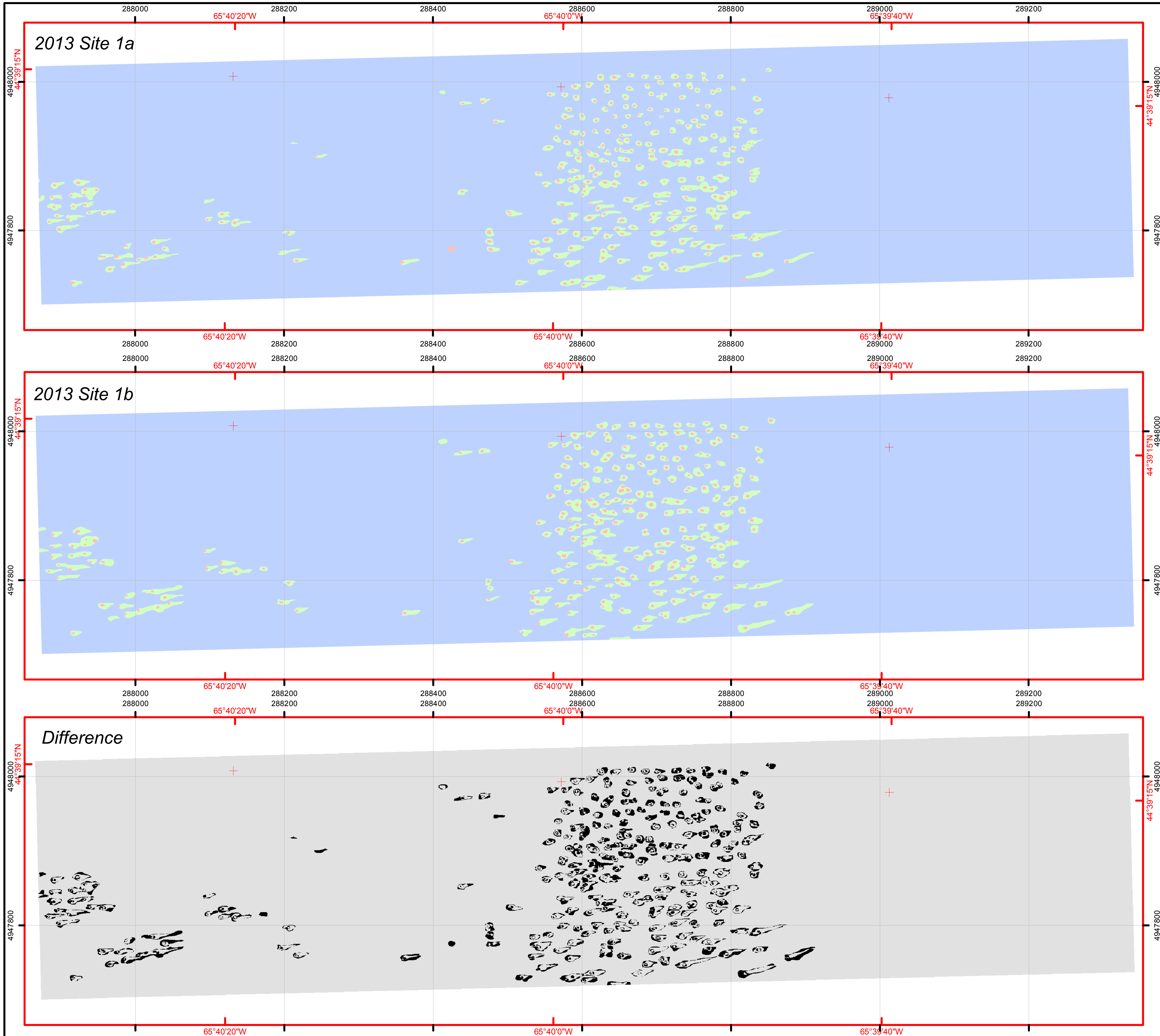

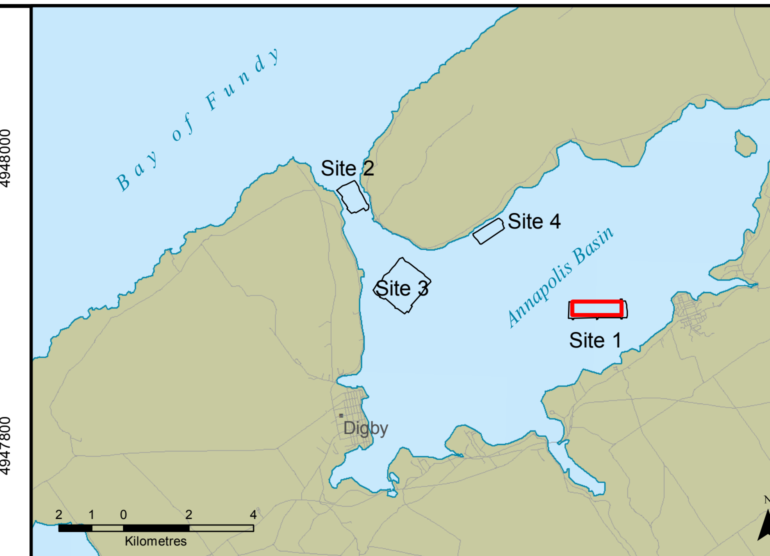

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Units: Meter

N W E S

100 50 0 100 200 300 400
Metres

Seafloor Features
- Silty Sand
- Scour
- Oyster Cage

Difference
- Change
- No Change

Note:
Map scale 1:5,250 when printed on 11x17 size paper

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Difference Map of Manual Interpretation

2013 Site 1a & 2013 Site 1b

Annapolis Basin
Bay of Fundy

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Figure: 11b

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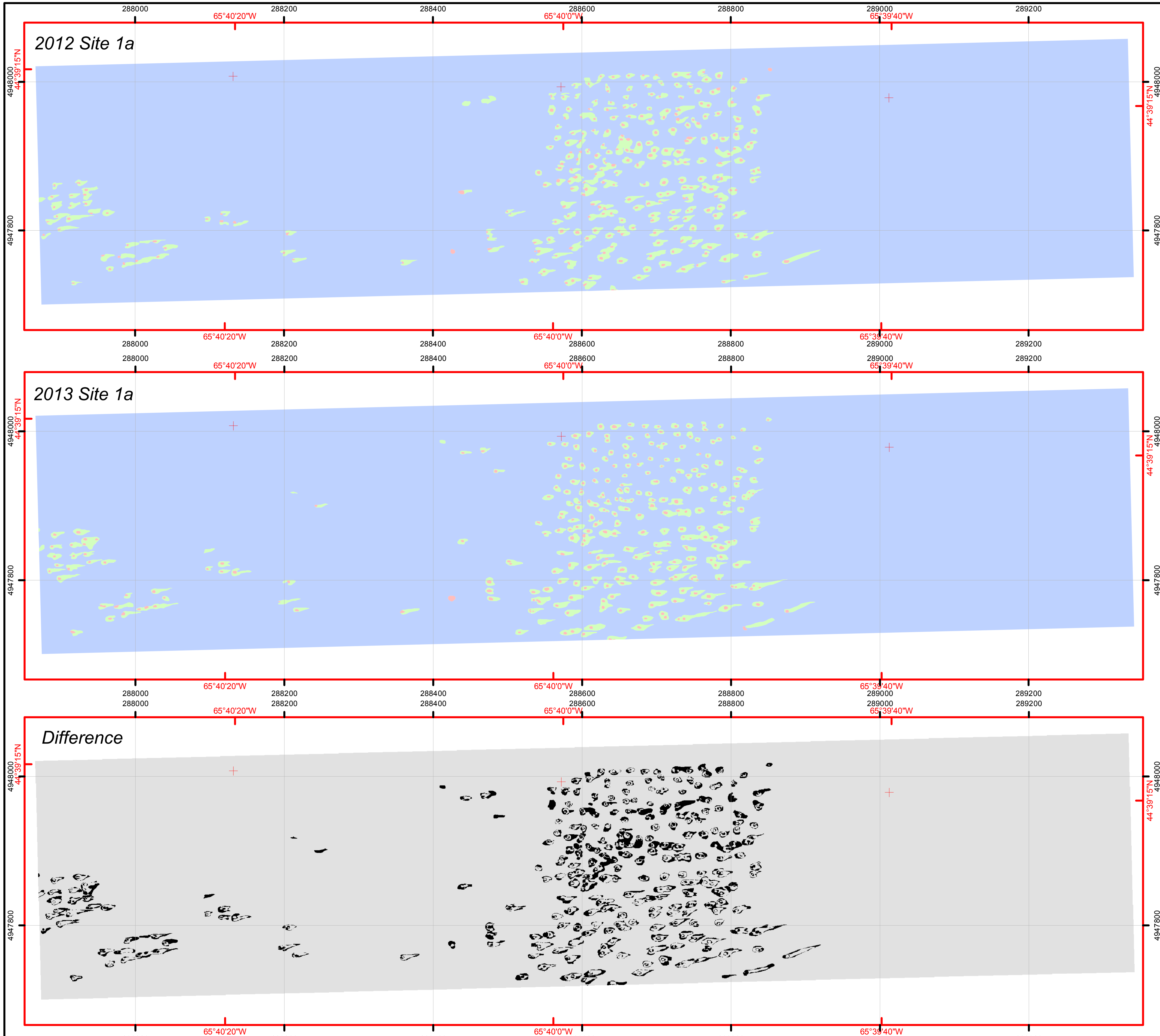

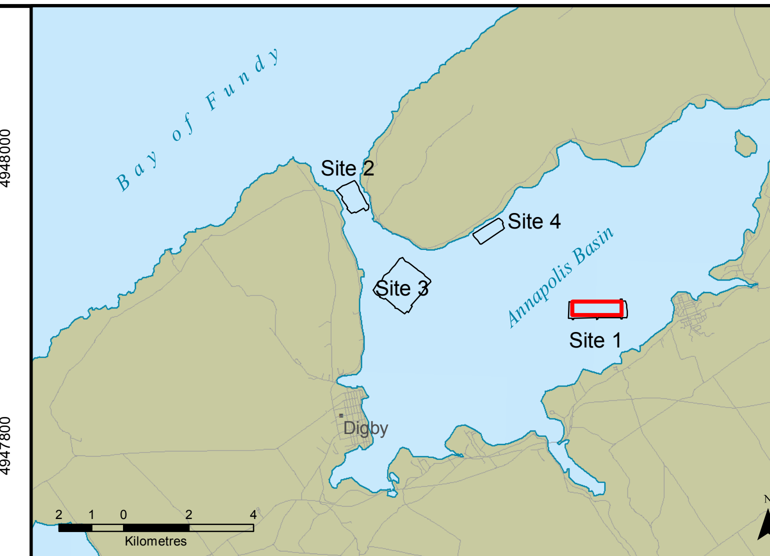

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Latitude Of Origin: 0.0000
Units: Meter

N W E S

100 50 0 100 200 300 400
Metres

Seafloor Features	Difference
Silty Sand	Change
Scour	No Change
Oyster Cage	

Note:
Map scale 1:5,250 when printed on 11x17 size paper

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Difference Map of Manual Interpretation

2013 Site 1a & 2012 Site 1a

Annapolis Basin
Bay of Fundy

McGregor GeoScience Limited

McGregor GeoScience Ltd.
Bedford, Nova Scotia, Canada

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Figure: 11c

McGregor Project No.: 1311

Filename: 1111_DifferenceC

3.1.2 Research Activity 2: Inter-annual repeat biological surveys - Summary of research conducted.

Data Acquisition – Benthic Grab Sampling

Biological sampling at selected stations was conducted on the 14th May 2012 and on the 17th May 2013 from the MV *Passage Provider*, a 14m fibreglass Cape Island style vessel. The sampling surveys were also run as a training exercise for the students on the NSCC COGS field camp to demonstrate benthic sampling methodology to the students.

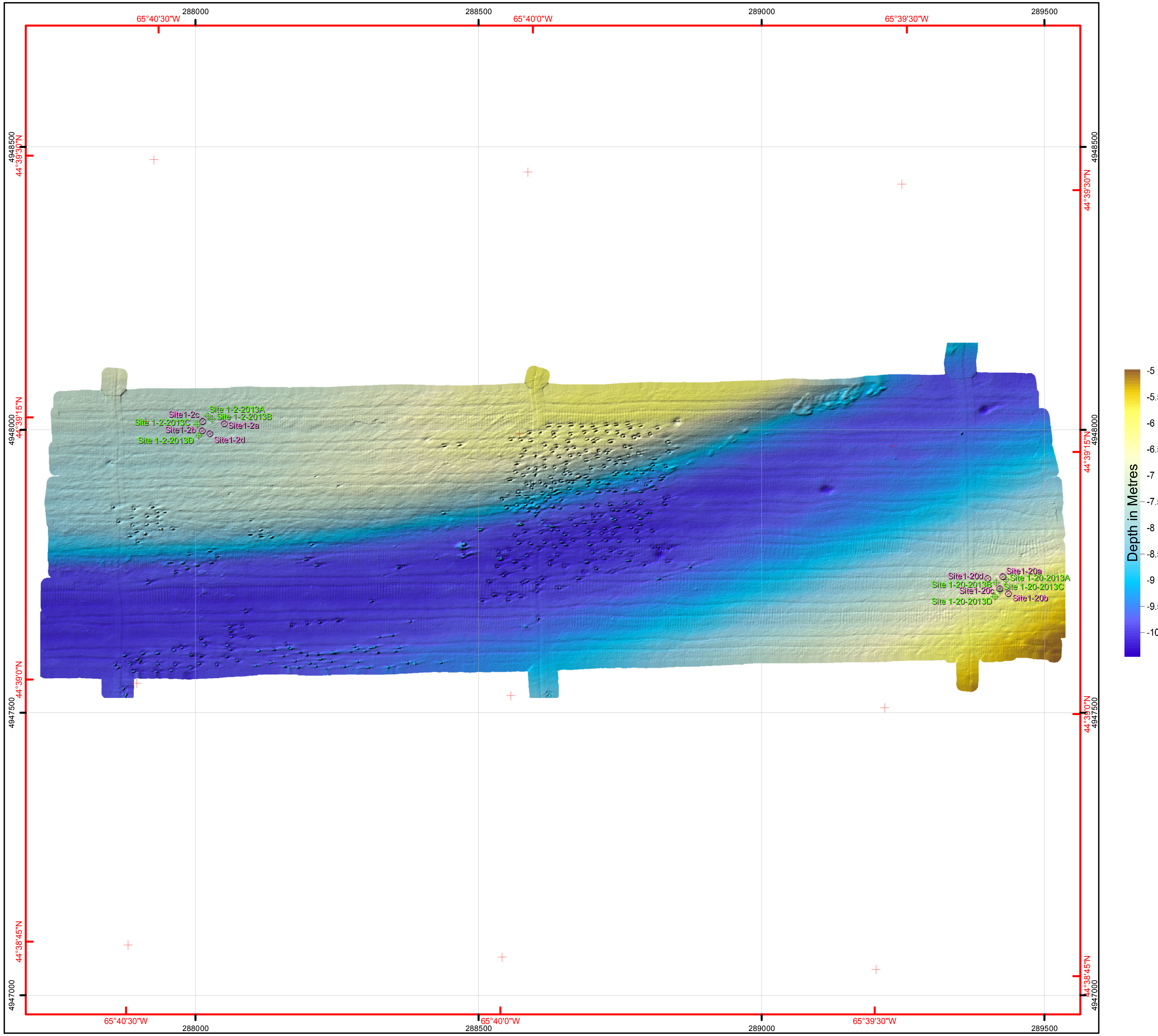
Sampling stations were selected to provide long-term, inter-annual monitoring sites to compare benthic assemblage structure which addresses research objective 3, and to measure particle grain size characteristics. A total of 12 benthic grab samples were collected from Site 1 and Site 3 in each year of the project (2012 and 2013) using a 0.1 m^2 van Veen grab sampler (**Table 2**). These comprised of: four replicate grab samples from two sampling station at Site 1 in each year (2012 and 2013); and four replicate grab samples collected from one sampling station at Site 3 in each year (2012 and 2013) (**Figure 12**). The grab was deployed from the starboard side of the vessel using a pot-hauler. A GPS fix was recorded each time the grab sampler reached the seafloor. To provide representative samples from different bottom types, station locations were chosen based on backscatter characteristics. Samples were considered “replicates” if they fell within a 50m range ring of the station position (**Figure 12** and **Table 2**).

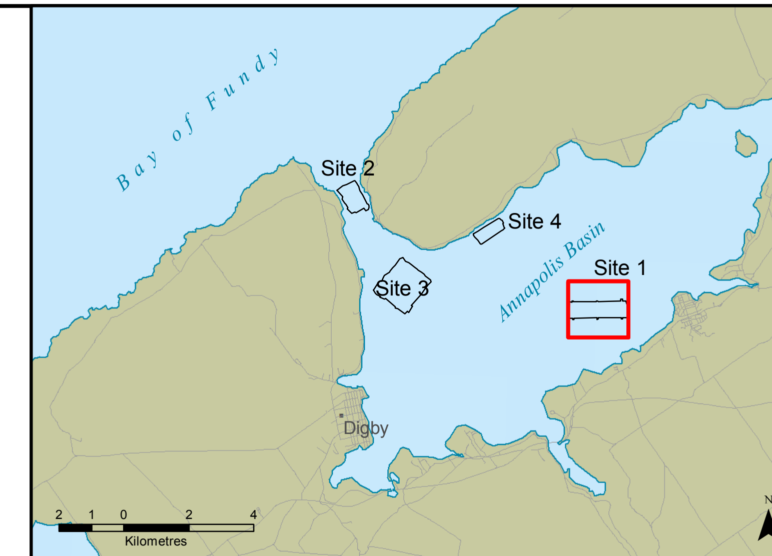
All benthic samples collected in 2012 and 2013 were photographed upon retrieval to the surface (**Figure 13**). Sub-samples were taken for particle grain size analysis, and the samples were washed over a 0.5mm sieve to remove fine grained sediments. Sieved residues were photographed and then fixed in formalin for transport back to the McGregor benthic laboratory for faunal analysis.

McGregor has a well-defined set of procedures for processing and identification of fauna from benthic samples. These procedures have been developed to comply with Oslo/Paris convention for the protection of the marine environment of the North-East Atlantic (OSPAR) and National Marine Biological Analytical Quality Control Scheme (NMBAQC) regulations, which ensure repeatability of the methods which is essential if the data is to be used for monitoring change. Each of the 12 benthic faunal samples from each survey year was washed with freshwater over a 500µm sieve to remove any preservative residue. All macrofauna were extracted from each sample, and identified to the lowest practical taxonomic level by specialist taxonomists at the McGregor GeoScience environmental laboratory in Bedford, Nova Scotia. The abundance of each taxa within each sample was recorded into Excel spreadsheets for further analysis of the data. All sample analyses were carried out in accordance with NMBAQC standards and all quality control steps were completed and recorded. A full reference collection of all specimens encountered was compiled for further clarification of putative species groups where/if required.

Table 2 - Benthic grab sample locations at Site 1 and Site 3 (2012 and 2013)

2012 Grab Samples				
	Location			
Grab Name	**Northing**	**Easting**	**Physical Properties**	**Biological Observations**
Site 3-1-2012A	4948640.34	282655.77	Cobbles, Pebbles, (some sand)	Hydrates, Barnacles, Epifauna
Site 3-1-2012B	4948626.86	282660.85	Cobbles, Pebbles, (some sand)	Shell, Sea Slug, Polychaete Worm, Epifauna
Site 3-1-2012C	4948630.95	282669.73	Cobbles, Pebbles, (some sand)	Shell piece, Scallop, Polychaete Worm, Epifauna
Site 3-1-2012D	4948495.87	282400.09	Cobbles, Pebbles	None
Site 1-2-2012A	4948011.86	288049.74	Silty Sand	Female Rock Crab, Polychaete Worm
Site 1-2-2012B	4947999.21	288010.22	Sandy Silt (Mud)	Amphipod (Crustacean), Polychaete Worm
Site 1-2-2012C	4948016.20	288011.53	Silty Sand	Amphipods
Site 1-2-2012D	4947993.73	288023.96	Silty Sand	Polychaete Worms, Bar Clam, Amphipods
Site 1-20-2012A	4947741.82	289424.84	Silt - Sandy Silt	None
Site 1-20-2012B	4947711.48	289435.21	Silt, Clay	Amphipods
Site 1-20-2012C	4947720.11	289420.00	Clay, Silt	Polychaete Worms, Amphipods
Site 1-20-2012D	4947737.88	289398.14	Silt, (some clay)	Amphipods
2013 Grab Samples				
Grab Name	**Northing**	**Easting**	**Physical Properties**	**Biological Observations**
Site 3-1-2013A	4948644.44	282651.46	Cobbles, Pebbles	Small sample. Course sediment with epifauna
Site 3-1-2013B	4948638.73	282666.19	Cobbles, Pebbles	Small sample. Course sediment with epifauna
Site 3-1-2013C	4948630.37	282685.57	Cobbles, Pebbles	Small sample. Course sediment with epifauna
Site 3-1-2013D	4948601.68	282670.82	Cobbles, Pebbles	Small sample. Course sediment with epifauna
Site 1-2-2013A	4948025.20	288020.85	Silty Sand	Amphipods abundant
Site 1-2-2013B	4648019.57	288028.11	Silty Sand	Amphipods abundant
Site 1-2-2013C	4948010.74	288001.80	Silty Sand	Amphipods abundant
Site 1-2-2013D	4947990.81	288004.71	Silty Sand	Amphipods abundant
Site 1-20-2013A	4947736.33	289430.71	Sandy mud	Anoxic layer - abundant fauna. Good penetration
Site 1-20-2013B	4947730.96	289413.89	Sandy mud	Anoxic layer. Cohesive mud below surface
Site 1-20-2013C	4947716.56	289420.21	Sandy mud	Sandy mud over cohesive anoxic layer
Site 1-20-2013D	4947705.69	289411.37	Sandy mud	Sandy mud over cohesive anoxic layer





NAD 1983 CSRS UTM Zone 20N
Projection: Transverse Mercator
Datum: North American 1983 CSRS
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: -63.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Meter

125 62.5 0 125 250 375 500
Metres

2012 Grab Location

2013 GrabLocation

Note:
Map scale 1:7,000 when printed on 11x17 size paper
Bathymetric data on this map is from 2012 survey data

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Benthic Grab Sampeling Locations in 2012 and 2013

Site1

Annapolis Basin
Bay of Fundy

McGregor GeoScience Ltd.
Bedford, Nova Scotia, Canada

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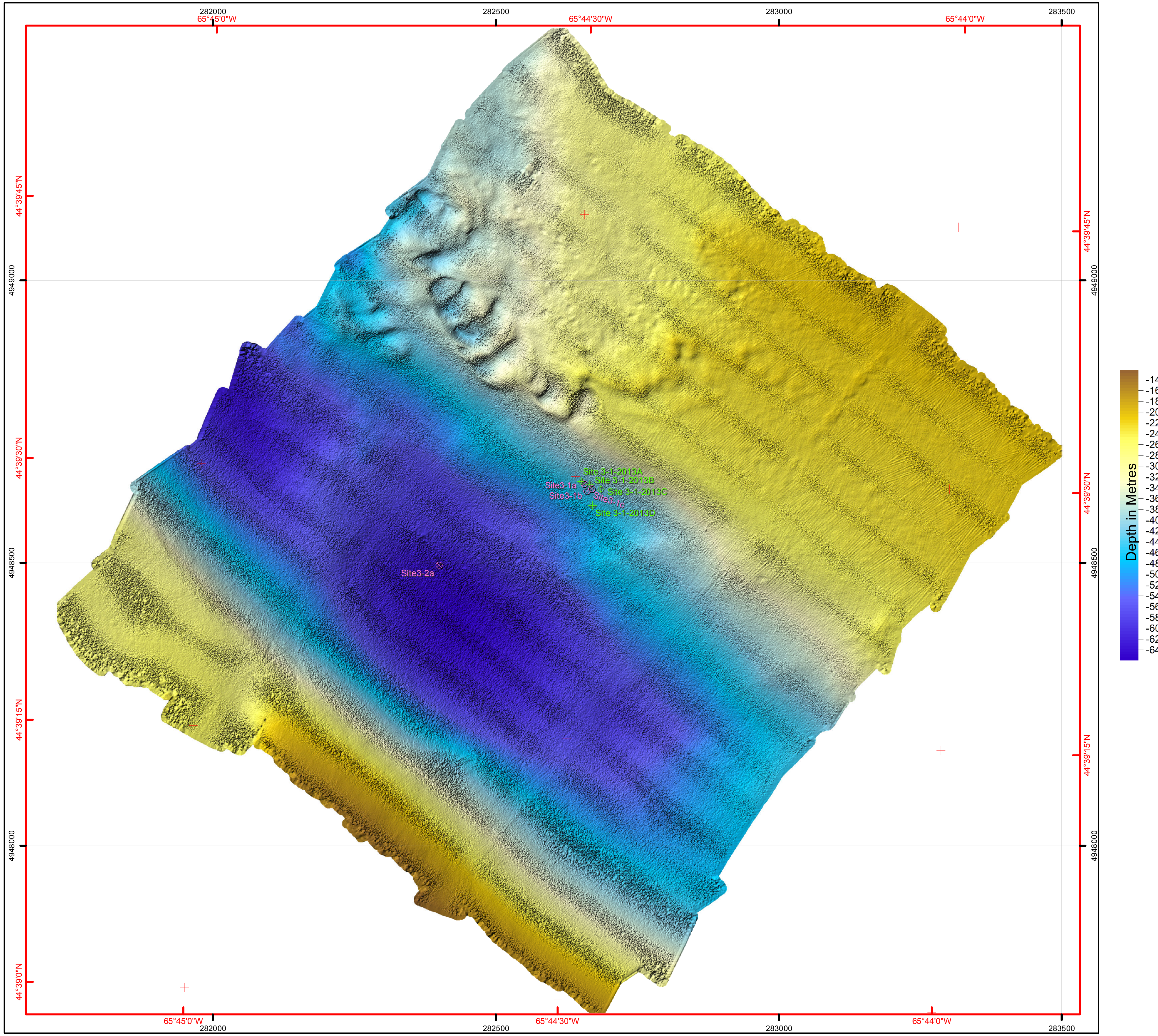
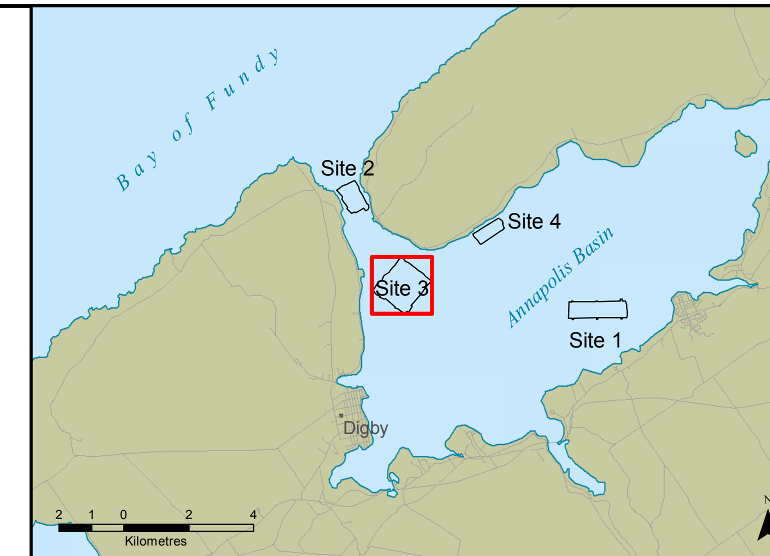
Figure: 12a

McGregor Project No.: 1111

Filename: 1111_s1GrabCompare





NAD 1983 CSRS UTM Zone 20N
Projection: Transverse Mercator
Datum: North American 1983 CSRS
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: -63.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Meter

N W E S

125 62.5 0 125 250 375 500
Metres

2012 Grab Location

2013 GrabLocation

Note:
Map scale 1:7,000 when printed on 11x17 size paper
Bathymetric data is from 2012 survey data

OERA Offshore Energy Research Association of Nova Scotia

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OffShore Research
Association Of Nova Scotia

Benthic Grab Sampeling Locations in 2012 and 2013

Site3

Annapolis Basin
Bay of Fundy

McGregor GeoScience Limited

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Bedford, Nova Scotia, Canada

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Figure: 12b

McGregor Project No.: 1111

Filename: 1111_s3GrabCompare

McGregor
GeoScience
Limited

Figure 13 Representative Photos of Benthic Samples in 2012 & 2013 Figure 13

Results- – Benthic Grab Sampling

Particle size analysis (PSA) was undertaken on the subsamples collected from each grab sample collected in 2012 and 2013. Results indicated a subtle but noticeable change in the grain size distribution at both stations 2 and 20 at Site 1 (**Table 3** and **Figure 14**). Sediments at both stations showed consistently coarser sediments in 2013 compared to 2012. This could be due to a number of environmental factors, including inter-annual changes in sedimentation/erosion at the site between years (*i.e.* higher sedimentation in 2012, stronger bottom currents in 2013 removing fines, or a combination of the two). This demonstrates that the sampling approach is sensitive enough to detect subtle shifts in grain size composition. Differences in grain size distribution at Site 3 should be interpreted with caution. The coarse nature of the sediments at this site make sampling with the van Veen grab challenging. It is possible that the grain size composition could be affected during sampling, as coarse grained particles could cause washout of the fine sediment fraction upon retrieval of the sample to the surface.

Table 3 - Particle grain size data from the benthic grab samples

2012 Station/Sample	% Gravel	% Sand	% Silt/Clay
Site 1 - 20-2012A	0.00	64.90	35.10
Site 1 - 20-2012B	0.00	64.29	35.71
Site 1 - 20-2012C	0.00	66.90	33.10
Site 1 - 20-2012D	0.00	58.96	41.04
Site 1 - 2-2012A	0.00	81.78	18.22
Site 1 - 2-2012B	0.00	81.84	18.16
Site 1 - 2-2012C	0.00	80.55	19.45
Site 1 - 2-2012D	0.00	82.38	17.62
Site 3 - 1-2012A	No sample		
Site 3 - 1-2012B	No sample		
Site 3 - 1-2012C	57.08	31.73	1.35

2013 Station/Sample	% Gravel	% Sand	% Silt/Clay
Site 1 - 20-2013A	0.00	74.25	25.75
Site 1 - 20-2013B	0.00	76.43	23.57
Site 1 - 20-2013C	0.00	78.48	21.52
Site 1 - 20-2013D	0.00	74.61	25.39
Site 1 - 2-2013A	0.00	86.39	13.61
Site 1 - 2-2013B	0.00	84.90	15.10
Site 1 - 2-2013C	0.00	87.01	12.99
Site 1 - 2-2013D	0.00	86.39	13.61
Site 3 - 1-2013A	82.12	17.80	0.08
Site 3 - 1-2013B	87.15	12.81	0.04
Site 3 - 1-2013C	95.31	4.62	0.07
Site 3 - 1-2013D	92.32	7.65	0.03

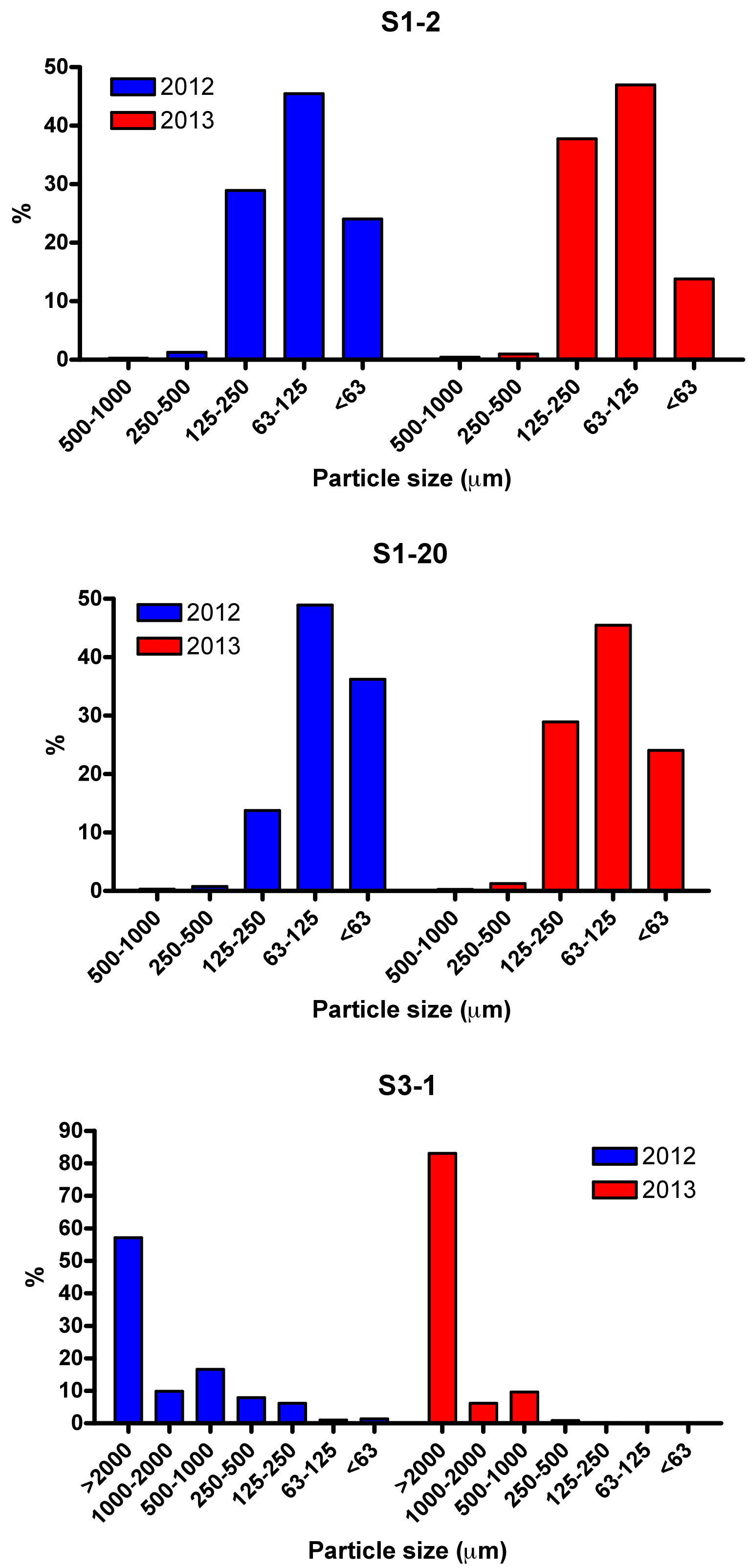

Figure 14: Comparison of sediment grain size distributions at stations S1-2, S1-20 and s3-1 between samples collected in 2012 and 2013.

In 2012, a total of 4,699 individuals comprising 129 taxa were recorded from the 12 benthic grab samples. The top five dominant taxa were the amphipod *Leptocheirus pinguis* (accounting for 16.2% of total abundance), the polychaetes *Bipalponephtys neotena* (accounting for 15.7%) and *Spirorbis granulatus* (accounting for 9.4%), nematodes (accounting for 14.8%), and the oligochaete Tubificidae sp. (accounting for 4.9%).

In 2013, a total of 18,607 individuals were collected and 144 taxa were recorded from the 12 benthic grab samples. The top six dominant taxa were the amphipod *Leptocheirus pinguis* (accounting for 46.9% of total abundance), the polychaetes *Bipalponephtys neotena* (accounting for 9.8%), *Leitoscoloplos fragilis* (accounting for 5.5%), and *Filograna implexa* (accounting for 3.2%), the oligochaete Tubificidae sp. (accounting for 6.5%), and the bivalve *Heteranomia squamula* (accounting for 4.9%). *F. implexa* and *H. squamula* were only found on hard substratum at Site 3, while other species only occurred in soft sediments at Site 1 stations. High abundance at S1-20 in 2013 was mainly attributed to the amphipod *Leptocheirus pinguis* with the highest value of 2,897 individuals per grab sample.

Comparison between the 2012 and 2013 infaunal data sets revealed interesting inter-annual differences in community composition at all stations, especially stations at Site 1. These differences can be primarily attributed to differences in the top five dominant taxa (**Table 4**). Comparison of univariate diversity measures between 2012 and 2013 revealed higher species abundance and diversity in 2013 compared with 2012, which was particularly evident at site 1 (stations S1-2 and S1-20) (**Figure 15**).

Multivariate statistical analysis techniques were also used to compare the benthic infaunal assemblage data between the 2012 and 2013 repeat surveys, and revealed similar patterns. Hierarchical agglomerative clustering and non-metric multi-dimensional scaling (nMDS) were employed to investigate inter-annual faunal patterns from the seafloor samples collected at Site 1 and Site 3, based on sample similarities, using the software PRIMER 6 (Clarke and Warwick, 2001). Both methods revealed that a shift in infaunal assemblage structure could be detected between the 2012 and 2013 sampling periods (**Figures 16 and 17**). Differences in community structure at site 3 were less obvious (smaller difference in similarity between 2013 and 2012 samples). However, Site 1 displayed a high level of dissimilarity between 2012 and 2013 (50-60% dissimilarity between years), which can be primarily attributed to the high abundance of the amphipod *Leptocheirus pinguis* in 2013 (**Figures 16 and 17**). This is clearly visible by the high degree of separation of samples from 2012 and 2013 in the MDS ordination (**Figure 17**), while the tight clustering by station within year supports that replicate samples showed a high level of similarity.

The reasons for these differences are not certain, but could be due to changes in inter-annual environmental conditions at the site. A subtle but noticeable change in the grain size distribution at both stations 2 and 20 at Site 1 was recorded (see particle grain size analysis results above). Sediments at both stations showed consistently coarser sediments in 2013 compared to 2012, which in turn could affect the infaunal community composition (**Figure 17**). This could be due to a number of environmental factors, including inter-annual changes in sedimentation/erosion at the site between years (*i.e.* higher sedimentation in 2012, stronger bottom currents in 2013 removing fines, or a combination of these two factors). These results demonstrate that the sampling/monitoring method is sensitive enough to detect subtle shifts in grain size composition and community composition over inter-annual time periods.

Table 4 - Comparison of top five dominant species and abundance % inter-annually

Station	2012	2013
S1-2	Nematoda spp. (34.7%) *Leptocheirus pinguis* (26.3%) *Nephtys ciliata* (6.4%) *Leitoscoloplos fragilis* (3.4%) *Tubificidae* sp. (3.3%)	*Leptocheirus pinguis* (45.5%) *Nematoda* sp. (7.5%) *Tubificidae* sp. (7.0%) *Leitoscoloplos fragilis* (6.5%) *Aricidea suecica* (3.7%)
S1-20	*Bipalponephtys neotena* (43.7%) *Leptocheirus pinguis* (17.4%) *Tubificidae* sp. (10.3%) *Leitoscoloplos fragilis* (5.1%) *Meganerilla penicillicauda*? (3.8%)	*Leptocheirus pinguis* (57.2%) *Bipalponephtys neotena* (14.5%) *Tubificidae* sp. (7.7%) *Leitoscoloplos fragilis* (6.4%) *Tharyx acutus* (3.2%)
S3-1	*Spirorbis granulatus*? (36.7%) *Euclymene zonalis* (8.7%) *Exogone verugera* (7.7%) *Circeis spirillum* (6.7%) *Heteranomia squamula* (4.7%)	*Heteranomia squamula* (35.4%) *Filograna implexa* (22.7%) *Ischyrocerus anguipes* (6.1%) *Exogone verugera* (4.9%) *Modiolus modiolus* (3.1%)

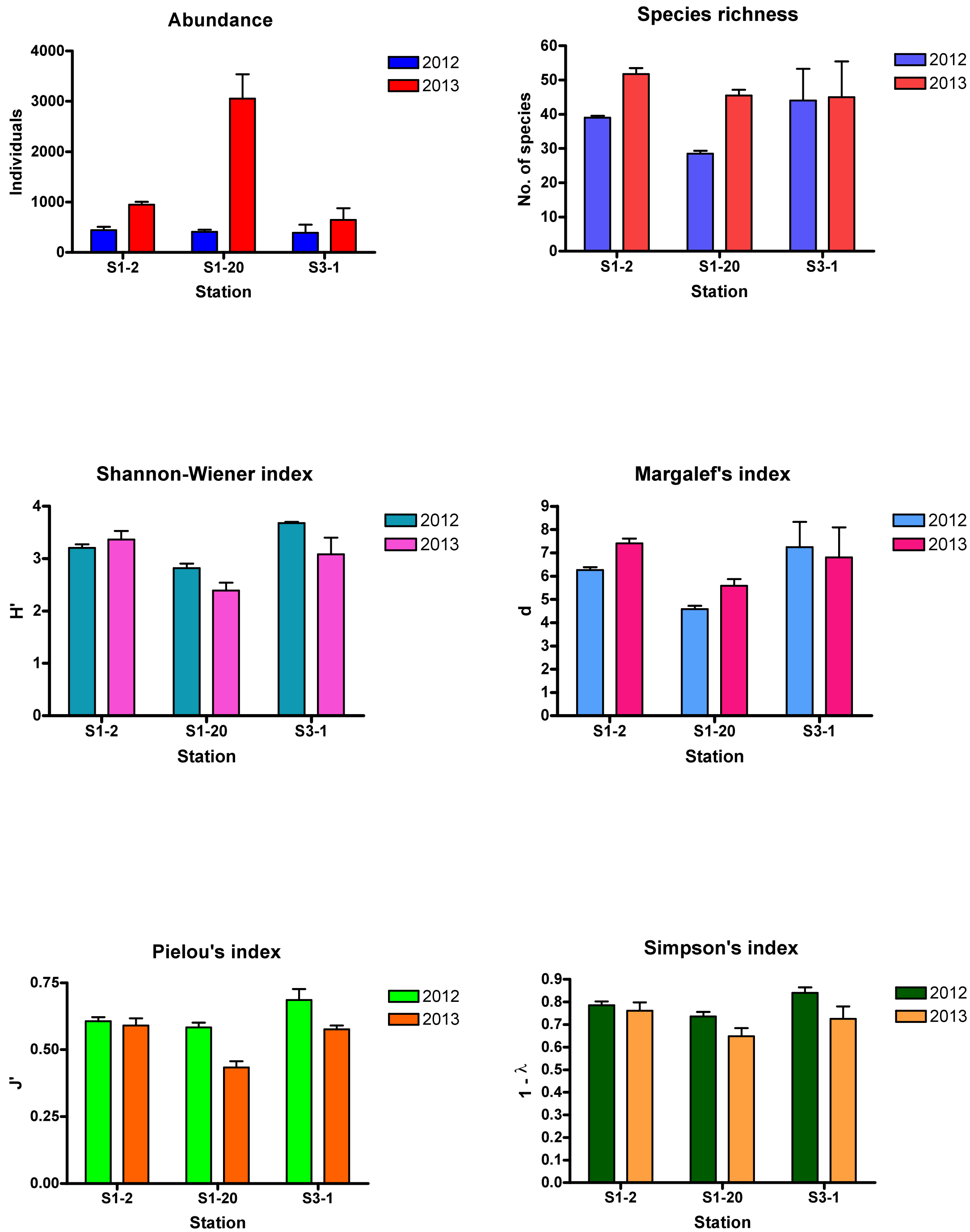

Figure 15 - Comparison of univariate diversity indices between the 2012 and 2013 inter-annual data sets. Results show differences between years, with generally higher species abundance and diversity recorded in 2013, especially at Site 1.

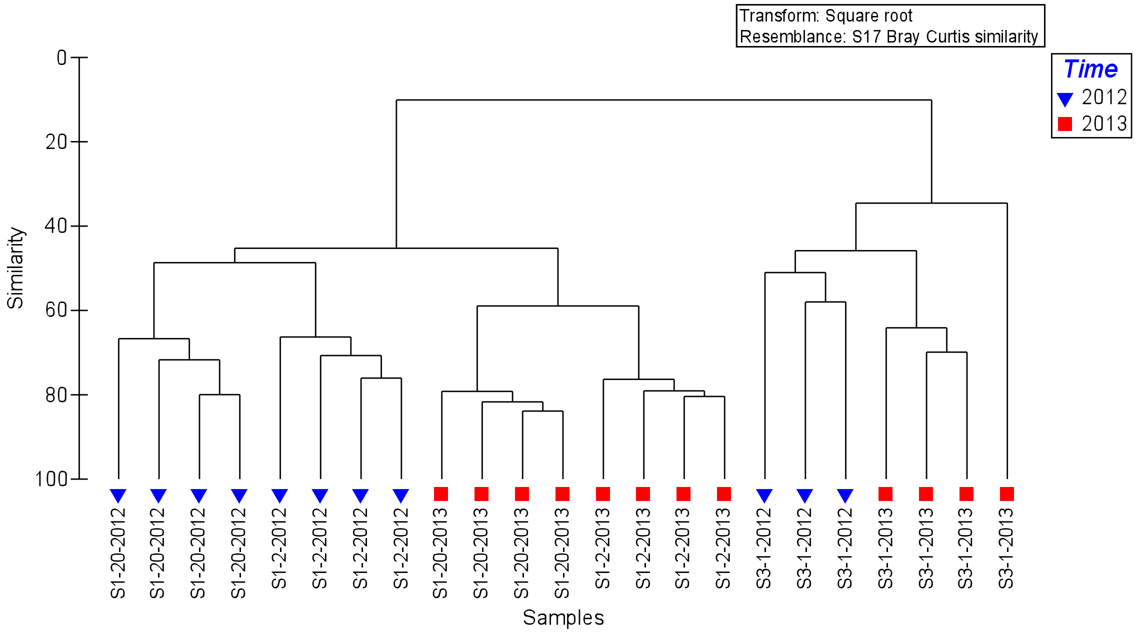

Figure 16 - Dendrogram from multivariate analysis of the benthic macrofaunal community data from 2012 and 2013 using the software PRIMER. Results show grouping (*i.e.* high similarity) of replicate samples from each selected monitoring station within each year, and a relatively high level of dissimilarity within stations between years (at Site 1).

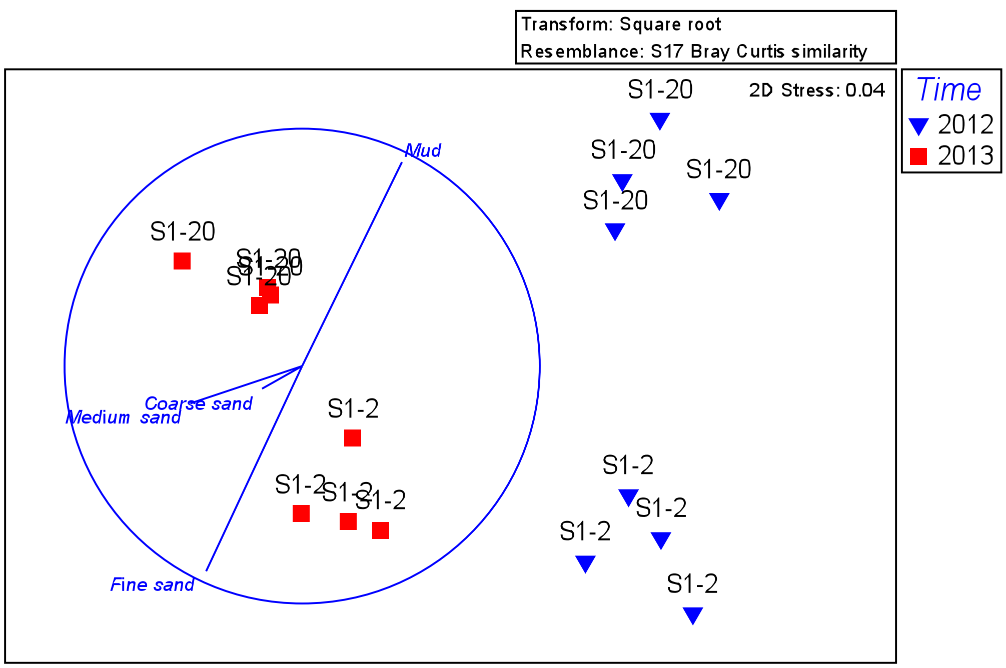

Figure 17 - nMDS ordination plot (with stations coded by survey station and year) for samples collected at Site 1. Results show grouping (*i.e.* high similarity) of replicate samples from each selected monitoring station within each year, and a relatively high level of dissimilarity (*i.e.* greater separation) between years.

Data Processing – Evaluation of subsampling methods

McGregor has a well-defined set of procedures for processing and identification of fauna from benthic samples which have been developed to comply with OSPAR and NMBAQC regulations. These standards ensure repeatability of the methods which is essential if the data is to be used for monitoring programs. However, sub-sampling techniques are sometimes employed in non-NMBAQC compliant laboratories (particularly in North America) to expedite sample processing and reduce sample processing costs. The impact that these sub-sampling techniques have on data quality and the relative sensitivity of the approach to detect change in community composition are often unknown, and are not documented in the scientific literature. Additional work was therefore carried out to test the impact that these sub-sampling methods have on the quality of the data and subsequent sensitivity to detect change. The 2012 and 2013 samples from Site 1 were re-sorted using two different subsampling techniques. This exercise allowed comparison with the full NMBAQC compliant data sets presented above, and each sub-sampling method could therefore be evaluated. The results from these additional sub-sampling trials are presented below.

Two subsampling methods were tested: 1) “Quarterizer” subsampler; 2) Marchant Box (**Figure 18**). The “Quarterizer” is an instrument used to subsample 25% of the total sediment residue. The sample is placed in the top collection cylinder of the device and mixed (gently shaken) and then allowed to settle into the four equal segments at the base of the cylinder. One of these segments is then removed from below into a collection container for sorting and identification of fauna. These types of subsamplers are frequently used for processing marine faunal samples.

Marchant boxes are designed and routinely used for subsampling benthic invertebrate samples from freshwater systems, and are not usually used in marine sample processing. However, the subsampling approach could equally be used for marine applications, and the method was trialed as part of this investigation. Each cell of the Marchant box is filled ¾ full with water. It is important not to overfill the cells as the sub-sampling will not be effective. The lid is securely fastened to the box so that it creates a water tight seal. The box is then flipped over (180 degrees, top to bottom) and stirred gently to evenly distribute the sample. When the sample appears to be mixed in the open area of the lid, the box is quickly flipped back onto the bottom side where the sample should be evenly distributed across the 100 cells. If the cells do not show even distribution, the process of flipping and stirring the sample should be repeated until a uniform sub-sample is created.
A random number table is used to select cells from which to extract the residue (*i.e.* 25 cells are selected to subsample 25% of the sample). A vacuum pump is used to extract the sample gently into a collecting flask. The sides of the cell must be rinsed to ensure that all organisms are collected. The sub-sample in the flask can then be carefully transferred to a Petri dish or sorting tray for extraction of fauna.

Eight 0.1 m^2 replicate samples collected in 2012 and 2013, two each from S1-2 and S1-20 in each year, were sub-sampled using a Marchant box and a quarterizer. Each sample was sub-sampled with both methods. Residue and all specimens in each sample were recombined and mixed up, and one-fourth residue volume was sub-sampled and re-sorted. Abundance of each species in each sub-sample was multiplied by 4 before statistical analysis.

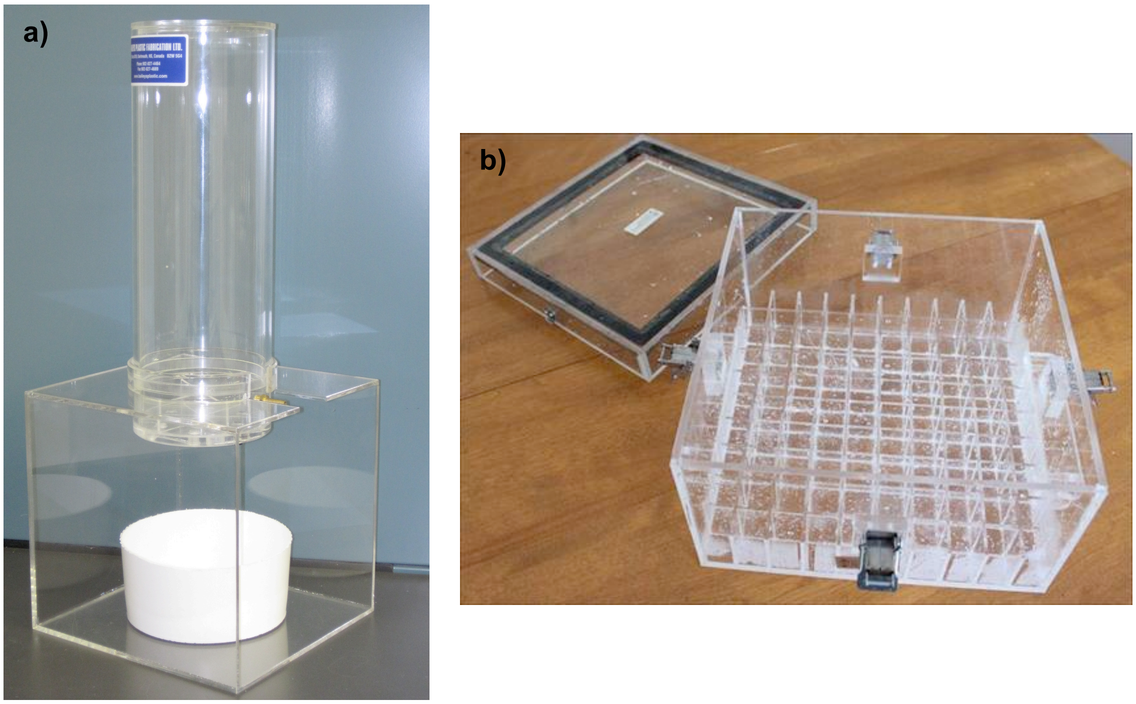

Figure 18 - Subsampling methods/equipment: a) Quarterizer – the sample is shaken in the top collection cylinder and allowed to settle into the four equal segments at the base of the cylinder. One of these segments is them removed from below into a collection container for sorting and identification of fauna; b) Marchant box. The subsampler contains 100 cells. The sample is mixed and distributed across the cells, and the residue from a random subset of cells can be extracted to subsample a percentage of the total volume (*i.e.* 25 cells selected to subsample 25% of the sample). A vacuum pump is used to extract the sample gently into a collecting flask for further processing.

Sub-sampling did not change the significant differences in similarity between sites and years (**Figures 19 and 20**). Highest similarities were found within each sample group (**Figure 19**), which indicates that the subsampling methods did not affect the faunal patterns when compared against the full NMBAQC methodology.

In general, there were no significant changes caused by sub-sampling in abundance, Shannon-Wiener diversity index and Simpson's index (**Figure 21**). However, species richness indices (species number and Margalef's index) were significantly lower in sub-samples from all groups, while Pielou's evenness index was higher for sub-samples, due to increased percentages of rare species and then lower dominance of dominant species in sub-samples.

No significant differences were found between the sub-samples using the two sub-sampling methods. These findings suggest that subsampling methods still allow trends in faunal composition (*i.e.* community structure) to be determined over a time series data set. This would allow faster, more cost effective sample processing to take place when collecting benthic infaunal samples as part of long term monitoring programs. However, it should be noted that subsampling methods do affect diversity measures, and resulted in lower species richness estimates from samples. This can have important consequences if accurate diversity estimates from an area are required. In such cases, the full NMBAQC methodology, which processes the entire sample, are recommended.

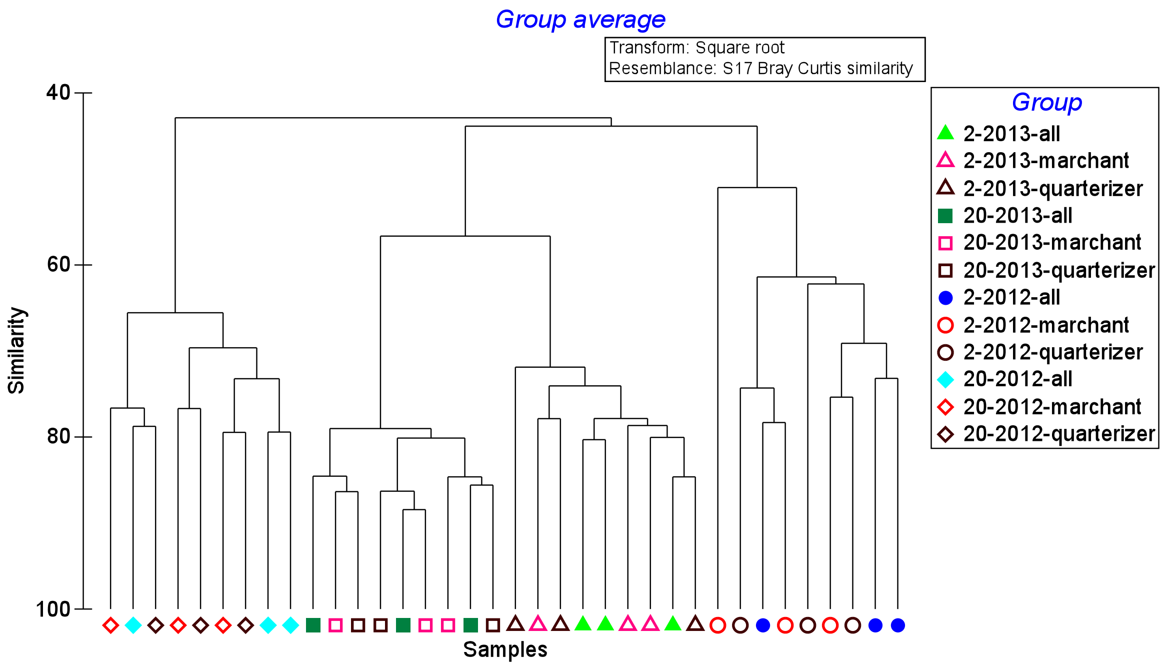

Figure 19 - Dendrogram from multivariate analysis of the benthic macrofaunal community data showing the results from the two subsampling methods and the full NMBAQC methodology using the software PRIMER. Results show grouping (*i.e.* high similarity) of samples from each selected monitoring station for all three sampling methods (*i.e.* full NMBAQC, Marchant and quarterizer).

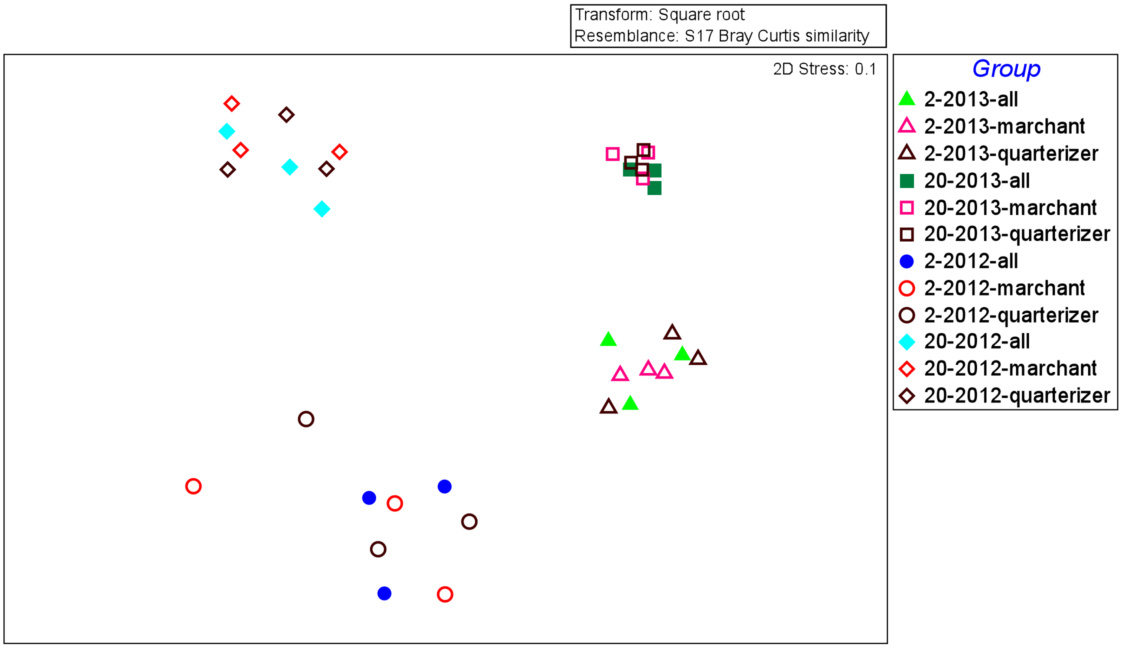

Figure 20 - nMDS ordination plot (with stations coded by survey station and subsampling method). Results show grouping (*i.e.* high similarity) of subsampling methods from samples from each selected monitoring station, and a relatively high level of dissimilarity (*i.e.* greater separation) between stations. The results indicate that subsampling of the samples (irrespective of subsampling method) had no adverse effect on the faunal patterns that could be determined from the community structure. The same shifts in community composition between 2012 and 2013 described above from the full NMBAQC methodology could still be detected in the data where subsampling techniques were applied.

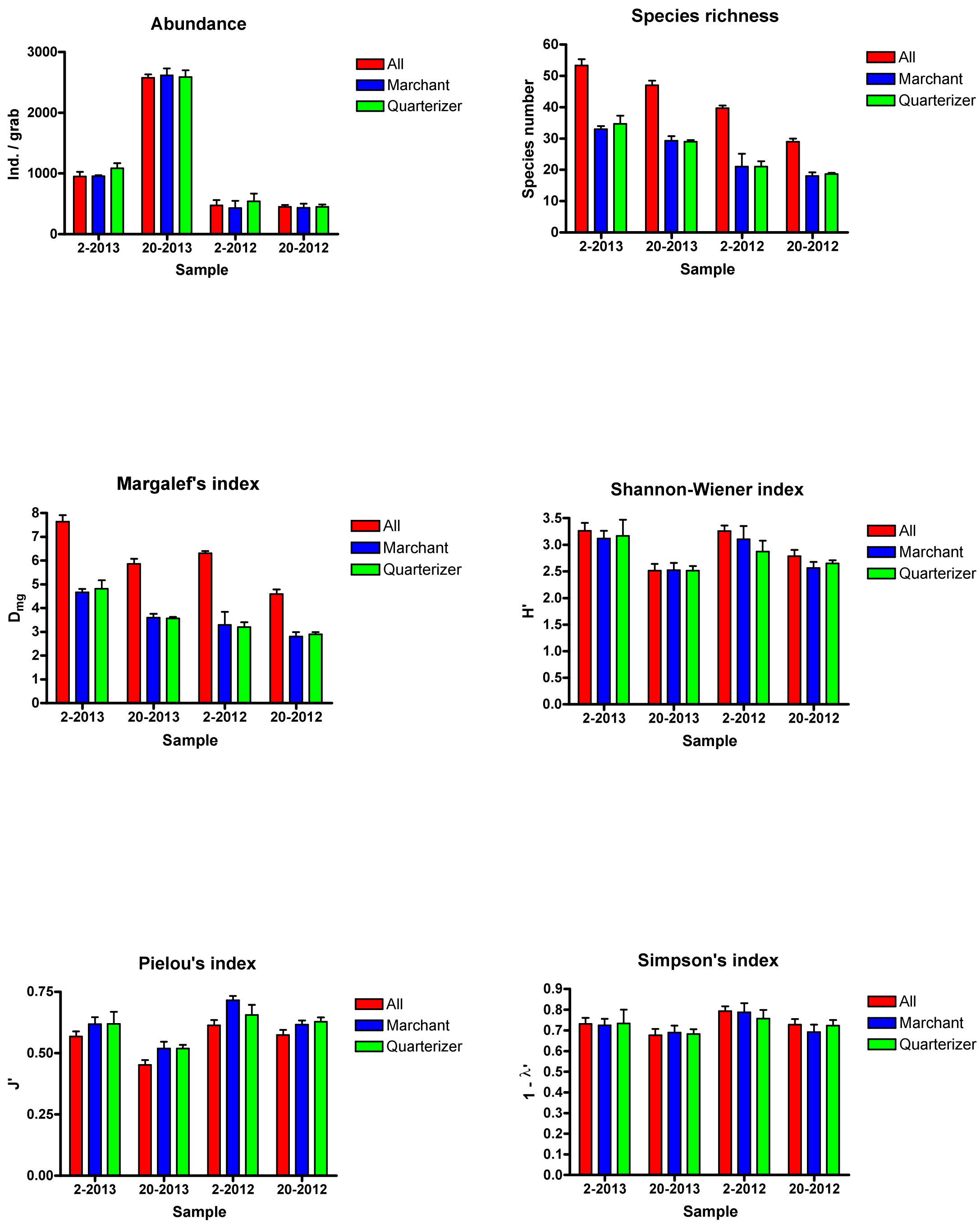

Figure 21 - Comparison of univariate diversity indices between the two subsampling methods (Marchant Box and Quarterizer) and the results from the full NMBAQC methodology. Results show differences between years, with generally higher species abundance and diversity recorded in 2013, especially at Site 1.

Data Acquisition – Underwater video/photographic surveys

Underwater camera surveys were conducted over survey site 1, 3 and 4 between 22-24 November, 2012. Site 2 (in Digby Gut) was not surveyed due to the large number of fixed fishing gear in the area at the time of survey, which presented a significant safety concern for deployment of the camera system. Fixed fishing gear was also present at Site 3, thus only 3 camera transects were run at this site. Repeat camera surveys were conducted on December 20th 2013 at Site 1 and Site 4. These were processed and form the basis for inter-annual comparison of epifaunal community composition.

Surveys were planned over each study sites using a drop-down camera system, fitted with underwater video and stills. The shallow-water camera system was configured to work optimally in relatively shallow waters (<100m) and where tidal flows pose challenging field survey conditions. The system consisted of an Imenco Tiger Shark digital stills camera system with separate Imenco Latern Shark flash unit and a Deepsea Power & Light colour video camera. The Imenco Tiger Shark has an integrated laser scaling system. The system was mounted on a metal drop-down frame which was towed at the seabed. The output from the camera was controlled from the surface using a video stream supplied from the camera and a number of function controls operated through a soft-tow cable. The camera captured 14mp still photographs of the sea bottom to determine sediment composition and to allow for faunal identification. Positioning of the system was maintained throughout each drop using the vessel's offset tow position. The camera system was deployed over the side of the *Strait Surveyor*, and lowered to the seafloor. When the camera system was at an optimal height above the seafloor (~1 m), the vessel was allowed to drift at target speeds of approximately 0.5kts to 1.0 kts (0.25 to 0.5 m/sec) for at least 5 minutes and a minimum of 20 digital stills photographs were acquired at each station.

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Data Processing – Underwater video/photographic survey

Camera surveys conducted in 2012 covered three of the study sites (Site 1, 3 and 4). Data was collected from 22 stations at Site 1, from 3 stations at Site 3, and from 29 stations at Site 4. A total of 252 high-quality images were deemed suitable from these 2012 stations for full faunal identification and quantification for the purpose of inter-site comparison and characterization. All visible fauna was identified to the highest taxonomic resolution possible and quantified (where possible) as percent cover or absolute abundance/unit area. Colonial species such as tunicates, bryozoans and hydrozoans, and encrusting sponges were noted as presence/absence within the stills. In addition, miscellaneous features such as burrows, shell fragments etc. were also noted. Substrate characteristics (% boulders, cobbles, gravel, sand and silt/clay) were also estimated for each image (to the nearest 5%) based on the Wentworth-Udden classification. Total area of the field of view (represented in m^2) was calculated for each image using the laser scale system and recorded.

Data were analysed using univariate and multivariate statistical techniques to explore faunal patterns across the survey areas, and investigate likely relationships between benthic community structure and seafloor environmental parameters (*i.e.* sediment characteristics, seafloor morphology characteristics derived from the multibeam data etc.). Example images from a selection of the ground-truthing stations over the three sites surveyed in 2012 are shown in **Figure 22.** Multivariate analyses methods (*i.e.* hierarchical agglomerative clustering and non-metric multi-dimensional scaling - nMDS) were employed to investigate faunal patterns from the seafloor photographs across the 54 camera stations, based on sample similarities, using the software PRIMER 6 (Clarke and Warwick, 2001). All images were standardized to 1 m^2 (using the laser dot separation in the images) prior to multivariate analysis in order to show relationships between the camera stations.

Multivariate patterns revealed a difference in epifaunal community structure in relation to site and surficial geology (**Figure 23**). Non-metric MDS ordination by image, as measured from the photographic data, revealed clustering by site, with distinct grouping of stations within Site 3 suggesting the assemblage structure over the three survey stations at this site was similar. Assemblage patterns over the other two sites were less distinct, with greater variation between images. Faunal data from the images from Site 1 were widely spread in the ordination. This is likely due to the sparse, low density of epifauna at the site, which would result in lower levels of similarity between seafloor images. Faunal data from the images from Site 4 were broadly grouped in the ordination, but displayed a wide spread. This is likely due to the higher degree of habitat variation at the site. These results demonstrate that underwater video and photographic techniques are highly suitable for site characterization, and can be used to link acoustic remote sensed data sets (*i.e.* multibeam and sidescan sonar data) with faunal characteristics for site evaluation baseline mapping of potential TISEC locations. This is in agreement with a large number of studies published in the scientific literature where this approach has been adopted for the production of seafloor habitat maps for site evaluation and assessment (*i.e.* see Brown *et al*, 2011 for a review on this topic).

Shell hash and bryozoan growth around the oyster pots at S1-2

S1-11

S3-6

S3-6

S4-11

Similar sparse marine growth at D-41 in 2012

Figure 22 - Representative seafloor photographs from Sites 1, 3 and 4, collected during the November 2012 surveys

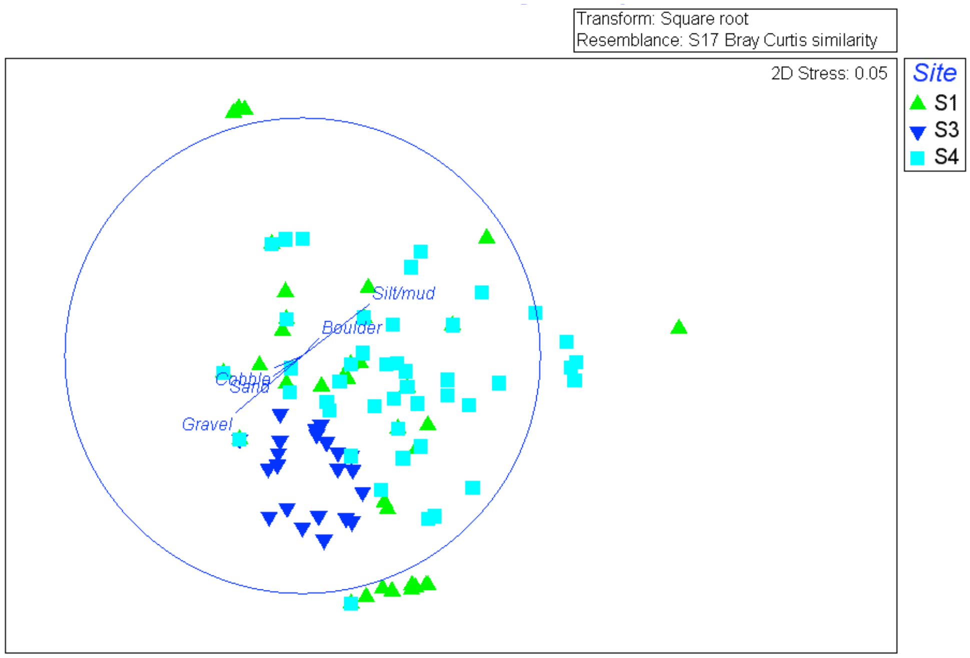

Figure 23 - nMDS ordination plot by seafloor image (with images coded by survey site) and sediment type (%boulder, cobble, gravel, sand, silt) for faunal data from seafloor photographs.

Comparison of 2012 and 2013 data sets

A total of 161 images were deemed suitable from the 2012 and 2013 stations for full faunal identification and quantification and inter-annual comparison. All visible fauna were identified to the highest taxonomic resolution possible and quantified (where possible) as percent cover or absolute abundance/unit area. Colonial species such as tunicates, bryozoans and hydrozoans, and encrusting sponges were noted as presence/absence within the stills. In addition, miscellaneous features such as burrows, shell fragments etc. were also noted. Substrate characteristics (% boulders, cobbles, gravel, sand and silt/clay) were also estimated for each image (to the nearest 5%) based on the Wentworth-Udden classification

Epifaunal data from photographs were pooled by station and presence/absence data were used in statistical analyses. Multivariate statistical analysis techniques were used to compare the benthic epifaunal assemblage data between the 2012 and 2013, and revealed some inter-annual differences in community composition (**Figure 24**). These differences may be due to the changes of sediment grain sizes between two years, with coarser sediments found in 2013 (**Figure 24**).

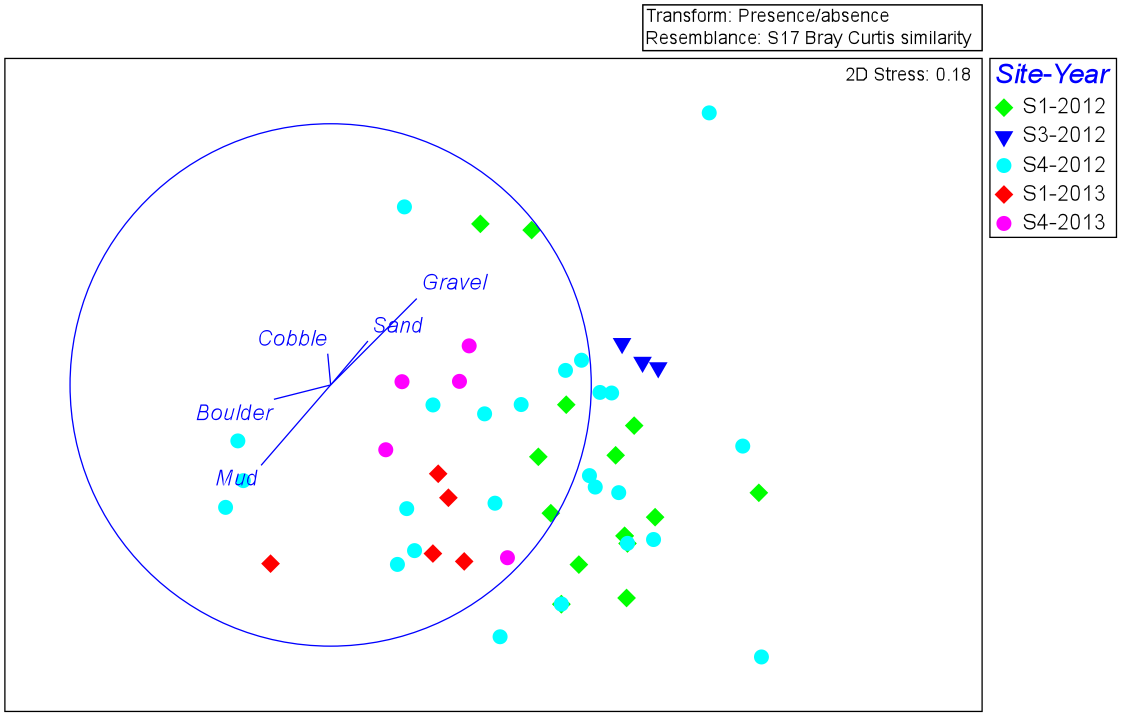

Figure 24 - nMDS ordination plot for epifaunal data from 2012 and 2013.

Some caution is needed when interpreting these results. It is difficult to determine change from this approach due to highly variable factors when collecting seafloor image and video from a passive drop camera system. Variable factors include the inability to replicate the exact transect line with a drop camera system. Repositioning of a camera system over the exact transect is usually only possible using diver deployed systems over fixed seafloor transect lines, or with Remote or Autonomous underwater platforms fitted with accurate positioning systems. However, these types of surveys are costly, and can be logistically challenging in high-current flow environments such as those where TISEC systems may be deployed. Diver surveys are also limited by depth, and are not suitable in water depths greater than those suitable for safe scientific diving operations (*i.e.* >40m).

Image and video quality can also a factor. Image quality in 2012 was superior compared to imagery from 2013 surveys when survey conditions were poorer, therefore resolvability of species in 2012 was greater compared to the poorer quality images collected in 2013. This can skew the epifaunal community data extracted from the imagery, and lead to perceived shifts in community composition where there may not be any. These are well documented issues associated with underwater visual surveys (see van Rein *et al*, 2009, 2011a, 2011b, 2012), and still pose significant challenges when attempting to set up epifaunal monitoring surveys. Nonetheless as demonstrated in this study, passive drop camera systems can be used to assess benthic faunal characteristics from an area, and provide semi-quantitative or qualitative assessments of a site over as part of a monitoring program. This can be particularly valuable when done in association with other types of sampling (*i.e.* temporal benthic grab sampling).

3.1.3 Research Activity 3: Time-lapse environmental monitoring - Summary of research conducted.

This project objective aimed to test the feasibility of low-cost seafloor instrumentation that may prove beneficial for obtaining time-lapse footage in areas with extreme environmental conditions, where the chance of equipment damage and loss is high. Equipment such as this, if effective, may be useful for assessing changes and movement of biota (*i.e.* fish and mega-benthos) over various temporal timeframes.

A system was designed around the GoPro Hero3 imaging engine and new technology LED lighting. A Time Lapse Intervalometer was integrated with the system which controls the camera directly and switches the LED lights with an external trigger circuit custom-made in-house by McGregor GeoScience personnel. For proof of concept testing, the LEDs, switching circuit and power source (batteries) were housed in a reconditioned deep sea pressure housing rated to 6000 m, and the camera was housed in a custom delrin and polycarbonate housing rated to 500 m (**Figure 25**).

Field trials of the system took place in February 2014 from the Bedford Institute of Oceanography wharf, in water depths of 4 m. The trials were successful and yielded 72 hrs of time-lapse data from an area of seafloor adjacent to the wharf (**Figure 26**). The camera was configure to take an image every 30 seconds, and the imagery was subsequently stitched together to form a time-lapse movie. Movement of biota was clearly visible, and excellent quality images were acquired in both day time and night time conditions, demonstrating that the synchronized lighting system worked effectively for illumination of the camera's field of view. The system would cost in the region of $3000 to manufacture (based on estimated costs for fabrication of underwater housings for the camera and lighting units, GoPro Hero3 imaging engine and circuit control system to synchronise power and control units). The proof of concept demonstrates that low-cost time-lapse camera systems can be fabricated relatively easily from commercially available components, with potential benefits for in-situ monitoring at TISEC sites (*i.e.* time-lapse assessment of benthic conditions, movement and stability of seafloor TISEC hardware etc.). Further sea trials in deeper water environments are planned with the system in the near future.

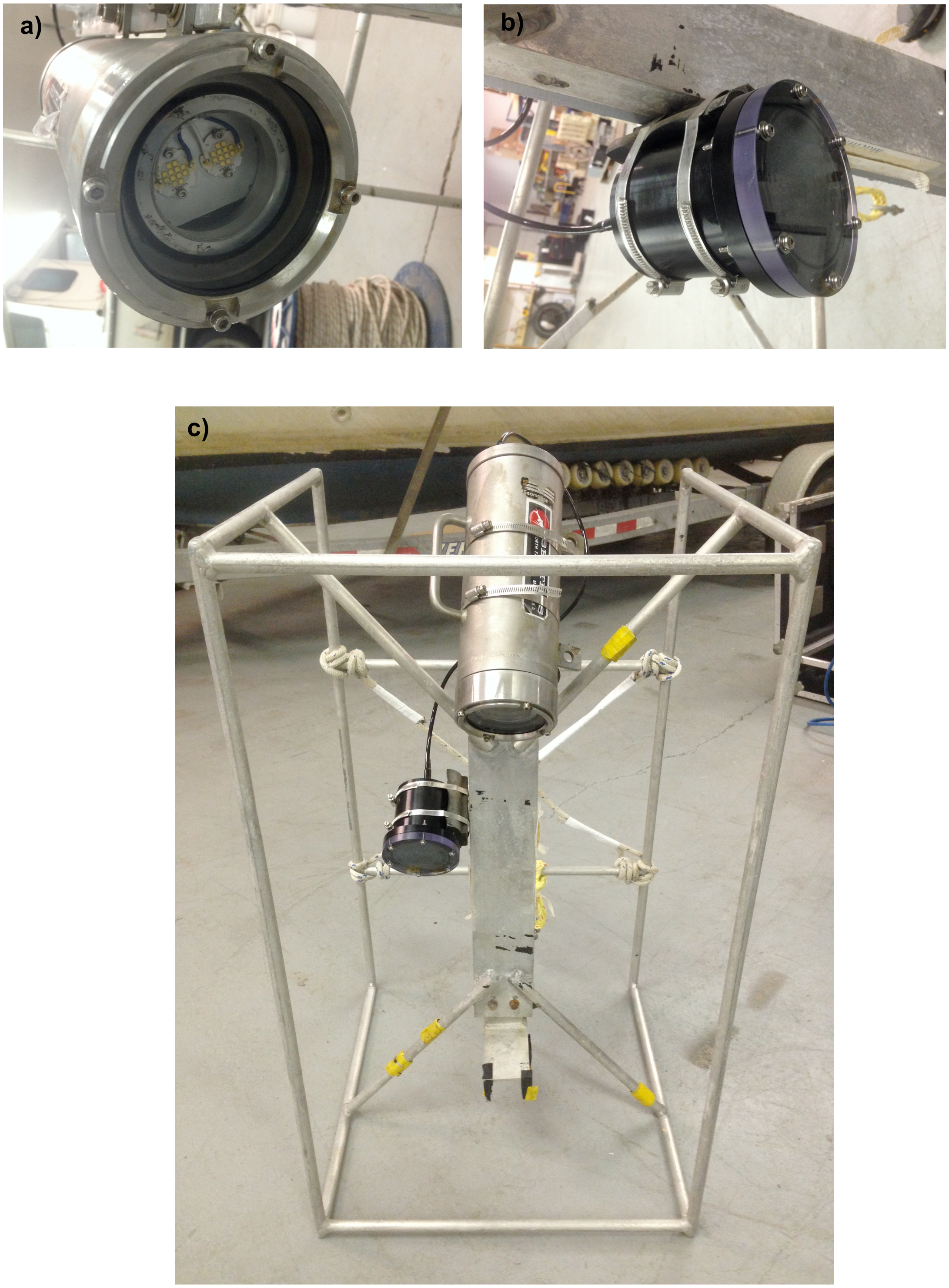

Figure 25 - Proof-of-concept, low-cost underwater time-lapse camera system. a) LED lighting system in 6000m-rated underwater housing; b) Delrin and polycarbonate housing containing the GoPro underwater camera unit; c) Integrated system (*i.e.* camera and light) on the deployment frame.

Figure 26 - Single still image of the test site collected by the time-lapse camera system. Imagery was stitched together into a time lapse video showing movement and activity of benthic fauna over the duration of the trial.

3.2 DISSEMINATION AND TECHNOLOGY TRANSFER

A number of activities and meeting took place throughout the duration of the project with a variety of individuals from relevant government, academic and private sector organizations, to discuss the research program, raise awareness of the project, and disseminate the findings of the research.

Close collaboration was established with the Nova Scotia Community College (NSCC, Centre for Geographic Sciences - COGS). Field surveys in the Annapolis Basin were scheduled to coincide with the COGS field camp, and efforts were made to share resources and involve COGS students in field survey work as part of the McGregor project. Equipment was shared between COGS and McGregor (*i.e.* RTK base station, benthic grab sampling equipment and *MV Passage Provider*), and McGregor staff ran training exercises with respect to benthic sampling methodology for the COGS students. In 2012, 2013 and 2014, lectures were given to COGS students enrolled on the Marine Geomatics program by Dr. Craig Brown from McGregor on the topic of seafloor habitat mapping, which included an overview of this research project.

An oral presentation was given by Dr. Brown from McGregor at the Geohab Conference 1-4 May 2012 on Orcas Island, Washington State, USA (Marine Geological and Biological Habitat Mapping - www.geohab.org). The presentation was given as part of a special workshop on "Geoscience Characterization of the Seabed for Environmental Assessment for Marine Renewable Energy Activities". The presentation provided an overview of the project, outlining the goals, objective and 2012 survey plans within the Bay of Fundy. A copy of the submitted abstract is provided in Appendix 1.

A poster presentation was also given at the Nova Scotia Energy Research and Development Forum, which took place between May 16th and 17th 2012. Mr. Dimitri Tzekakis from McGregor GeoScience presented the poster, which provided an overview of the project to date, outlining the project goals and objectives, methodology, test sites and anticipated outcomes, at the forum. Preliminary results from the filed surveys were also included. A copy of the poster is included in Appendix 2.

Meetings have also taken place between McGregor staff and a number of individuals from relevant organizations, to discuss the research program, raise awareness of the project, and further develop collaborative links and synergies with other academic and industry initiatives for the benefit of the proposed research. In June 2012, McGregor staff held meetings with representatives from Acadia University (Dr. Anna Redden) to discuss links with MSc student projects at Acadia which will commence in the forthcoming academic semester at Acadia University in Q3 of 2012. Discussions also took place between McGregor staff and FORCE regarding work in the Minas Passage and synergies with FORCE activities at the FORCE test areas.

An oral presentation was given by Dr. Brown from McGregor at the *Oceans of Opportunity Marine Symposium*, hosted by NSCC in Port Hawkesbury on October 11-12, 2012. Dr. Brown's presentation entitled, "*Oceans of Opportunity: Business, Training and Technology for Atlantic Canada's Marine Sector*" focused on the application of acoustic remote sensing methods and provided reference to the OERA research project.

An invited oral presentation was also given by Dr. Brown at an international workshop on seabed mapping methods and technology hosted by the Norwegian Geological Survey in Trondheim, Norway, October 17-18, 2012. The workshop was organised as part of the Mareano Project (http://www.mareano.no/en) to discuss progress in the Norwegian national seafloor mapping project, and reflect on other ongoing research in this field in other parts of the world. Dr Brown provided a synopsis of progress in the field of benthic habitat mapping in Canada. The application of these methods in the context of environmental monitoring were discussed at length, including reference to the OERA project.

An oral presentation was given by Dr. Brown from McGregor at the Nova Scotia Tidal Energy symposium and Forum at Acadia University, 14-15 May 2013. Dr. Brown's presentation entitled *"Development of Temporal Monitoring Techniques for Benthic*

Habitat Impacts of Tidal Energy" provided an overview of the OERA project, and presented the preliminary results from the first year of the study.

Results from Research Activity 1 demonstrated that significantly more research effort is required to understand the role that backscatter can play in broad-scale monitoring of seafloor systems. These issues are currently being documented through an International Backscatter Working Group (BSWG) operating through the GeoHab conference forum (www.geohab.org/BSWG). The BSWG (of which Craig Brown is a Chairing member) aim to publish a recommendations and guidance document on backscatter at some stage in 2015. The results and findings from this OERA project are currently being used to facilitate the development of the BSWG recommendations document.

Publication of the findings from Research Activity 2 is underway. The results from the benthic infaunal sampling, and the results from the subsampling investigation are currently in the process of being written up for submission to a peer-reviewed scientific journal (submission planned by Q3 of 2014 – journal yet to be determined). This will provide guidance and documented evidence regarding the utility of benthic infauna as indicators for change in benthic ecosystems. While this approach is widely used in Europe, it is less commonly applied in North America. The results demonstrate the benefits of this approach in providing a robust indicator of change in benthic systems. It also provide evidence to companies working in this field that subsampling of faunal samples may be acceptable in certain situations, while still proving sensitive enough to detect change in community composition.

Research Activity 3 has demonstrated that low-cost camera systems can be constructed for deployment in ocean environments for time-lapse monitoring of environmental conditions. Further trials are planned and the system will likely be used in commercial surveys/applications by McGregor GeoScience.

While the focus of this research program was on applications of the tested methodology for the Tidal Energy Industry, the findings from all three research activities are of significance to the broader offshore energy industry and Nova Scotia. Seafloor mapping and the use of multibeam backscatter data is equally relevant to offshore oil and gas activities, offshore wind, and installation of subsea power cables. All of these offshore energy activities rely on the collection of detailed seafloor data, and the finding of this program of research contribute to the understanding of how these data sets can be applied in a monitoring context. Similarly the use of in situ sampling techniques and in situ time lapse monitoring can be applied to all of these industry sectors.

3.3 CONCLUSIONS AND RECOMMENDATIONS

3.3.1 Research Activity 1: Conclusions and Recommendations

1. Multibeam sonar and sidescan sonar offer very suitable methods for broad-scale mapping of sites for deployment of TISEC devices, providing baseline information on the seafloor conditions for site evaluation.

2. The use of backscatter data for monitoring change in seafloor conditions is currently limited due to the uncalibrated nature of the backscatter intensity values acquired from MBES systems. Detection of relative (*i.e.* qualitative) changes in backscatter are possible between temporal data sets, but further research is required before quantitative changes in backscatter intensity can be used to monitor and detect changes in seafloor parameters from the backscatter signal. These issues are currently being documented through an International Backscatter Working Group (BSWG) operating through the GeoHab conference forum (www.geohab.org/BSWG). The BSWG aim to publish a recommendations and guidance document on backscatter at some stage in 2015. The results and findings from this OERA project are currently being used to facilitate the development of the BSWG recommendations document.

3. The results demonstrate that conventional By-eye interpretation is still a valuable approach to assessing change in benthic systems from acoustic remote sensed data sets, and provide a method for assessing change in seafloor conditions around TISEC devices.

4. Automated backscatter classification tools show promise in monitoring change in temporal MBES data sets. However, due to the uncalibrated nature of the backscatter signal (see point 2 above), the ability of these new analysis methods to detect changes in seafloor condition are limited. It is likely that these methods will mature over the next few years as further research is conducted to develop and advance this analytical approach.

5. *QTC Swathview* classification identified and delineated areas of different seafloor characteristics using an image-based classification approach, and showed promise for automated classification of seafloor features. However, limitations in the raster-based interpolation procedure do not provide clear resolvability of the edges of fine-scale features, which is a significant limitation of this approach within a TISEC monitoring context. The cessation of the software package is also a consideration when evaluating this approach for future monitoring applications.

6. The *Geocoder* ARA classification identified and delineated areas of different seafloor characteristics using an signal-based classification approach, and showed promise for automated classification of seafloor features. However, the scale of analysis of the ARA classification was too coarse to detect fine scale futures such as the oyster cages and associated tidal-scour pits. This likely limits the scope of this classification approach for monitoring finer-scaled changes in seafloor conditions that may be associated with the placement of TISEC devises on the seafloor (*i.e.* formation of scour features, impact on benthic habitat conditions around turbines and cables etc.). Nonetheless, this approach may hold value in the future as these analysis methods are improved and refined. Work is ongoing in the development of the software (pers. coms. with representatives from QPS), and this approach may hold potential in the near future as these methods mature.

3.3.2 Research Activity 2: Conclusions and Recommendations

1. Repeat benthic infaunal sampling, following NMBAQC procedures, demonstrated that this approach was able to detect shifts in seafloor conditions over inter-annual time periods. Difference in seafloor infaunal community structure were detected, demonstrating that this method can be used as a robust method for monitoring impacts in benthic systems.

2. The results from the study showed no significant differences were found between the sub-samples using the two sub-sampling methods. These findings suggest that subsampling methods still allow trends in faunal composition (*i.e.* community structure) to be determined over a time series data set. This would allow faster, more cost effective sample processing to take place when collecting benthic infaunal samples as part of long term monitoring programs. However, it should be noted that subsampling methods do affect diversity measures, and resulted in lower species richness estimates from samples. This can have important consequences if accurate diversity estimates from an area are required. In such cases, the full NMBAQC methodology, which processes the entire sample, are recommended.

3. Results from the study demonstrated that underwater video and photographic techniques are highly suitable for site characterization, and can be used to link acoustic remote sensed data sets (*i.e.* multibeam and sidescan sonar data) with faunal characteristics for site evaluation baseline mapping of potential TISEC locations. This is in agreement with a large number of studies published in the scientific literature where this approach has been adopted for the production of seafloor habitat maps for site evaluation and assessment (*i.e.* see Brown *et al*, 2011 for a review on this topic).

4. Results from this study demonstrated that passive drop camera systems can be used to assess benthic faunal characteristics from an area, and provide semi-quantitative or qualitative assessments of a site over as part of a monitoring program. However, position of passive camera systems is challenging in high-current flow environments. Variable factors include the inability to replicate the exact transect line with a drop camera system. Repositioning of a camera system over the exact transect is usually only possible using diver deployed systems over fixed seafloor transect lines, or with Remote or Autonomous underwater platforms fitted with accurate positioning systems. However, these types of surveys are costly, and can be logistically challenging in high-current flow environments such as those where TISEC systems may be deployed. Diver surveys are also limited by depth, and are not suitable in water depths greater than those suitable for safe scientific diving operations (*i.e.* >40m). These issues are well documented in the scientific literature (see van Rein *et al*, 2009, 2011a, 2011b, 2012). Nonetheless, passive drop camera surveys can be valuable when done in association with other types of sampling (*i.e.* temporal benthic grab sampling) for monitoring change in benthic systems.

3.3.3 Research Activity 3: Conclusions and Recommendation

1. The proof of concept demonstrates that low-cost lime-lapse camera systems can be fabricated from "off-the-shelf" components, with potential benefits for in-situ monitoring at TISEC sites (*i.e.* time-lapse assessment of benthic conditions, movement and stability of seafloor TISEC hardware etc.). Further sea trials in deeper water environments are planned with the system in the near future.

3.4 PUBLICATIONS

Results from Research Activity 1 demonstrated that significantly more research effort is required to understand the role that backscatter can play in broad-scale monitoring of seafloor systems. These issues are currently being documented through an International Backscatter Working Group (BSWG) operating through the GeoHab conference forum (www.geohab.org/BSWG). The BSWG (of which Craig Brown is a Chairing member) aim to publish a recommendations and guidance document on backscatter at some stage in 2015. The results and findings from this OERA project are currently being used to facilitate the development of the BSWG recommendations document.

Results from the benthic infaunal monitoring are showing particular promise, and are currently being written up as a manuscript for submission to a suitable scientific journal. It is anticipated that work on this manuscript will be complete, and the manuscript submitted at by the end of 2014.

Dimitri Tzekakis is also continuing to work with the data sets as part of his MSc studies. The data sets from Research Activity 1 are being processed using a number of other backscatter classification methods (*i.e.* Object Based Image Analysis – OBIA techniques). It is anticipated that the results from these studies will generate 1-2 publications regarding application of ASC methods for monitoring marine benthic habitats over meso- and broad- scales in connection with deployment and operation of TISEC devices. The MSc research will continue (part-time) over the next 2 years, with publications expected some time in 2015/2016.

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