# INFORMING TOUGH CHOICES: DEVELOPING TOOLS TO HELP HERITAGE MANAGERS RESPOND TO THE EFFECTS OF COASTAL INNUNDATION ON CULTURAL HERITAGE

by © Ariel Belsheim

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# Abstract

Coastal archaeological resources are at considerable risk of impact from climate change, in particular, sea level inundation. Heritage managers across the country are tasked with protecting and managing these resources. This thesis investigates the impact of data resolution on a desk-based site vulnerability assessment. With 71% of surveyed cultural resources in Bonavista Bay, Newfoundland, actively eroding, identifying sites most at risk and prioritizing for management is integral. The goal of this thesis is to develop a vulnerability assessment tool for at-risk coastal sites and to provide heritage managers with practices and methods for selecting highly vulnerable sites for management response. Using a desk-based site vulnerability model, 81% of surveyed sites are expected to be at risk by 2025. This assessment illustrated the importance of accurate site location in desk-based modelling. Through an analysis of current practices, a method for utilizing the exposure of a site and a “value-based” approach is suggested. This method is then applied in Bonavista Bay to demonstrate how heritage managers may be able to prioritize vulnerable archaeological sites for management action.

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# List of Abbreviations and Symbols

AB – Alberta

ALERT – Archéologie, littoral et réchauffement terrestre

CARRA – Coastal Archaeological Resource Risk Assessment

CDED – Canadian Digital Elevation Dataset

CITiZAN – Coastal and Intertidal Zone Archaeological Network

CSRS – Canadian Spatial Reference System

DEM – Digital Elevation Model

DGPS – Differential Global Positioning System

GIS – Geographical Information System

GPS – Global Positioning System

HyVSEP – Hydrographic Vertical Separation Surfaces

ICAHM – International Committee on Archaeological Heritage Managment

IPCC – Intergovernmental Panel on Climate Change

LiDAR – Light Detection and Ranging

MAI – Maritime Archaic Indian

NAD83 – North American Datum of 1983

NL – Newfoundland and Labrador

PAO – Provincial Archaeology Office

RCP – Representative Concentration Pathway

RCZA – Rapid Coastal Zone Assessment

RSLR – Relative Sea Level Rise

RTK – Real Time Kinematic

SCAPE – Scottish Coastal Archaeology and the Problem of Erosion

SCHARP – Scotland’s Coastal Heritage at Risk Project

SLR – Sea Level Rise

UTM – Universal Transverse Mercator

YK – Yukon

# List of Appendices

# Co-Authorship Statement

All chapters in this thesis were researched and written by the author, with editorial and comments provided by the committee.

The development of the research proposal was completed through an extensive literature review and guidance from my thesis supervisor Dr. Trevor Bell. All data related to this thesis was collected and processed by the author. Notable exceptions include the involvement of field assistants, who helped collect data in the field and the help from Marc Storey for raw LiDAR data processing used in the model discussed in Chapter 2. The model used to identify sites vulnerable to sea level rise and increased storm surge for Chapter 2 was developed in collaboration with the Coastal Archaeological Resource Risk Assessment (CARRA) project. The data produced by the model were evaluated and disseminated by the author to appropriate governing bodies. Including Parks Canada and the Provincial Archaeology Office of Newfoundland and Labrador.

Chapter 3 was developed to address CARRA objectives further, identifying current methods for site prioritization and suggesting applications for site management.

Chapter 2 and Chapter 3 were both written as stand-alone papers with aspirations to submit to the Journal of World Archaeology or the Journal of Island and Coastal Archaeology.

# Chapter 1: Introduction

## 1.1 Introduction

Climate change is negatively impacting the state of coastal archaeological resources globally (Cassar et al., 2006; Erlandson, 2008; Murphy et al., 2009; Reeder-Myers, 2015). Sea level rise, storm surges, and associated erosion are all intensified, both in amplitude and frequency, by climate change (Stocker et al., 2013). Global sea level is expected to rise 0.98 metres by 2100 if greenhouse gas emissions continue to increase following the current trend (Stocker et al., 2013). Such a rise would submerge coastal lowlands within a metre above sea level (FitzGerald et al., 2008; Gesch, 2009). Another threat to coastal areas is storms, which also intensify in frequency and severity with climate change (Gesch, 2009; Fitzpatrick et al., 2012; Stocker et al., 2013). Although small storms are far more frequent, the cumulative impact of many small storms can have an equally severe impact as a large one. Successive storms can remove sediment and, with insufficient time for the coastline to re-stabilize, erosion can be severe (Cassar et al., 2006; Nicholles et al., 2007; Erlandson, 2008; Murphy et al., 2009).

Coastal archaeological sites are particularly vulnerable to the impacts of climate change. Woody debris, high winds, sea level inundation, storm surge and erosion, can damage or destroy coastal archaeological sites (Cassar et al., 2006; Nicholles et al., 2007; FitzGerald et al., 2008). In 2005, Hurricane Katrina devastated an estimated 1000 archaeological sites along the Gulf of Mexico (Nicholles et al., 2007). This example illustrates how a single storm can impact the integrity of our global coastal archaeological heritage.

Archaeological resources, including both historic and prehistoric sites, are found in coastal areas due to the access to marine resources and transportation routes. Although the spatial definition of the coastal zone is not set, the coastal region is considered to be the area where land and sea interact (Nicholles et al., 2007; FitzGerald et al., 2008; Murphy et al., 2009; Gesch, 2009). The coastal zone may range from a few hundred metres to hundreds of kilometres inland (e.g., to the edge of the watershed) depending on the coastal terrain.

This research was conducted as part of the Coastal Archaeological Resource Risk Assessment (CARRA) project. This thesis aims to help support heritage managers identify and manage coastal archaeological resources in the face of climate change.

The specific objectives of this thesis are to:

1. Explore how improved geospatial data quality impacts the results of a desktop assessment for coastal archaeological site vulnerability to coastal inundation.
2. Identify which sites in Bonavista Bay, Newfoundland, are at risk to the impact of sea level rise and increased storm surge by 2025, 2050, and 2100.
3. Identify current practices in archaeological site prioritization for management purposes and apply them to high-risk sites in Bonavista Bay.

## 1.2 The CARRA Project

The CARRA project aims to help address the impacts of sea level rise and increased storm surge on coastal archaeological resources. Based at Memorial University of Newfoundland, the project has three objectives related to heritage management: identifying sites at risk, prioritizing sites and implementing management strategies (Pollard-Belsheim et al., 2014).

The first objective involves refining an existing coastal archaeological resource risk assessment developed by Westley et al. (2011). This study identified that 20% of archaeological sites in three study areas of Newfoundland were at risk due to the impacts of sea level rise and increased erosion. Some issues with the data used in this study are highlighted by Westley et al. (2011), specifically the effect of data resolution. The model created by Westley et al. (2011) showed coastlines with 90° angles, and sites known to be actively eroding were identified as low risk. These issues were in part determined to be linked to incorrect site locations. For instance, the Beaches site, a well-known Beothuk site in the Bonavista Bay region of Newfoundland, was identified as low risk, contradicting years of physical evidence indicating the severity of erosion at the site, due to inaccurate site location data (Carignan, 1974; Catto et al., 2000; McLean, 2006; Westley et al., 2011).

The second objective of the CARRA project is to compare the current methods heritage managers use to determine which sites are excavated or abandoned, as well as how vulnerable sites should be prioritized for management action. Since heritage managers across Canada are tasked with protecting and monitoring archaeological resources, methods for managing all these sites must be understood.

The third objective of the CARRA project is to develop case studies that would provide management options for heritage managers in response to at-risk archaeological sites. With the intention to distribute these cases studies and offer heritage managers across Atlantic Canada, management options based on shared experience.

To meet these objectives the CARRA project established four study areas across Newfoundland and Labrador: Port Au Choix, Strait of Belle Isle, L'Anse aux Meadows, and Bonavista Bay including Terra Nova National Park (Fig 1.1). At each of these study areas, terrain data with varying resolutions were collected, archaeological sites were surveyed, and localized sea level projections were established. The multitude of data allowed for the application of a desk-based site vulnerability model across Newfoundland, demonstrating the efficiency of the model on different landscapes with varying glacial legacy. The research described in this thesis focuses on the Bonavista Bay and Terra Nova National Park study area.

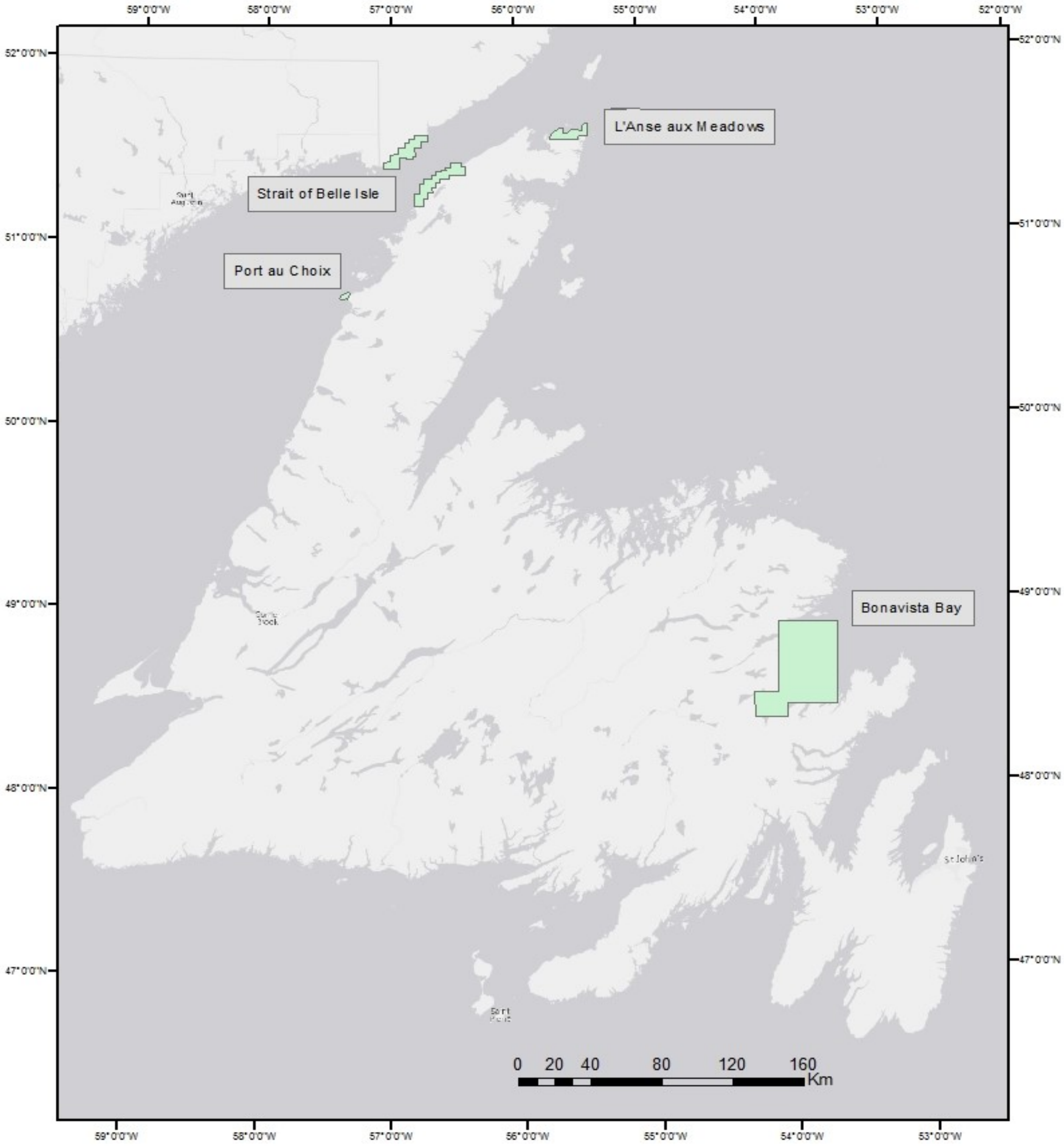
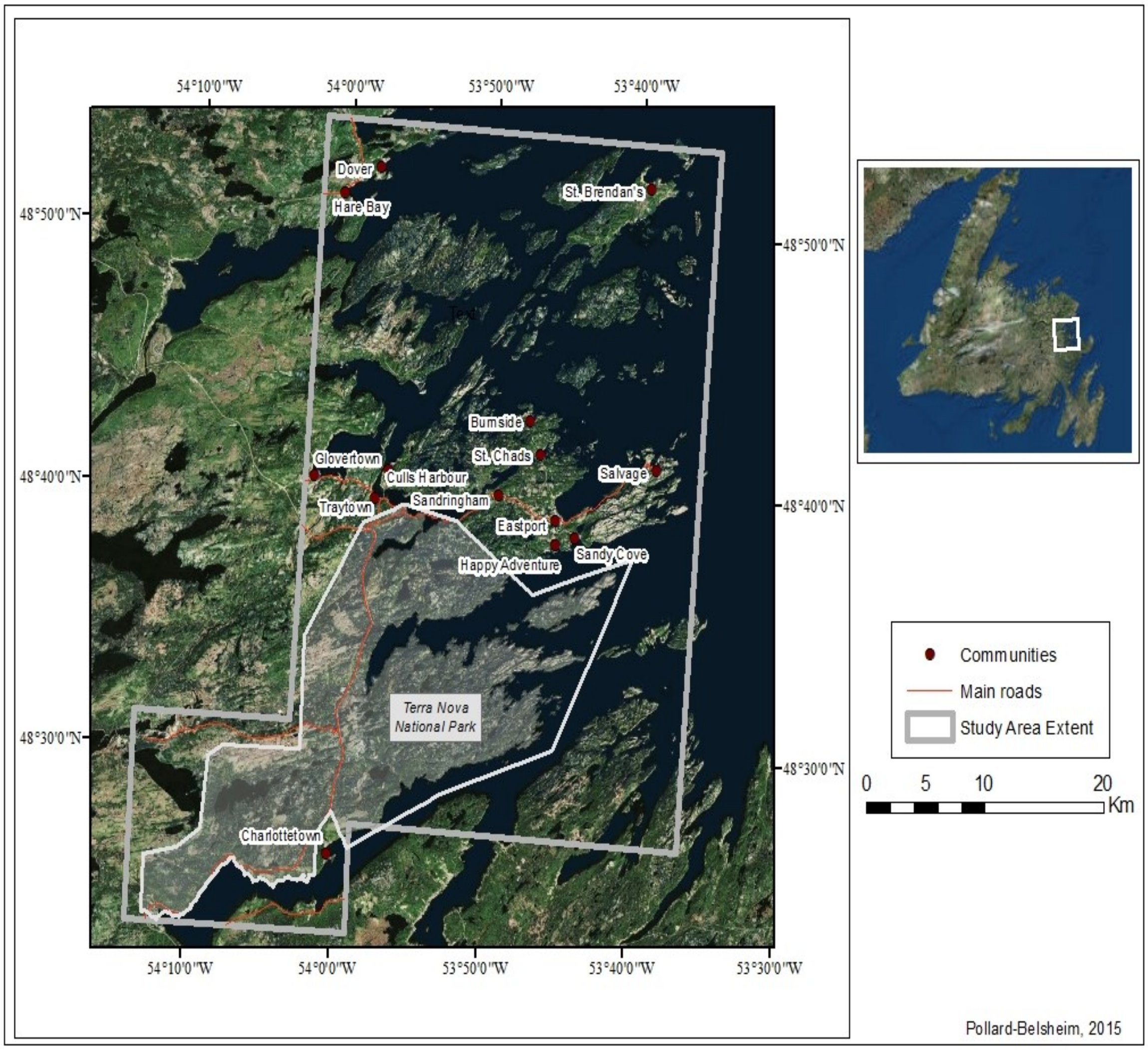


*Figure 1.1: CARRA study areas within Newfoundland and Labrador.*

## 1.3 Study area: Bonavista Bay, Newfoundland

Bonavista Bay is located on the east coast of Newfoundland (Fig. 1.2). The study area covers approximately 1885 km$^2$ and extends from Hare Bay in the north to Charlottetown in the south. The Bonavista Bay study area provides an excellent landscape in which to assess the impact of data resolution on modelling archaeological resources at risk. The study area boundaries represent the extent of LiDAR (Light Detecting and Ranging) data available in the region. It also outlines an area with many remote archaeological sites that have been identified as eroding during previous field surveys (Carignan, 1974; Tuck, 1976; McLean, 2006, Curtis, 2007; Curtis, 2008). Bonavista Bay allows for the assessment of vulnerable sites in a highly dynamic landscape, both physically and culturally.

The CARRA model was developed from the model established by Westley et al. (2011). The original model also used part of the Bonavista Bay study area, which allows for a direct comparison of results. Bonavista Bay is unlike the other three study areas in the CARRA project (Port Au Choix, Strait of Belle Isle and L'Anse aux Meadows) as it represents the longest submerging landscape (Quinlan and Beaumont 1981). Quinlan and Beaumont (1981) suggested that the area in which Bonavista Bay is located would be considered a Type B zone. During the Last Glacial Maximum, Newfoundland and Labrador was located at the southeastern extent of the Laurentide Ice Sheet (LIS). The LIS extended over the northernmost part of the Great Northern Peninsula (Grant, 1970; Liverman, 1994). Newfoundland was covered by its own ice cap: Newfoundland Ice Cap (NIC). Due to the weight of the ice cap, an ice-marginal forebulge was formed resulting from the lithosphere being under extreme pressure, bulging out in front of the ice margin. In Newfoundland, this caused distinct zones to develop, each with its specific sea-level history (Liverman, 1994). When the NIC melted, the Bonavista coastline experienced net emergence, followed by continuous submergence up to the present (Type B zone). This means that Bonavista Bay will not only face the impacts of sea level rise because of climate change but also the effect of land subsidence.



Pollard-Belsheim, 2015

*Figure 1.2: Bonavista Bay study area, Newfoundland and Labrador.*

The settlement of Bonavista Bay by prehistoric cultures is closely related to its sea level history due to their marine oriented subsistence strategies. Many of the earliest archaeological sites in the area are already underwater, with the low stand around 7.8 metres below mean water level (Quinlan and Beaumont, 1981; Shaw and Forbes, 1995). The remaining sites are all clustered along the coastline; many sites are built on top of each other (Bell and Renouf, 2004). The Beaches site in Bonavista Bay is the third oldest site in Newfoundland with evidence of the Maritime Archaic Indian (MAI) occupation, dated around 4900 BP +/- 230 (Carignan, 1974). Following MAI occupation, evidence at the Beaches site also indicates a period of occupation by various prehistoric groups.

With a dynamic landscape, glacial legacy and rich cultural history, Bonavista Bay is an ideal study area for evaluating the limitations of data quality in a desk-based site vulnerability, and the need for site prioritization as a method of heritage management.

### 1.3.1 Physical characteristics

The coastline in Bonavista Bay is dominated by bedrock, with small pocket beaches of gravel or coarse sand. Small shrubs and heath vegetation are dominant along the shoreline and backed by boreal forest (Hedderson, 1992). The vegetation throughout the study area is indicative of a maritime boreal forest environment, with alders, spruce, birch, short grasses, and heath vegetation being the most common (Ryan, 1978; Hedderson, 1992). Erosion in Bonavista Bay is prevalent (Mclean, 2006).

*Figure 1.3: Examples of a typical coastal environment in Bonavista Bay. A) Gravel beach with sparse vegetation. B) Shallow heath vegetation on a bedrock coastline. C) A viewscape of Bonavista Bay looking out over Morris Channel.*

Local and regional effects influence the resilience of the coastline to coastal erosion. High winds, a broad fetch, and shallow soils over gravel or bedrock beaches create conditions susceptible to erosive processes. The coast was classified as moderately to very highly sensitive to erosion (Catto, 2011). This sensitivity considers sea level change, topographic relief, mean annual maximum wave height, rock/sediment type, landform type, shoreline displacement, and tidal range as influences (Shaw et al., 1998; Catto, 2011). The sensitivity of the coastline varies. Further inland the beaches are protected and therefore less sensitive to external forces. Exposed shorelines further seaward are more susceptible to coastal erosion (Catto, 2011). These coastlines, although susceptible to erosion, also provide suitable landscapes for marine subsistence oriented cultures to settle.

### 1.3.2. Cultural history

Access to the sea has been and still is, a dominant factor for human settlement in Newfoundland (Bell and Renouf, 2004). From MAI to Early European (French and English) settlers, the ocean has been a focus of settlement. The MAI is the earliest cultural group identified in Newfoundland, which dates from 5500 to 3200 BP (Bell and Renouf, 2004). They focused on a broad range of food resources such as seal, fish, caribou, and birds (Bell and Renouf, 2004)  Much like the MAI, the Groswater Pre-Inuit (formerly Groswater Paleoeskimo (Whitridge, 2016); 2800-1950 BP) and Dorset Pre-Inuit (formerly Dorset Paleoeskimo (Whitridge, 2016); 2000-1300 BP) both settled along the coast to capitalize on marine animals for subsistence (Holly, 2013). Four complexes make up the Recent Indian occupation (~2000 BP – 200 BP): Cow Head, Beaches, Little Passage and the Beothuk (Erwin et al., 2005; Holly, 2013). The Recent Indian cultures utilized both terrestrial and maritime resources. Sites have been identified both along the coast and inland. The Beothuk, although considered part of the Recent Indian occupation, are often discussed separately from the other three complexes. Also, marine-oriented, the coast played a large role for the Beothuk people, providing access to seabirds, marine, and terrestrial subsistence (Kristensen and Holly, 2013). Descendants of the Little Passage, the Beothuk inhabited the island when the Europeans began to settle in Newfoundland during the early 16th century (Major, 1983). Records from early European explorers describe the bow-and-arrow use by the Beothuks and some of the interactions between the two groups (Cadigan, 2009). As migratory fishing became commonplace in Newfoundland, the Beothuk seemed to move inland (Holly, 2000). The battle for resources was between the French and European fishermen. It was not until the 19th century that permanent settlements were established in Bonavista Bay (Major, 1983; -). Sites are located along the coast for ease of access to marine resources both as a mode of subsistence, but also transport. Lumbering was a dominant industry in Bonavista Bay. In Terra Nova National Park, the remains of four sawmills can still be seen (Major, 1983; Curtis, 2008, Holly, 2013). The historic settlement of Newfoundland was primarily along the coastline, as indicated by the remains of early fishing and logging communities.

## 1.4 Background

Over the past decade, there has been an increased focus on identifying, analyzing and preparing for the impacts of climate change on archaeological heritage (Grossi et al., 2007; McFadgen and Goff, 2007; Sabbioni et al., 2010; Erlandson, 2012; Reeder-Myers, 2015). Advances in technology have allowed researchers to evaluate the impact of external forces on both built and buried archaeological heritage, both in the field and in the lab (Bickler et al., 2013; Reeder-Myers, 2015). Desk-based modelling (computer modelling of the real world) has provided an environment in which we can test the impact of external forces on archaeological heritage, such as sea level rise. Discussed below are some of the current projects working on identifying and prioritizing archaeological heritage at risk, both in the field and using a desk-based modelling approach.

### 1.4.1 Field and desk-based approaches to establishing site vulnerability

Identifying sites at risk is needed to support effective management of archaeological heritage in the face of climate change. Risk is a function of the severity of a threat (e.g., sea level rise, erosion, and increased storm intensity), its frequency, and the sensitivity of a given site (Birkmann, 2007). An exposed coastal site may be vulnerable to storm surges (i.e., a threat), but if there are limited exposure and limited probability of storm activity in this area, then a site would not be at risk despite its high vulnerability. It is important to note that although sea level rise and storm surge impacts are not mutually exclusive, they are discussed this way throughout this thesis, due to the nature of the proposed vulnerability model.

There are two methods currently used for identifying and monitoring sites vulnerable to the impacts of sea level rise. The first method for identifying vulnerable and at-risk archaeological sites is commonly referred to as the field-based method. Programs such as the Scottish Coastal Archaeology and the Problem of Erosion (SCAPE) trust surveys in Scotland, Archéologie, littoral et Réchauffement Terrestre (translated to: Archaeology, Coasts, and Global Warming; ALERT) in France, and the rapid coastal zone assessment surveys (RCZAS) in England all conduct field assessments of coastal archaeological sites at risk (Heritage, 2006; Scape, 2010; Daire et al., 2012; Dawson, 2013). These local programs allow heritage managers to utilize public participation in the monitoring of archaeological resources. Due to the frequent re-visitation of sites by public participants, it is easier for heritage managers to monitor and address sites as they are impacted. These programs are successful due to the large number of volunteers available to heritage managers and the accessibility of the archaeological resources.

The second method for identifying at-risk archaeological sites is a desk-based modelling approach. The development of desk-based vulnerability models can provide heritage managers with a method for determining risk at many sites even with limited human resources (Sabbioni et al., 2009). Many heritage management agencies and researchers have utilized the desk-based modelling approach. They allow heritage managers to utilize available datasets including site location and boundaries, substrate, sea level rise, average coastal erosion or shoreline change models and assesses how each of these factors works to influence the integrity of the archaeological resource (McCoy, 2018). Desk-based modelling allows for the current or future condition of the site to be evaluated without constant re-visitation. It can also be of use in areas where sites are remote, such as the Arctic region (Dawson et al., 2013).

Utilizing Geographical Information Systems (GIS) the desk-based modelling approach has become a staple in vulnerability modelling (McCoy, 2018). Many different threats can impact coastal zones, from sea level rise to urban expansion (Reeder et al., 2012). The ability to evaluate the impact each threat has on vulnerable sites provides heritage managers with a holistic assessment of archaeological site risk.

In New Zealand, Canada, and the United States, researchers have worked to identify at-risk sites using desk-based methods. These projects evaluate local risk factors and aim to map future vulnerability by considering the current state of each element, including site slope, coastline retreat rate, coastal topography, and geomorphology, as well as projected sea level rise for the study area. In New Zealand, Bickler et al. (2013) developed two models to assess the vulnerability of coastal archaeological sites. They first examined the current threats faced by archaeological sites. Then an assessment of potentially at-risk or vulnerable sites was done, focusing on the impact of sea level rise, including erosion, flooding, changing the land cover and land instability. Although both models produced reasonably good results (based on field observations and comparisons with the first model), there were many caveats mentioned, including the uncertainty in the accuracy of site location data, as well as inconsistencies in site records and available data. This issue with archaeological site location and record inconsistencies was standard among many of the identified archaeological vulnerability assessments (Bickler et al., 2013; McCoy, 2018).

Along the coast of Georgia, USA, researchers evaluated the threat faced by heritage resources from the impacts of shoreline erosion, sea level rise and bluff retreat. Robinson et al. (2010) illustrated the role that spatial scale has on the ability to perform archaeological site vulnerability assessments. Since the study area was relatively small for this research, the authors were able to physically measure the current shoreline position and site boundary. They were then able to use this information in conjunction with orthorectified aerial imagery to map past shorelines and determine whether there was a long-term trend of erosion or accretion at the site. Site-specific shoreline change data was then generated to rank the sites based on whether they were eroding, stable, or accreting (Robinson et al., 2010). Unfortunately, performing this same type of analysis across the country would take more funds and time than available, making this type of site assessment only practical for small areas (Robinson et al., 2010; Reeder et al., 2012).

On a broader scale, Reeder et al. (2012) developed a coastal vulnerability index for the Santa Barbara Channel Region in California, USA, combining urban expansion expectations, archaeological site location, coastal geomorphology, historical erosion rates, elevation, and long-term wave height estimates. Each of these variables was mapped using GIS and evaluated based on a coastal vulnerability index (Reeder et al., 2012). These variables were then combined to generate a final coastal vulnerability index value. Reeder et al. (2012) noted that spatial scale was a determinant factor in the types and resolution of the data available to them. Localized scales, which deal with only a few archaeological sites, such as the study by Robinson et al. (2010), allow researchers to develop specific datasets for each site, particularly concerning historical rates of change. Large-scale archaeological site vulnerability assessments are important for heritage managers since localized data are not always available and can be time-consuming to collect and process.

Westley et al. (2011) demonstrated the role of regional coastal vulnerability assessments for heritage managers. Three regions in Newfoundland were assessed for local vulnerability, with an evaluation of site-specific risk. The project evaluated site risk based on anticipated sea level rise and the sensitivity of the coast to erosion with the latter criteria based on slope and sediment type. Areas exposed to coastal inundation were developed based on anticipated sea level rise (SLR) projections and storm surge information for 2025, 2050 and 2100. Areas of risk were based on whether the sediment was unconsolidated (high risk) or bedrock (moderate to low risk) and the associated slope, less than 6º was high risk, between 6º and 12º moderate risk, and low risk higher than 12º. More specifically, the vulnerability of a site to coastal erosion due to sea level inundation and storm surge. Combining these three areas with the location of archaeological sites, Westley et al. (2011) highlighted which sites may be at risk from the impacts of sea level inundation and increased erosion.

That same study highlighted issues with data quality when performing regional risk assessments. Digital Elevation Models (DEM) are essential data in desk-based modelling (Webster et al., 2006; McCoy, 2018). The resolution of the DEM will impact the accuracy of the result. Higher resolution terrain data can influence the characterization of shorelines and the way in which sea level rise impacts the landscape and therefore coastal sites (McCoy, 2018). This same issue is also highlighted by the archaeological site data. The accuracy of archaeological site locations is integral to effective modelling of risk. In many cases site location is not accurately recorded or is poorly known (Robinson et al., 2010; Westley et al., 2011; Bickler et al., 2013; Reeder-Myers, 2015).

Desk-based modelling has proven to be useful for assessing areas at-risk (Mclaughlin and Cooper, 2010; Reeder et al., 2012; Bickler et al., 2013). The use of a GIS allows for multiple datasets to be assessed and the combined influence illustrated. Two aspects that are key to developing a useful model are the spatial scale and the quality of the data. These two aspects are dynamically linked; at a finer spatial scale, higher resolution data can be collected, while at a coarser spatial scale, lower resolution data are typically available (Westley et al., 2011; Reeder-Myers, 2015; McCoy, 2018). However, developing regional assessments require higher resolution data to provide accurate results (McCoy, 2018). Determining the sensitivity of desk-based assessments of archaeological sites can help heritage managers effectively allocate their available resources to develop a reliable desk-based model for assessing risk faced by archaeological resources (Reeder-Myers, 2015; McCoy, 2018).

### 1.4.2 Prioritizing at-risk coastal archaeological resources

Once at-risk coastal archaeological resources have been identified, the next task is to prioritize sites for management. The term "management" varies globally, regarding archaeological resources. In Canada, provincial and territorial governments are mandated to address archaeological site risk. Under the Historic Resources Act of Newfoundland and Labrador,

"The minister is responsible for the:

(a) protection and preservation;

(b) co-ordination of the orderly development;

(c) study and interpretation; and

(d) promotion and appreciation

Of the historic resources and paleontological resources of the province".

(Historic Resources Act [NL], 1990, 2001 c31 s2).

Although the statement above is specific to Newfoundland and Labrador, similar, if not exact wording, can be found in the Historic Resources Acts across Canada (Historic

Property Act [NS], 1989; Historical Resources Act, 1990 [NL]; Ontario Heritage Act, 1990; Heritage Conservation Act [BC], 1996; Denhez, 2000; Historical Resources Act [AB], 2000; Historic Resources Act [YK], 2002). Parks Canada, however, is not mandated to protect all resources. Instead, they are tasked with managing resources with a greater emphasis on safeguarding national historic sites (Parks Canada, 2013). With varying mandates come varying priorities. Assessing and managing or protecting archaeological resources at risk is a difficult task. Limitations of resources, both human and financial, can further exacerbate the overwhelming responsibility for governing bodies mandated to protect and preserve these resources (Erlandson, 2008; 2012). Developing a best practice of site prioritization for management can assist heritage managers in making more informed decisions (Moratto and Kelly, 1976; 1978). Having a detailed methodology for assessing sites for the prioritization of management can help to protect resources not only currently valued by society but sites that may become important to future generations with changing research, political and societal interests (Moratto and Kelly, 1976). Although researchers advocate for a methodology, none has yet to be developed for broad-scale use (Robinson et al., 2010; Reeder et al., 2012; Daire et al., 2012; Westley et al., 2011; Bickler et al., 2013; Dawson, 2013; Reeder-Myers, 2015). The primary evaluation technique for archaeological site management and prioritization is how “at-risk” the site is, in other words, the exposure, sensitivity, and threats faced by that site. Although this method limits bias, it does not always make the task more manageable. A more robust approach for assessing site priorities for heritage managers can make addressing multiple high-risk sites more manageable.

Current practice does not directly deal with the prioritization of sites for management but instead assesses the determination of the significance of an archaeological site as a management tool (Moratto and Kelly, 1978; Schiffer and Gumerman, 1977; Walton, 1999, Dawson, 2013). Moratto and Kelly (1976; 1978) discuss methods for determining the significance of an archaeological resource, highlighting issues of ethics surrounding the systematic protection or destruction of archaeological resources with changing criteria. To use significance as a method for prioritizing archaeologists must understand that it is what they call “intrasite significance,” which refers to the changing value of a site based on context (Moratto and Kelly, 1978). One example, provided by Moratto and Kelly (1978), is the importance of fossil pollen for one research project, and the alternate importance of ceramics for another research project. Within the context of the same site, two completely different research priorities emerge.

Seven key values of significance are discussed by Moratto and Kelly (1976; 1978): 1) historical significance, 2) scientific or research significance, 3) ethnic significance, 4) public significance, 5) legal aspects of significance, 6) geographic significance, and 7) monetary significance.

Historical significance is evaluated based on whether or not the cultural resources can be associated with an individual event in history or whether it can inform on the broader cultural patterns during the historic era (Schiffer and Gumerman, 1977; Moratto and Kelly, 1978). Scientific or research significance is a broad category, encompassing not only the scientific value to archaeologists but other disciplines as well.

Scientific significance is the potential of a site to fill in knowledge gaps, which may come from numerous disciplines (Schiffer and Gumerman, 1977). It includes the potential of a site to help understand the past and make generalizations not only regarding a particular culture, but also certain tool types, or a better understanding of cultural distribution over an area. Scientific significance may also relate to the importance of a site or groups of sites for informing past species distribution, paleo-landscapes, or past adaptation strategies.

Ethnic significance is related to the value an archaeological resource has for mythology, spirituality, or symbolism (Schiffer and Gumerman, 1977; Moratto and Kelly, 1978). This attribute often overlaps with the next factor, public significance.

Public significance can relate to the importance of a site to local communities for many reasons, including spiritual or symbolic importance; however public significance also goes a step further by evaluating the benefits of maintaining the site. This may include the educational benefits, monetary benefits through tourism, and the use of the site for public viewing and enjoyment (Schiffer and Gumerman, 1977). The legal aspects of significance relate directly to the method of prioritization set out by Parks Canada. Nationally historic sites are prioritized as more important than sites not linked to national history. The legal aspect of significance assesses the value of a site based on government criteria such as those listed in the Parks Canada Cultural Resources Management policy, or the American National Register of Historic Places and the associated Historic Resources Act in Canada and Historic Site Preservation Act in the USA (National Historic Preservation Act, 1966; Parks Canada, 2013). This literature typically focuses on sites which are relevant to the understanding of national history, particularly sites that can be associated with a specific person or event in history (National Historic Preservation Act, 1966; Parks Canada, 2013).

Another aspect of significance relates to the value of a site spatially. The geographical significance of a site directly refers to the importance of the site for understanding cultural patterns across an area (Darvill, 1995; Deeben et al., 1999; Daire et al., 2012; Dawson, 2013). On occasion, geographic significance can be related to the rarity of the site if the site type is the only one within an area. The spatial relationship of a site to surrounding sites and analysis can provide consideration in determining the geographical significance. The last factor mentioned by Moratto and Kelly (1978) is the importance of monetary value. Although the assessment of the fiscal importance of a site seems to go against traditional archaeological thought, it is important to understand what the cost of losing a site may be. Additionally, it is important to consider the cost of excavating a site so that infrastructure can be built (Moratto and Kelly, 1976). If the monetary value of a site is assessed based on the cost of excavation, this may not accurately represent the importance of that site. For instance, although a lithic scatter may easily be removed using heavy machinery, it does not mean that site does not have high value to the archaeological community. It is for this reason that monetary value is typically disregarded as a useful assessment of site significance (Schiffer and Gumerman, 1977; Raab and Klinger, 1977). The destruction of archaeological resources should not be based on how inexpensive it would be to destroy. The value a site has for the community both economically and educationally should be taken into consideration (Schiffer and

Gunerman, 1977; Darvill, 1995). Many communities operate on tourism revenue. It is important that this be a consideration when determining the priority of that site for management (Moratto and Kelly, 1976; Schiffer and Gunerman, 1977; Darvill, 1995).

Similar factors for assessing significance are also published in Europe (Darvill, 1995; Deeben et al., 1999; Daire et al., 2012, Dawson, 2013). More commonly referred to as an assessment of value (the values-based method), the valuation process includes such factors as aesthetic value, historical value, integrity, preservation, rarity, research potential, group value, education, recreation/tourism, and representativity (Darvill, 1995; Deeben et al., 1999). Aesthetic value directly relates to built heritage and the visual condition and integration into the landscape. This valuation or significance factor can be applied to built heritage but does not necessarily have well-defined criteria for addressing pre-contact sites (Preservation, 1991; Deeben et al., 1999). Historical value, similar to the historical significance discussed earlier, in this relates to the memories a site may evoke. Integrity and preservation are both considered physical factors for significance. Integrity refers to "…the degree to which disturbance has taken place…" and the preservation is "…the degree to which the archaeological material has survived…" (Deeben et al.,1999). These values are also only applicable to built heritage structures since buried archaeological sites are much more difficult to monitor how much of the site has already been destroyed. These physically based values can be applied more generally by addressing the current condition of the site, and whether it is intact or at risk (Dawson, 2013). These values are applicable not only to built heritage but buried sites as well.

Rarity in previously mentioned factors of significance or value has only been implied. Geographical significance and scientific significance are implicitly related to how rare an archaeological resource is, spatially and regarding the potential for research. A site that is rare regarding location, cultural affiliation, and period or site type may have the potential to fill knowledge gaps (Preservation, 1991). The research potential value, or scientific significance, has been described in North American literature concerning whether the site has been excavated in the past or not, whether similar sites have been excavated, and how recently and systematically research has occurred in that area (spatially and culturally) (Preservation, 1991). The group value is important to address when prioritizing archaeological sites, as sites are commonly inter-related. Sites that collectively inform on cultural patterns and practices can be assessed as significant since together they inform research questions or may be historically significant (Preservation, 1991; Deeben et al., 1999). The final value, representivity, addresses how well a group of sites or monuments can represent similar assemblages across space. This includes the physical quality of the site, as well as the quality or amount of data currently known about that site and surrounding sites (Deeben et al., 1999).

Prioritization methods are typically referred to values-based assessments or significance assessments. Although named differently they include similar criteria, such as the value to the public, education, monetary, spiritual, as well as the importance to research and our collective knowledge both for scientific aspects and historical understanding. The need for some method of prioritization is consistently referred to in the literature. At the same time, researchers warn that no standardized methodology will work, archaeological value is dynamic and relative to changing social dynamics and research interests (Schiffer and Gumerman, 1977; Schiffer and House, 1977; Moratto and Kelly, 1978; Deeben et al., 1999; Reeder et al., 2010; Westley et al., 2011).

## 1.5 Methods

### 1.5.1 Explore how improved geospatial data quality impacts the results of a desktop assessment for coastal archaeological site vulnerability to coastal inundation.

Effective modelling of archaeological sites at risk requires an accurate understanding of where the site is located, as well as the size and extent of the site relative to the shoreline. To refine upon this model, Chapter 2 focuses on the evaluation of site-specific risk to sea level rise inundation. LiDAR data was acquired to accurately represent the coastal topography with a horizontal accuracy of 0.5 mand a vertical accuracy of 14 cm. This dataset allowed for an accurate representation of coastal terrain. Refined site locations, complete with site boundaries were used to create site-specific assessments of risk. The regional sea level rise estimates consider not only projections for sea level rise but the additional factor of submergence (James et al., 2014). Using high-resolution data, archaeological sites in Bonavista Bay were assessed to determine the risk to sea level rise at two-time points: 2025 and 2100. Sites that were below the 2025 sea level rise extent are considered at high risk of sea level inundation. Sites between the 2025 extent and 2100 sea level rise extent were considered at moderate risk, and above 2100 at low risk. The results produced from the model were evaluated using field data for each site and the current condition of the site. Once at-risk sites have been identified, heritage managers are tasked with determining how to prioritize sites for management action.

### 1.5.2 Identifying current practices in archaeological site prioritization and developing a framework for application in Bonavista Bay

Choosing which archaeological site to protect first requires a great deal of subjective decision making (Moratto and Kelly 1978). There are two primary ways of prioritizing sites for heritage management: 1) addressing sites based on the severity of risk, and 2) assessing sites for management based on the significance of the site. Current practice does not directly deal with the prioritization of sites for management but instead addresses the determination of significance as a management tool. The methods used to determine a site's significance can vary greatly due to the subjective nature of archaeological site interpretation and the influence of changing political and social climates. Assessing the efficiency of current practice in prioritizing sites at risk for management is important. Although not all sites will be saved, it is critical that a thorough site prioritization methodology be established. This is particularly important for heritage managers who are working with limited site data. Limited data makes it difficult to determine which site is more significant, thus making the evaluation of sites "deserving" management action one-sided.

To determine current practices, a literature review was completed. Keywords were used to help direct the literature review, including, Coastal archaeology, Coastal resources risk management and prioritization, site prioritization, Impact assessment and more. Both peer-reviewed and grey literature were evaluated. The literature review provided insight into current practices and values in determining site significance as a method of prioritization. These values were then used to develop a framework to prioritize sites that are at risk of sea level rise. To determine the appropriateness of the framework for application to high-risk sites, it was applied to high-risk sites in Bonavista Bay (as modelled by CARRA).

## 1.7 Thesis Structure

This thesis is structured in a manuscript format. Chapters 2 and 3 are written with the intent of being published as stand-alone papers. Some overlap between the articles is expected.

Chapter 1 introduced the hazards and risks associated with climate change. Specific attention was allotted to the impacts climate change will have on coastal archaeological resources and how heritage managers can efficiently respond. Chapter 2 proposes a desk-based method of assessing the vulnerability of coastal archaeological sites and demonstrates the sensitivity of data resolution on the results using Bonavista Bay, Newfoundland and Labrador, as a case study. This paper explains the need for high-resolution data for desk-based site vulnerability modelling. Chapter 3 addresses the next step after archaeological sites at-risk have been identified: prioritizing. This paper lays out a method of prioritizing sites at risk for management purposes, based on an evaluation of significance. A sensitivity analysis of criteria used to determine significance was also done using high-risk sites identified in Bonavista Bay, Newfoundland. Chapter 4 summarizes the results of this thesis.

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# Chapter 2: The impact of data resolution on desk-based coastal archaeological site vulnerability assessments: a case study in Bonavista Bay, Newfoundland.

## Abstract

The increasing impacts of climate change, specifically sea level rise, will have a disastrous effect on coastal archaeological resources. Heritage managers and archaeologists around the world are facing decisions on what to do in the face of eroding cultural heritage. Action is needed now to protect or retrieve the information from significant sites under threat in coastal areas before they are completely eroded. In responding, heritage managers face potentially tough questions about which sites are most at risk. Identifying the spatial data resolution required to perform an accurate desk-based assessment for at-risk coastal archaeological heritage is imperative. This paper evaluates the impact of digital elevation models, site location information, and the magnitude of two sea level rise estimates by modelling site vulnerability and comparing it against observational field data. Of the three datasets, site location, and particularly site extent, have the biggest impact on the results of the model. Moving forward, it is suggested that heritage managers pay attention to the collection of digital data for representing site boundaries.

## 2.1 Introduction

Coastal archaeological sites are at considerable risk from the impacts of sea level rise resulting from anthropogenic climate change (Erlandson, 2008; Blankholm, 2009; Westley et al., 2011; Barreau et al., 2013; Reeder-Myers, 2015). The Fifth report from the Intergovernmental Panel on Climate Change Rising (IPCC, 2013) indicated that a 2º Celsius increase in global temperatures could increase sea level by 5 metres by 2100 (Church et al., 2013). With much of the world's cultural history located along the coast, sea level rise threatens our global cultural heritage (Erlandson, 2008; Hambrecht and Rockman, 2017). Archaeological heritage is an important social and economic asset. It may inform on past lifeways, and climate change adaptations (Erlandson, 2008; Marzeion and Levermann, 2014; Hambrecht and Rockman, 2017). With accelerated sea level rise and increased storm surges anticipated over the next decade (Rahmstorf, 2017), it is imperative that the vulnerability of coastal archaeological resources be determined (Brimblecombe et al., 2006; Erlandson, 2008; Perry, 2011; Horton et al., 2015; Reeder-Myers, 2015). Vulnerability is defined exposure and sensativity of an archaeological site to harm. In this study, vulnerability particularly relates to the negative impact of sea level inundation.

In Canada, Provincial and Territorial heritage are mandated to plan and preserve all archaeological resources from anthropogenic influences (Historic Resources Act [NL], 1990; Ontario Heritage Act, 1990; Heritage Conservation Act, 1996; Denhez, 2000; Historical Resources Act [AB], 2000). Climate change will make the job of a heritage manager even more difficult (Huggins, 2007; Erlandson, 2008; Perry, 2011). With one of the longest coastlines in the world, Canada is at risk to sea level rise, and coastal archaeological resources around the country are under threat.

One method for determining site vulnerability is using field-based assessments. Projects such as SCAPE (Scottish Coastal Archaeology and the Problem of Erosion) in Scotland, ALERT (Archéologie, littoral et Réchauffement Terrestre = Archaeology, Coasts, and Global Warming) in France, and the CITiZAN (Coastal and Intertidal Zone Archaeological Network) in England, all utilize public engagement to monitor archaeological sites vulnerable to sea level rise inundation and erosion (Our Fragile Island Heritage, n.d.; Scape, 2010; Daire et al., 2012; Dawson, 2013). Utilizing a volunteer workforce allows for frequent re-visitation and detailed monitoring (Scape, 2010; Daire et al., 2012; Barreau et al., 2013).

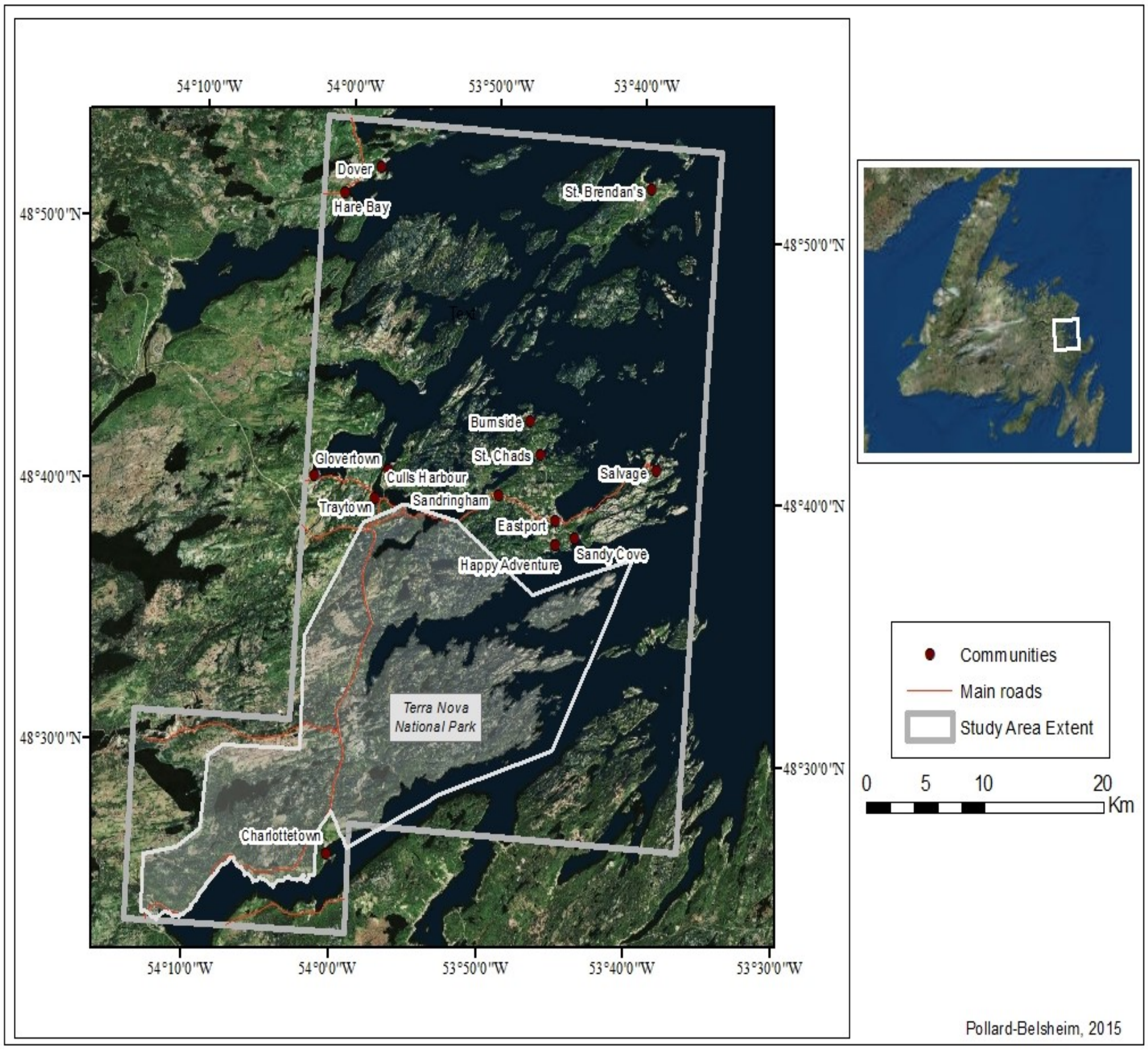
Field-based assessments can provide heritage managers with reliable data to help determine management priorities. This method is excellent for closely monitoring archaeological resources at risk to coastal threats. However, this method is not necessarily feasible for the majority of heritage managers. With thousands of kilometres of coastline and thousands of remote sites, Newfoundland and Labrador is an example of a province where field-based assessments with yearly re-visits for monitoring sites would not be practical. This is where a desk-based modelling approach to determining site vulnerability is far more applicable. Desk-based models for assessing archaeological site risk to coastal hazards have been carried out in Georgia, Newfoundland, California, Texas, and Virginia (Robinson et al., 2010; Westley et al., 2011; Reeder et al., 2012; Bickler et al., 2013; Reeder-Myers et al., 2015). Each of these assessments aimed to identify archaeological sites that are most at risk. These desk-based assessments identified the vulnerability of sites over a larger area and provided a basis for which to compare the level of risk faced by each site. To develop a desk-based model for at-risk site identification a digital elevation model must be acquired to illustrate the local landscape, site location information must be available, and data regarding the risk (e.g., sea level rise estimates, areas of coastal erosion, areas of urban expansion) is needed.

The Coastal Archaeological Resource Risk Assessment (CARRA) project, based at Memorial University of Newfoundland, focuses on the impact of sea level rise on coastal archaeological resources and on methods for identifying and addressing the vulnerability of these sites. The CARRA project has three main objectives: (1) to develop methodologies that identify archaeological resources at risk to sea level rise (2) to provide potential strategies for prioritizing at-risk archaeological resources for management purposes based on current literature, and (3) to provide heritage managers with a knowledge base of adaptation responses to coastal threats on archaeological heritage (Pollard-Belsheim et al. 2014). This paper focuses on the first of these objectives through refinement and field testing of  a desktop vulnerability assessment, first developed by Westley et al. (2011). Although their study identified a remarkable 20% of all known coastal archaeological sites in select regions of Newfoundland were at risk to inundation and erosion by rising sea level, they acknowledged limitations to the approach, particularly the use of low quality geospatial data that were available at the time.

Specifically, the present study addresses the question of whether improved geospatial data quality improves the results of a desktop assessment for coastal archaeological site vulnerability to rising sea level. It utilizes high-quality terrain and archaeological data collected by CARRA for Bonavista Bay (northeastern Newfoundland) to conduct the comparative assessment and most importantly evaluates the accuracy of the assessment predictions for 2025 sea level projections with field observations of  current site conditions.

## 2.2 Study Area

The study area used in this paper is located in the southern part of Bonavista Bay (Fig. 2.1). Bonavista Bay was chosen for this study for multiple reasons. The sea level history in the area provides an opportunity to evaluate the compound impacts of land submergence and sea level rise. Quinlan and Beaumont (1981) suggested that the area in which Bonavista Bay is located would be considered a Type B sea-level curve. This means that as the last glacier melted in the area, the Bonavista coastline experienced net emergence until around 8500 BP, followed by continuous submergence up to the present (Grant, 1989; Liverman, 1994; Shaw and Forbes, 1995; Liverman, 2004). This submergence has a direct impact on the rate of sea level rise in the area (James et al., 2014). In Bonavista Bay, regional land submergence is measured through a Global Positionings System (GPS) located at St. John's where the rate of -0.29 mm/year has been recorded (James et al., 2014).



Pollard-Belsheim, 2015

*Figure 2.1: Bonavista Bay study area, Newfoundland, and Labrador.*

The sea level history in Bonavista Bay and the submerging coastline influence the record of cultural history in the area. Bonavista Bay is one of the longest continuously occupied landscapes on Newfoundland, with one of the earliest Maritime Archaic Indian (MAI) occupations at the Beaches site around 4900 BP[1] +/- 230 (Carignan, 1974). These early

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[1] BP: Before Present. This timescale represents radiocarbon years before present (i.e. before 1950). This timescale is used due to its widespread use in archaeological reporting.

cultures settled along the coastline to maintain quick access to marine resources. This, in conjunction with land submergence, has caused a clustering of sites along the coastline (Bell and Renouf, 2004; 2005). These sites are also clustered on top of each other, meaning that when one site erodes, multiple years of cultural history erode with it. In this area, a high number of sites have been documented as eroding (McLean, 2006; Curtis, 2008). The final reason for the selection of Bonavista Bay was due to the previous work on archaeological site vulnerability modelling by Westley et al. (2011). By incorporating the Westley et al. (2011) study area within the study area for this paper, connections between vulnerability results could be made, and issues of data quality explored.

Within Bonavista Bay, the study area is approximately 1885 km$^2$. The boundaries of this study area were set based on data availability, site accessibility, and partially by request of Parks Canada. The outline of the study area is delineated based on the available extent of LiDAR (Light Detection and Ranging) in the area. This study area also provided opportunity to inform on the preservation status of archaeological sites not easily accessible to heritage managers. Although most sites were within a one-hour boat ride (pending appropriate ocean conditions), they were quite dispersed, and therefore only one or two sites could be visited within a day. The study area includes all of Terra Nova National Park due to the number of known eroding sites and on request of Parks Canada.

### 2.2.1 Physical environment

Inlets and various offshore islands dominate the area, with the coastline varying from steep bedrock cliffs and narrow gravel berms to sandy beach flats (Fig 2.2). The dominant wind comes from the North East. A large fetch and limited shoals provide opportunity for strong coastal erosion. Surficial geology of the bay is exposed bedrock, with small areas covered by vegetated sand or gravel along the bay heads (Liverman and Taylor, 1993; Westley et al., 2011). Catto (2012) indicated that much of the coastline has a sensitivity to coastal erosion and sea-level rise between moderate and very high. Using this sensitivity index, Catto (2012) indicated that most of the area has a high energy coastline, and a coastal retreat rate ranging from 0.1 m to more than 1.0 m annually; coastal erosion is highly variable throughout the area. The vegetation throughout the study area is indicative of a maritime boreal forest environment, with alders, spruce, birch, short grasses, and heath vegetation being the most common (Hedderson, 1992). Many of the offshore islands can be classified as coastal barrens, with stunted heath vegetation. This is also true for the headlands throughout the study area.

*Figure 2.2: Examples of typical coastal environment in Bonavista Bay. A) Gravel beach with sparse vegetation. B) Shallow heath vegetation on a bedrock coastline. C) A viewscape of offshore islands in Bonavista Bay looking out over Morris Channel.*

Coastal erosion in Bonavista Bay has been documented heavily. The Burnside Heritage Foundation and Parks Canada monitor many of the archaeological sites within Bonavista Bay and report to the PAO (McLean, 2006; Curtis, 2008; McLean 2009). At the Beaches site in Bonavista Bay, coastal erosion has been evident at this site since 1874, as noted by T.G.B. Lloyd. This site is the third oldest site in Newfoundland and has been recognized for its major contributions to the understanding of the Beothuk culture (Devereux, 1969; Carignan, 1975; McLean, 2009). Many archaeologists have worked to help stabilize and protect this archaeological site by excavating and building breakwaters to help limit coastal erosion. These methods have not stopped erosion at the site. Due to the shallow bedrock, the water undercut the structures and continued to erode the bank (Fig. 2.3; McLean, 2009).

*Figure 2.3: On the left: Image of first breakwater constructed to protect the Beaches site in 1995 and 1998; On the right: the second breakwater constructed to protect the site; Note: In both of these photos, it is evident that the protective measures at the site are not able to stop erosion completely.*

### 2.2.3 Cultural history

The earliest evidence of occupation in Bonavista Bay is the Maritime Archaic Indian (MAI) tradition. This tradition is represented by a marine adapted hunter-gatherer society that can be identified in Newfoundland from 5500 to 3200 BP (Bell and Renouf, 2004; Curtis, 2008). Following the MAI period, two Pre-Inuit groups have been identified in

Newfoundland with a slight chronological overlap: the Groswater Pre-Inuit (2800 to 1950 BP) and the Dorset Pre-Inuit (2000 to 1200 BP; Curtis, 2008). Although traditionally identified as Groswater and Dorset Palaeoeskimos, Whitridge (2016) suggested that Pre-Inuit is a more appropriate term than Palaeoskimos. Much like the MAI, both Pre-Inuit groups were hunter-gatherers focused on marine resources for subsistence. The importance of marine resources can be identified in all of the pre-historic cultures identified in Newfoundland. The Recent Indian complex (2000- 400 BP) includes the Cow Head, Beaches, Little Passage, and Beothuk complexes. During the end of this period, Newfoundland began to be occupied by English and French fishermen due to the abundance of cod. Early European settlers were also marine focused, often settling near or along the coastline. Even today, many of the communities in Newfoundland can be found along the coastline.

## 2.3 Methods

The approach to site vulnerability modelling taken in this paper is focused around the needs of the heritage manager. There are many sophisticated models that allow for in-depth modelling of coastal hazards. The model discussed here provides a feasible, flexible, and simple procedure for use by heritage managers. Rather than trying to analyze multiple risks facing coastal archaeological resources, a more general model of sea level rise impacts was created to provide opportunity to apply this model in many different environments. As well, it limited the role of unknown variables, such as expected rates of erosion, localized wind and fetch dynamics and localized influences of flora and fauna on the vulnerability of the site. The model informs on the impact of rising water levels on archaeological sites along the coastline. These sea level rise estimates were derived from the IPCC fifth report and included local glacioisostatic effects. Four projections were used: a median and a high scenario for 2025 and 2100. The higher-level scenario is a more conservative choice and provides opportunity for heritage managers to protect archaeological sites. Additionally, the impact of storm surge increases was also modeled (Catto, 2011). Although temporary, an increase in storm surge can have a dramatic influence on coastal archaeological resources.

In order to best understand archaeological site vulnerability to rising waters, the site elevation and location needed to be considered. For site location, the initial dataset used was easily accessible through the provincial government records. The second dataset used involved high-quality survey data collected during targeted field visits. The comparison of these two datasets provides heritage managers a better understanding of the advantages and disadvantages of the two datasets in desk-based modelling.

In order to best understand the topographic situation of the site and the coastal topography, two digital elevation models were selected: Canadian Digital Elevation Dataset (CDED) which is readily available to heritage managers across Canada but has limited resolution and Light Detection and Ranging (LiDAR) which is a high resolution but only available selectively in certain provinces and territories.

The goal of this study is to determine whether these different datasets options have an effect on the outcome of a simple desk-based vulnerability assessment. To evaluate the model output, field observations on site inundation and erosion were compared to the results of the model.

Although these data are somewhat limited, they do provide an opportunity for heritage managers to evaluate the potential vulnerability of coastal archaeological resources to the impacts of sea level rise.

### 2.3.1 Data sources

Three datasets were required to develop the site vulnerability assessment: 1) archaeological site data, 2) topographic (terrain) data, and 3) projected sea-level rise estimates. Two different spatial resolutions (i.e., raster grid cell size) were used for each of the three datasets to determine the impact of data resolution on site vulnerability assessments. The results of the site vulnerability assessment utilizing each dataset were compared to the results identified in the field to establish which resolution provided comparable results.

#### *2.3.1.1 Collection and processing of archaeological site data*

Two datasets were used for the location of archaeological sites. The first one was the dataset managed by the Provincial Archaeology Office (PAO) of Newfoundland and Labrador, which represents each site as a single point on the landscape. This dataset was compiled over many decades primarily using topographic maps, with only 30/113 sites (i.e., 27% in the Bonavista Bay study area) located using global navigation satellite systems (e.g., Global Positioning System or GPS). For sites not located using a GPS, locations were obtained using 1: 50,000-scale topographic maps onto which locations were estimated based on field drawings and local landscape descriptions. As many archaeologists with a range of available technology have collected the documentation on each site location, overall accuracy is difficult to assess.

The other dataset used for site location was created during the 2014 field survey. During this survey, 59 sites were visited in Bonavista Bay and surveyed using a differential GPS (DGPS) equipped with real-time kinematic (RTK) capabilities (Fig 2.4). DGPS uses a fixed, known position, over which the base station is located, to adjust real-time GPS signals and improve the accuracy of positional data. This not only provided a more accurate site location, with accuracies of up to 10 cm but also allowed site boundaries to be surveyed. For some sites, the 2014 field survey was the first re-visit in 20 years.

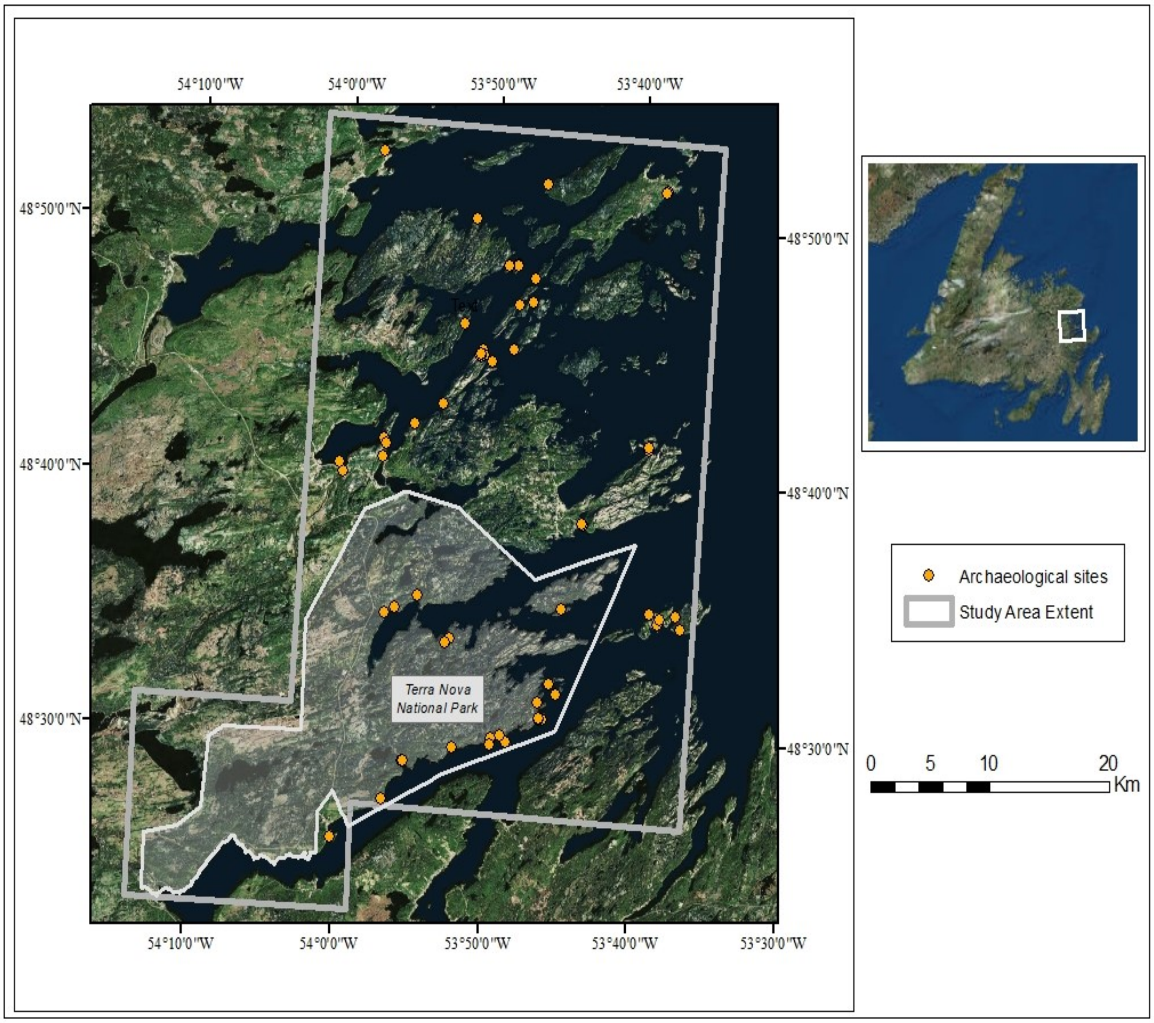


*Figure 2.4: Archaeological Sites Re-surveyed in Bonavista Bay, Summer 2014.*

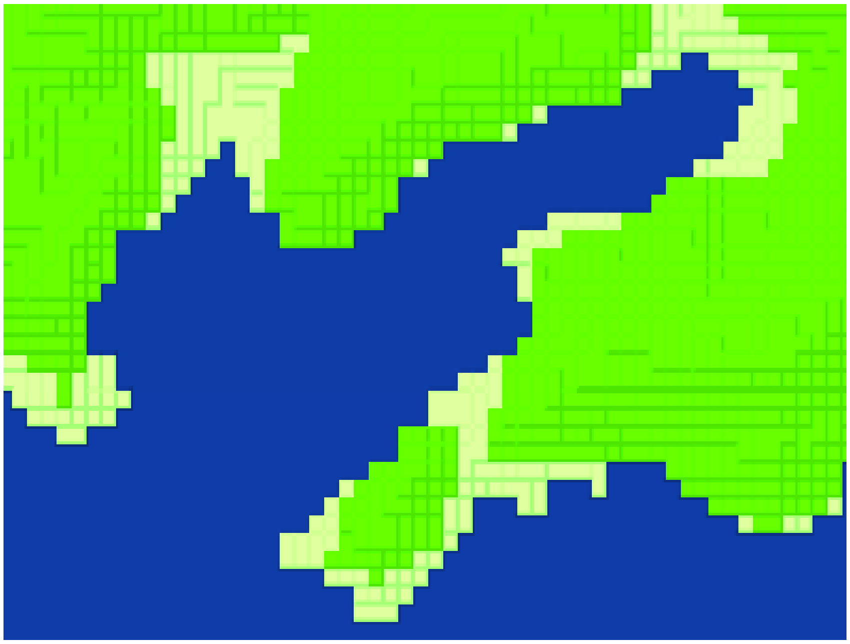
At each site, data were collected for different elements, including the location and geomorphic features (including the surveying of the assumed boundary of the site), visible features, recovered artifacts, vegetation line, tree line, seaweed line, and driftwood line where available. In cases where site documentation did not indicate where the GPS location was taken, it was assumed that it was in a central location. Many of the record documents had an estimated surface area indicated but no information concerning the orientation or shape of the site. For some sites, a review of unpublished reports and discussions with regional archaeologists helped establish approximate site boundaries for poorly documented sites.

Notes and photos recorded the current condition of the site, areas of erosion or inundation, features that may limit erosion or wave strength, such as shoals or barriers, and whether or not any archaeological material was visible during the visit to the site. Sites were classified as either being actively eroded or inundated, as represented by erosion scarps or a seaweed/driftwood line extending over the site boundaries, or in the absence of these indicators, not eroding. Sites that did not have seaweed or erosional scarps but were observed as being inundated by the tide were classified as eroding. Other processes of erosion, such as animal and human activity, were noted but not taken into consideration when modelling site vulnerability. Data were collected to best represent each archaeological site in its coastal context.

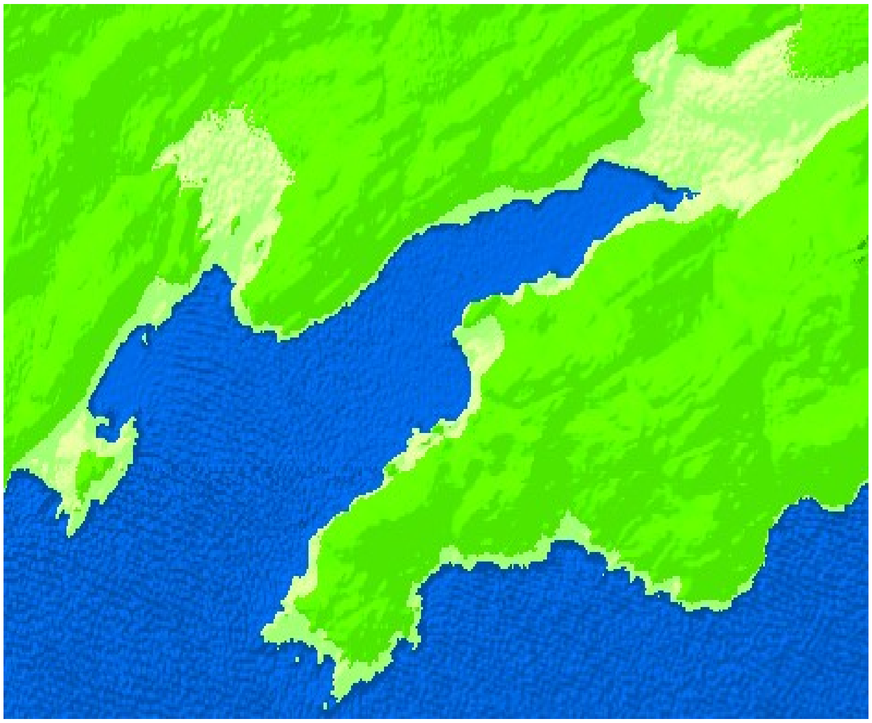
The 2014 surveyed site data were processed using a Geographic Information System (GIS). This involved digitizing the extent of each site using the surveyed points and creating a geo-referenced polygon. In areas where communication between the base station and the rover was poor (i.e., loss of survey accuracy), the site was digitized using a standard survey system (positional accuracy ±15 m) and site record details from previous archaeological visits. The centre of the re-surveyed sites was determined using the weighted centroid method (or mean centre), and the elevation was obtained from the LiDAR data (see next section for details). The PAO site dataset did not require any preparation, as it was provided as an Esri ArcGIS point shapefile.

### *2.3.1.2 Digital elevation models*

Two digital elevation models (DEM) in raster format were used to assess the role of terrain resolution in the site vulnerability assessment. Both datasets used the same datum: North American Datum of 1983 - Canadian Spatial Reference System. The lower resolution dataset is from the CDED. available for free from the Government of Canada. This dataset has a horizontal and vertical accuracies of ±20 m and ±10 m respectively (Geobase, 2007). The other dataset used was generated using LiDAR. The LiDAR survey, commissioned for the project, cost approximately \$90,000 for the 1885 km$^2$ study area. The LiDAR data had a horizontal and vertical accuracies of 50 cm and 7 cm respectively (Hogan, 2013). Although LiDAR data are only available for specific areas in Canada, many provinces and regions have commission LiDAR surveys of the coastline, including Prince Edward Island, Nova Scotia, and parts of the Canadian Arctic (Whalen et al., 2009; Davies, 2011; Jones et al., 2013; Proctor, 2016). The two datasets provide low and high-resolution terrain data for the study area (Fig 2.5). Unfortunately, there were no other datasets available that covered the entire study area at the time of this project.



CDED: 20 metre



LiDAR: 0.5 metre

*Figure 2.5: Illustration of resolution differences in raster format between CDED and LiDAR datasets in Terra Nova National Park. Notice the change in the level of detail, particularly around the coastline.*

#### *2.3.1.3 Sea-level rise and storm surge estimates*

Sea-level rise estimates determine how far inland water is expected to inundate the landscape, helping assess which sites will be at-risk (James et al., 2014). The projections of relative sea-level rise used in this paper were developed by James et al. (2014) based on the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (Church et al., 2013; Stocker et al., 2013). James et al. (2014) incorporated the implications of local glacial isostatic rebound effects by combining values observed using GPS at fixed stations across the province. The representative concentration pathways (RCP) values provided by the IPCC were adjusted using these local vertical movements as well as regional oceanographic effects (Stocker et al., 2013; James et al., 2014). The RCP scenarios are labeled by the amount of radiative forcing applied in each climate scenario. Of the five RCP values discussed in James et al. 2014, two were used in the model presented in this paper: RCP 4.5 (median) and RCP 8.5 (95%). The RCP 4.5 (median) scenario illustrates the potential impact of 4.5 $W/m^2$ of energy added into the energy balance equation and the resulting influence on sea level rise.

RCP 4.5 (median) was used to demonstrate the impact of a medium scenario on coastal archaeological site vulnerability in Bonavista Bay. RCP 4.5 (median) projects a relative sea-level rise (RSLR) of 0.11 m by the year 2025 and 0.54 m by 2100, using the vertical land movement measured for St. John’s, the closest survey monument established by the Geodetic Survey of Canada, to the study area. RCP 8.5 (95%) represents a more extreme scenario, and likely the more applicable scenario for heritage managers attempting to protect coastal archaeological sites. A more extreme projection allows heritage managers to prepare for the worst-case situation. It projects an RSLR of 0.20 m by 2025 and 1.13 m by 2100.

For the archaeological site vulnerability assessment, the RSLR projections were measured from the high tide level to determine the maximum level of inundation that could impact the coastal landscape. Specifically, the level used was the average highest high water largest tide (HHWLT) value from the most recent data provided by the Canadian Hydrographic Service for the hydrographic vertical separation surface (Robin et al., 2014). This data was combined with estimated storm surge heights of 2 m by 2025 and 3 m by 2100 based on current observations in Atlantic Canada (Vasseur and Catto, 2007; Catto, 2011). Tables 2.1 and 2.2 indicate the total values used to model RSLR in Bonavista Bay to determine site vulnerability.

*Table 2.1: Relative sea-level rise (RSLR) estimates for RCP 4.5 (median) in Bonavista Bay. All height values are expressed in metres.*

| Year | Current $\text{HyVSEP}_{\text{HHWLT}}$ | RCP 4.5 | Storm surge | Total RSLR RCP 4.5 |
|---|---|---|---|---|
| 2025 | 0.62 | 0.11 | 2 | 2.73 |
| 2100 | 0.62 | 0.54 | 3 | 4.16 |

*Table 2.1: Relative sea-level rise (RSLR) estimates for RCP 8.5 (95%) in Bonavista Bay. All height values are expressed in metres.*

| Year | Current $\text{HyVSEP}_{\text{HHWLT}}$ | RCP 8.5 | Storm surge | Total RSLR RCP 8.5 |
|---|---|---|---|---|
| 2025 | 0.617 | 0.20 | 2 | 2.812 |
| 2100 | 0.617 | 1.13 | 3 | 4.747 |

### 2.3.2 Site vulnerability model

The CARRA model discussed in this paper was created using a modified “bathtub” approach. The “bathtub” modelling approach floods a given grid cell from a raster terrain model if the elevation of the cell is at or below a given sea-level value (Poulter and Halpin, 2008; Gesch, 2009). In the CARRA model, contour elevation was used instead of cells to assess the flooded area, with a base contour elevation established at HHWTL. This negated issues with inland being inundated, a problem commonly associated with bathtub modelling approaches (Poulter and Halpin, 2008).

The CARRA model was developed using Esri ArcGIS (v. 10.2.2) software. Archaeological site location data and topographic data were projected in UTM Zone 22N projection, based on NAD83 CSRS datum. Four RSLR projections plus storm surge estimates (Tables 2.1 and 2.2), were modeled by establishing a contour line at each projected sea level estimate from the HHWLT. The areas between these contour lines represented expected zones of inundation under a RSLR projection (Table 2.3). In cases where sites fell into multiple vulnerability zones, the highest risk zone was chosen to represent the site. Using this same classification method, the percentage of a site area that occupies one or more vulnerability zones could be determined.

*Table 2.3: Criteria for determining the vulnerability of an archaeological site using the CARRA model. Water levels refer to the combined effect of RSLR and storm surge.*

| Areas of Vulnerability | Criteria for vulnerability assessment |
|---|---|
| High | All or part of the site is located below the projected 2025 water level |
| Moderate | All or part of the site is located between the projected water level for 2025 and 2100 |
| Low | All the site is above the projected water level for 2100 |

### 2.3.3 Sensitivity analysis of the CARRA approach

To assess the impact of data resolution on the site vulnerability assessment, the model was run eight times, each time with a different combination of data (Table 2.4). Tests helped assess which dataset provided the best results in comparison with field observations.

*Table 2.4: CARRA model iterations.*

| Run | Archaeological Site Data | Terrain Dataset | RLSR Estimate |
|---|---|---|---|
| 1 | PAO | LiDAR | RCP 8.5 |
| 2 | PAO | LiDAR | RCP 4.5 |
| 3 | Re-Surveyed Data | LiDAR | RCP 8.5 |
| 4 | Re-Surveyed Data | LiDAR | RCP 4.5 |
| 5 | PAO | CDED | RCP 8.5 |
| 6 | PAO | CDED | RCP 4.5 |
| 7 | Re-Surveyed Data | CDED | RCP 8.5 |
| 8 | Re-Surveyed Data | CDED | RCP 4.5 |

## 2.4 Results

The results of this study are presented in four sections. The results of the field survey in Bonavista Bay were evaluated to determine if they were representative of the archaeological record in the area, based on cultures affiliated and site type. Differences between the re-surveyed site data and the PAO records were also highlighted. The current condition of the archaeological sites in Bonavista Bay is discussed based on field observations.

### 2.4.1 Representativeness of visited sites

Of the 113 sites identified by the PAO within the study area boundaries, 59 (52%) were re-visited during the 2014 field season (Table 2.5). The remainder were not visited due to time and weather constraints. PAO records had GPS-measured location data for 11 of these 59 sites.

Almost two-thirds of the re-visited sites were prehistoric (63%, 37/59), while another one-fifth was historic, related to the extensive logging industry in Terra Nova National Park (22%, 13/59). Nine sites had both prehistoric and historic components (15%, 9/59; Table 2.5).

*Table 2.5: Cultural affiliation of archaeological sites visited in Bonavista Bay study area, Newfoundland, along with documented evidence of inundation or erosion.*

| Site Name | Borden Number | Culture | Evidence of Inundation/Erosion |
|---|---|---|---|
| Ashley Baker Island | DcAk-02 | GP; DP | No |
| Babstock | DeAl-23 | PC | No |
| Bank Site | DdAk-05 | MAI; GP; DP; RI | Yes |
| Barachois Beach (413A) | DdAl-05 | EN | Yes |
| Beaches | DeAk-01 | MAI; GP; DP; RI | Yes |

|  |  |  |  |
|---|---|---|---|
| Bloody Bay Cove 1 | DeAl-01 | MAI; DP; RI | Yes |
| Bloody Bay Cove 2 | DeAl-06 | DP; PC; EN | Yes |
| Bloody Bay Cove 3 | DeAl-05 | PC | No |
| Bloody Bay Cove Overhang | DeAl-18 | PC | No |
| Bloody Bay Cove Summit | DeAl-09 | PC | No |
| Bloody Bay Point | DeAl-10 | PC | Yes |
| Bread Cove 1 | DcAl-02 | EN | Yes |
| Bread Cove 2 | DcAl-03 | PC | Yes |
| Broad Cove Harbour | DeAk-04 | PC | Yes |
| Brown's Beach | DeAl-02 | MAI; DP; RI | Yes |
| Brown's Meadow | DdAj-08 | UP | Yes |
| Bruce Cove | DeAl-07 | DP | Yes |
| Buckley Cove (414A) | DdAl-06 | EN | Yes |
| Butler's Cove | DfAl-08 | EN | No |
| Cary Cove | DeAl-03 | RI | Yes |
| Chandler Reach (Minor Drainage) | DcAk-01 | PC | Yes |
| Chandler Reach 1 | DdAk-10 | MAI | Yes |
| Chandler Reach 2 | DdAk-11 | PC | Yes |
| Chandler Reach 3 | DdAk-12 | PC | Yes |
| Chandler Reach 4 (412A) | DdAk-19 | MAI; RI | Yes |
| Chandler Reach Long Islands | DdAj-02 | DP; RI | Yes |
| Chapple Tickle | DdAj-01 | DP; EN | Yes |
| Charlie Site | DeAl-11 | MAI; UP; RI | No |
| Charlottetown Point | DcAm-01 | PC | Yes |
| Clode Sound 1 | DdAk-03 | MAI; GP; DP | Yes |
| Clode Sound 2 | DdAk-04 | MAI | No |
| Culls Harbour Narrows | DeAl-19 | PC; RI; EU | No |
| Daisy | DeAk-13 | PC | Yes |
| Dock Cove French Cemetery | DfAj-01 | EU | Yes |
| Fox Bar | DeAk-03 | MAI; DP; RI | Yes |
| Fox Bar Burial Site | DeAk-02 | RI | No |
| Grassy Pond Sawmill | DcAl-04 | EN | Yes |
| Howard | DeAl-12 | UP; RI; PC | No |
| King Site | DdAl-04 | EN | Yes |
| Little Content | DfAl-01 | DP | Yes |
| Long Island, Bonavista Bay | DdAj-03 | MAI | No |
| Lou Island Tickle | DeAk-08 | DP | Yes |
| Matchim | DdAk-01 | GP; DP; RI; EN | No |
| Minchin Cove | DdAl-02 | EU | Yes |
| Moose Pasture | DcAk-03 | MAI; GP; EU | Yes |
| Moose Pasture Sawmill | DcAk-04 | EU | No |
| Moss | DeAk-12 | RI | Yes |
| Platters Picnic Area | DcAl-01 | EU | No |
| Sailor South | DeAj-05 | UP; EU | Yes |

| | | | |
|---|---|---|---|
| Sailors site | DeAj-01 | MAI; DP; RI; EU | No |
| Saltons Brook | DdAl-01 | EN | Yes |
| Sandy Cove 1 | DdAk-02 | MAI; DP | Yes |
| Squire's site | DeAl-20 | PC; EN | Yes |
| Stroud's Point Graveyard | DeAm-03 | EN | Yes |
| Swale Island | DdAk-08 | UP; RI | Yes |
| Terra Nova River | DeAm-02 | UP; EU | Yes |
| Unnamed Site | DdAj-04 | MAI; DP | Yes |
| Wicks' Site | DeAl-21 | PC | Yes |
| Wiseman's Cabin | DfAk-04 | EN | No |

MAI: Maritime Archaic Indian
GP: Groswater Pre-Inuit
DP: Dorset Pre-Inuit
RI: Recent Indian
PC: Pre-contact
UP: Unidentified Pre-Inuit
EU: European
EN: Euro-Newfoundlander

Sites surveyed in Bonavista Bay are representative of the cultural landscape within Bonavista Bay (Table 2.6). The number of surveyed Maritime Archaic Indian, Groswater Pre-Inuit, Dorset Pre-Inuit, Recent Indian, and Unidentified Pre-Inuit surveyed in the study area represent more than 75% of the total culturally affiliated sites. Some cultures were represented more heavily in the re-surveyed sample, including the Dorset Pre-Inuit by 10% and the Recent Indian by 9%. The Euro-Newfoundlander sites were slightly under-represented by 8% when compared to the larger study area.

*Table 2.6: Percentage of cultural affiliation in study area compared to surveyed sites (Note: percentages can exceed 100% as multiple sites can be linked to multiple cultures).*

| Cultural Affiliation | All Site Components | Surveyed Site Components |
|---|---|---|
| Maritime Archaic Indian (MAI) | 17% | 25% |
| Groswater Pre-Inuit (GP) | 5% | 10% |
| Dorset Pre-Inuit (DP) | 19% | 29% |
| Recent Indian (RI) | 18% | 27% |
| Pre-Contact (PC) | 34% | 29% |
| Unidentified Pre-Inuit (UP) | 7% | 10% |
| European (EU) | 13% | 15% |

| | | |
|---|---|---|
| Euro-Newfoundlander (EN) | 29% | 22% |
| | n=113 | n=59 |

Of those visted sites whose function or type was listed in the PAO records, one quarter was identified as habitation (27%), lithic scatter (15%), or a combination of the two (7%), which together are also the most common site types in the region (23, 9 and 4, respectively; Table 2.7). There is a broad similarity between the composition of sampled archaeological sites and all sites within the study area.

*Table 2.7: Percentage of site type in study area compared to surveyed sites. (Note: percentages can exceed 100% as multiple sites can be linked to multiple site types).*

| Site type | All Site Components | Surveyed Site Components |
|---|---|---|
| Campsite | 4% | 0% |
| Graveyard | 6% | 5% |
| Habitation | 23% | 27% |
| Habitation & Lithic Scatter | 4% | 7% |
| Habitation & Sawmill | 4% | 5% |
| Lithic Scatter | 9% | 15% |
| Multi-Component | 2% | 3% |
| Quarry | 1% | 2% |
| Quarry & Lithic Scatter | 5% | 5% |
| Sawmill | 10% | 5% |
| Shipwreck | 1% | 0% |
| Spot Find | 5% | 2% |
| Undetermined | 27% | 24% |
| | n= 113 | n=59 |

### 2.4.2 Re-surveyed site characteristics

Differences in site locations between the PAO records (central point) and re-surveyed locations (centroid) were on average 145 m. However, differences are not normally distributed, and the median value of 102 m is a more appropriate central measure. Several outlier sites impacted the overall results. For example, the location of one site was misplaced by 850 m in the PAO records (Figure 2.5). This resulted from an error when the site was initially recorded: an incorrect island was chosen for the site's position. Assistance from local archaeologist Laurie McLean and photos of the site confirmed the correct location for the surveyed site. Of the surveyed sites, almost two thirds (63%) of the sites were repositioned closer to the coast. The remaining sites moved further from the coast. Lateral changes were noted but were not discussed here due to the fact these changes were primarily caused by the differences in site size identified when re-surveying sites.

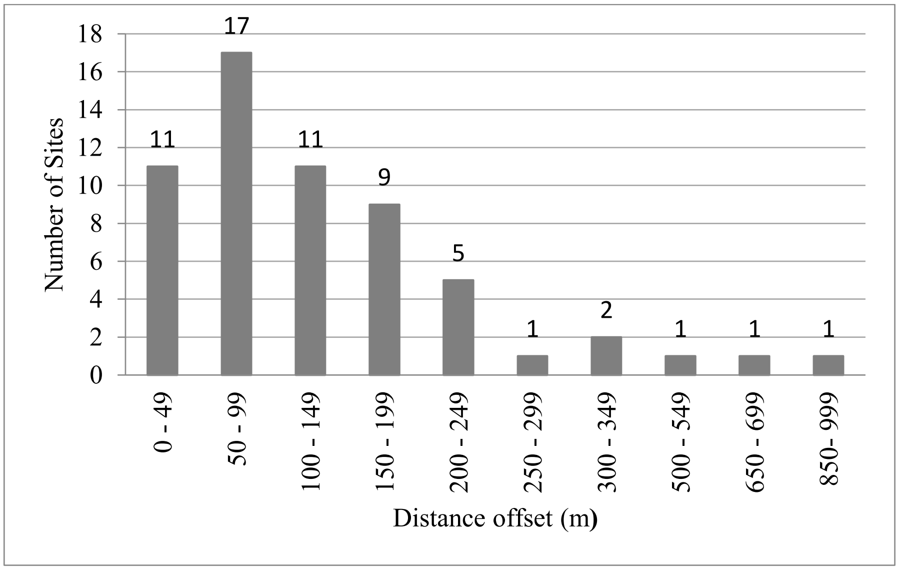


*Figure 2.6: Distribution of distance offsets between the official PAO location and the re-surveyed position based on surveyed site centroids. Note the change in scale on the x-axis and class sizes for the last three classes.*

The median site size was 431 m$^2$ with over 75% of the sites smaller than 2000 m$^2$ (Fig. 2.7). Comparing the resurveyed site dimensions to the PAO records revealed that more than half of the visited sites (56%) were larger than officially documented., due to how site boundaries were defined by current heritage managers. Only a quarter of the sites were smaller, potentially due to site erosion or high-resolution survey.

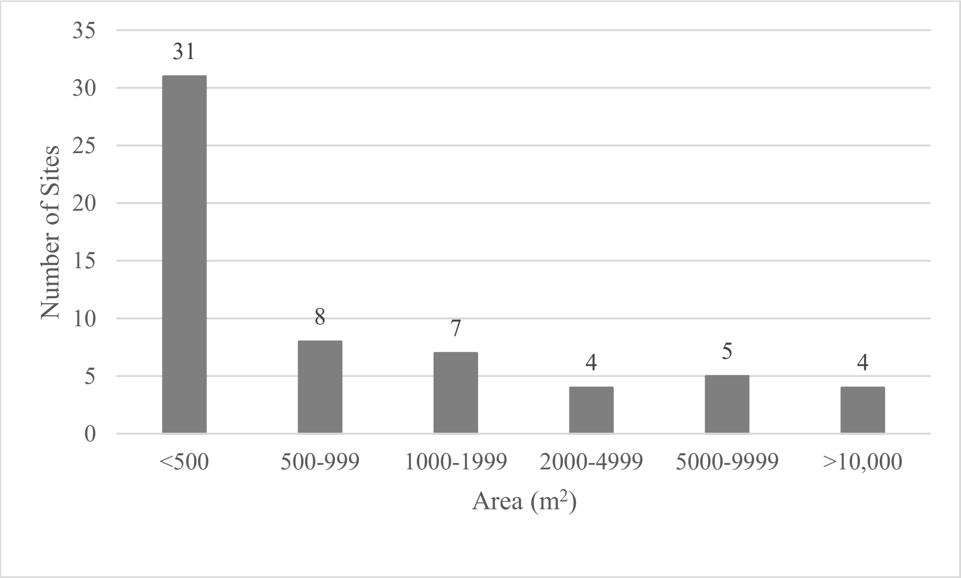


*Figure 2.7: Area frequency distribution for re-surveyed sites in Bonavista Bay. Note the varied class sizes.*

The elevation above sea level of the visited site centroids was derived from the LiDAR, which has an associated error margin of +/- 0.07 m. The median site centroid elevation is 1.85 masl (Fig 2.8). Most sites (81%) are within 4 m elevation of current sea level. Two sites have a part of their area located below the HHWLT. Re-surveyed sites were on average 1.45 m below than the lowest elevation documented in the PAO database.

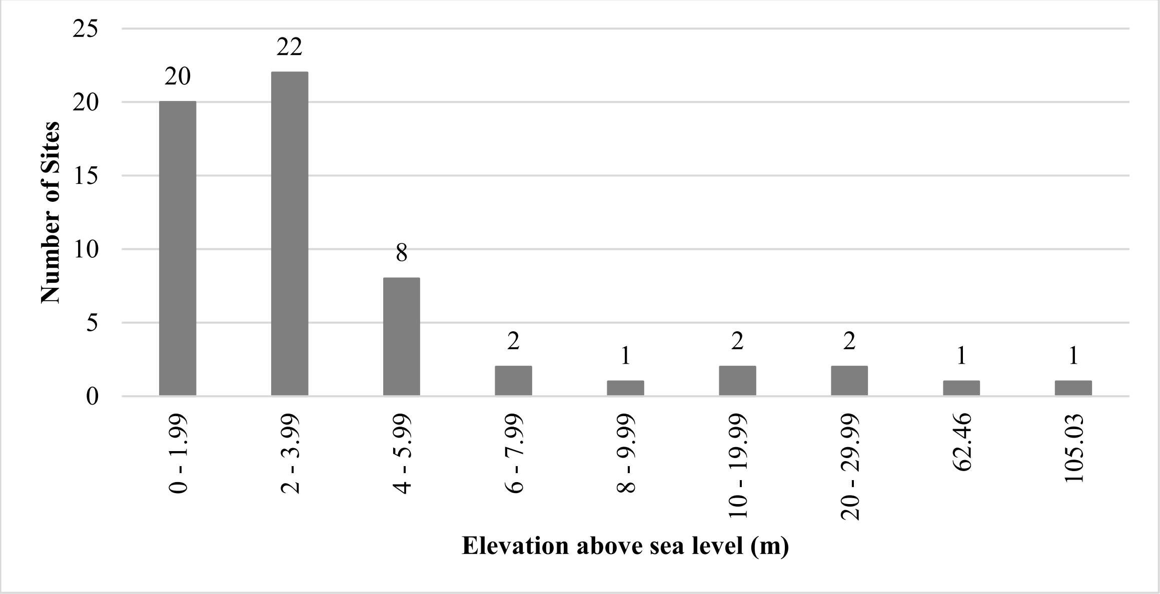


*Figure 2.8: Frequency chart of LiDAR-derived site centroid elevation for re-surveyed sites in Bonavista Bay. Note class changes.*

During fieldwork, 71% of sites were documented as either inundated or eroding (Table 2.5; Fig. 2.9). Erosion was observed at many of the sites, with artifacts eroding from the banks and scattered along the coast. At these sites, exposed bank sediment showed evidence of coastal erosion. Tidal inundation and possible storm surge was also identified at 51% of the eroding sites, established by the seaweed line.

*Figure 2.9: Evidence of erosion at archaeological sites in Bonavista Bay. A) Flakes eroding out the bank at the Moss Site. B) Headstone being eroded out of the bank, even with riprap protection at Stroud's Point Graveyard. C) Coastal erosion at the Beaches site.*

Presence of wind erosion was determined by the presence of blow-outs and in some cases observation of wind erosion at work (29%, Table 2.9). Human impact was determined by observing built structures, paths (recreational vehicle or foot trails), and refuse (31%). Finally, animal impact was determined through observational data (i.e., seeing an animal, animal tracks, or fecal matter) (17%).

*Table 2.8: Total number of sites influenced by erosional forces.*

| **Coastal Erosion** | **Tidal Inundation** | **Human Impact** | **Wind Erosion** | **Animal Impact** |
|---|---|---|---|---|
| 42/59 | 30/59 | 18/59 | 17/59 | 10/59 |
| 71% | 51% | 31% | 29% | 17% |

### 2.4.4 Modelling Archaeological sites vulnerable to sea level rise and storm surge

Modelling of archaeological site vulnerability using LiDAR data, the re-surveyed site locations and boundaries, and RCP 8.5 (95%) revealed that 81% (48/59) of sites in Bonavista Bay could be inundated to some degree by 2025, classifying those sites as high-risk (see appendix 3 for full results). The assessment run classified as high risk 40 of the 42 sites that are currently eroding as high risk, while the other two sites were classified as moderate risk. The remaining 6 sites indicated as not at risk, were identified in higher elevation locations. Of the 48 high-risk sites, 11 sites are anticipated to be completely inundated by 2025 (Fig 2.10).

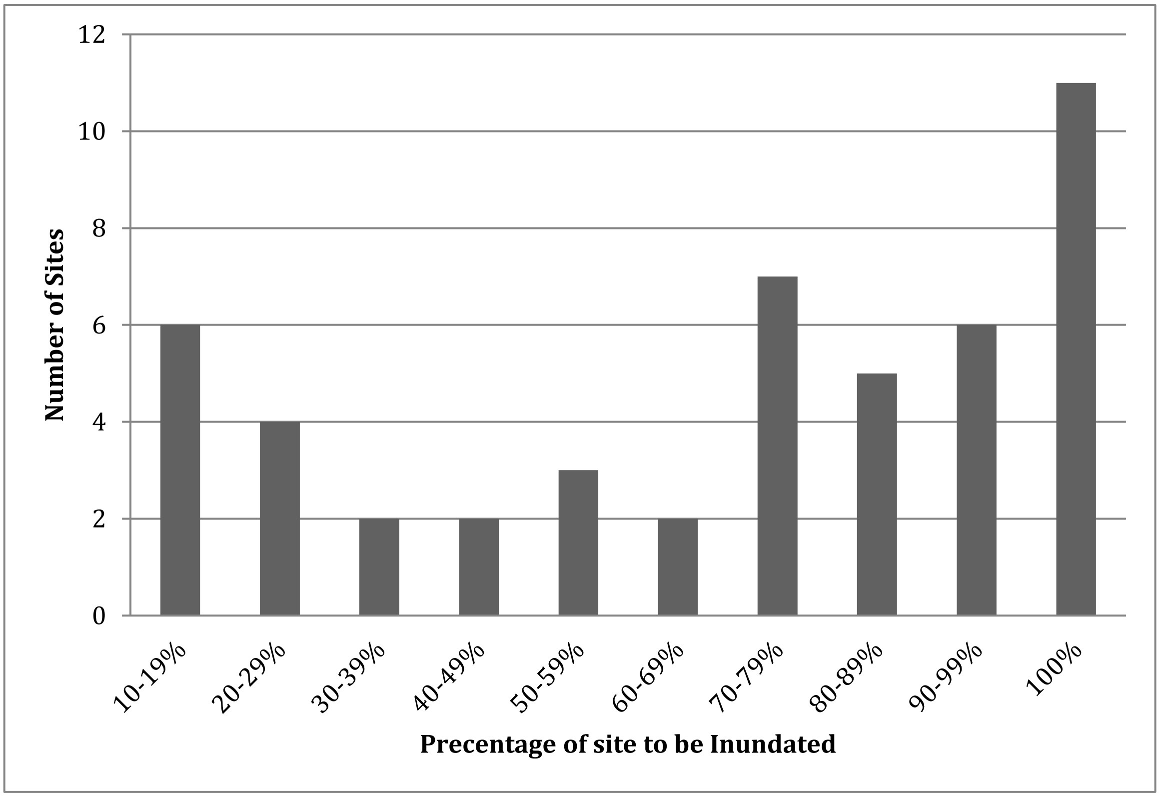


*Figure 2.10: Percentage of total site area projected to be inundated by 2025, for the high-risk sites identified in Bonavista Bay (n=48), using LiDAR, Re-Surveyed Archaeological site data and RCP 8.5. Note: All sites are anticipated to be inundated, at least partially, by 2025*

The site location data had an impact on the site vulnerability assessment. Modelling the vulnerability of the PAO site location with the high-resolution topographic data (LiDAR) and the more extreme sea level rise estimate (RCP 8.5) yielded poor results in comparison to the sites identified as eroding or inundated (based on seaweed line) during field assessments. In contrast, the newly surveyed site location data results were far more comparable to the sites eroding in the field (Table 2.10).

*Table 2.9: Impact of data quality Archaeological site location data using LiDAR and 8.5 RCP (n=59). Notice the difference between the observed site vulnerability and the classified site vulnerability using the PAO site data.*

| Vulnerability | Eroding in the field | PAO site location | Survey site location |
|---|---|---|---|
| High | 42 | 29 | 48 |
| Moderate | N/A | 10 | 3 |
| Low | 17 | 20 | 8 |

Models outputs based on PAO site location data indicated that about half of the archaeological sites (49%) were at risk of partial or complete inundation by 2025. Of those 29 sites, 6 (20%) were incorrectly identified as being at high risk when in fact these sites were not identified as inundated or eroded during field observations. The re-surveyed site location data, with site boundaries, nearly doubled the amount of modeled high-risk sites (48/59; 81%). The majority of sites went from low risk to high risk when the analysis was based on the higher spatial resolution data (Table 2.11).

*Table 2.10: Vulnerability classification change between the PAO site location and the re-surveyed site location.*

| | | **PAO Data** | | |
|---|---|---|---|---|
| | N= 23 | Low | Moderate | High |
| **Survey Data** | Low | ╳ | 0 | 1 |
| | Moderate | 2 | ╳ | 0 |
| | High | 11 | 9 | ╳ |

Knowing site locations and boundaries with a higher spatial accuracy increased the number of sites for which vulnerability classifications were accurate. Sixty-five percent of sites re-surveyed were located closer and lower to the coastline, increasing the likelihood of inundation.

Sites associated with each culture have similar levels of risk, with the highest being Euro-Canadian sites at 81% (Table 2.12). Euro-Canadian sites are any sites associated with the French, European, and early (Euro-) Newfoundlander occupation. Multi-component sites were counted once for each represented culture, meaning that one site may be included in cultural totals; one site may contribute to each culture. Table 2.12 highlights the risk faced by sites representative of the primary cultural groups identified in Bonavista Bay.

*Table 2.11: Vulnerability of archaeological sites based on cultural affiliation.*

| Vulnerability | Maritime Archaic | Pre-Inuit | Recent Indian | Euro-Canadian |
|---|---|---|---|---|
| High | 73.3% | 75.0% | 73.3% | 81% |
| Moderate | 13.3% | 12.5% | 6.7% | 9.5% |
| Low | 13.3% | 12.5% | 20.0% | 9.5% |

Determining the impact of terrain data resolution on site vulnerability assessments was done by modelling the newly surveyed archaeological site location with boundaries and the more extreme sea level rise estimate RCP 8.5 (95%) on each topographic dataset. Although the number of high-risk sites modelled using the CDED topographic dataset

(44) was about the same as the observed high-risk sites, there were differences in the actual sites selected. Of the 44 classified high-risk sites using the CDED terrain data, 9 were identified as stable in the field, while 7 of the 14 sites classified as low-risk are currently eroding. Of those 48 sites, 8 are currently not eroding. Of the remaining three sites eroding that were not modelled as high risk, two were modelled as moderately at risk due to the elevation above the active shoreline, and one was modelled as low risk, due to elevation. The eight sites that were modelled as high risk, but not identified in the field, are located on bedrock coastlines which, although resisting erosion, can be easily inundated with a 2 m storm surge.

*Table 2.12: Vulnerability classification impact from topographic data. Although both topographic data sets provided similar numbers with regards to high-risk sites, the sites identified were very different. Observational data matched best with the classification results of the LiDAR dataset.*

| Vulnerability | Eroding in the field | CDED | LiDAR |
|---|---|---|---|
| High | 42 | 44 | 48 |
| Moderate | N/A | 1 | 3 |
| Low | 17 | 14 | 8 |

Comparing the modelling results indicated that site vulnerability decreased when using the CDED dataset. Although only 12 sites changed vulnerability, the majority went from high vulnerability with the LiDAR dataset, to low vulnerability in the CDED dataset (Table 2.14).

*Table 2.13: Vulnerability classification change between CDED and LiDAR*

| | | **CDED** | | |
|---|---|---|---|---|
| | N= 12 | Low | Moderate | High |
| **LiDAR** | Low | ╳ | 0 | 2 |
| | Moderate | 0 | ╳ | 2 |
| | High | 8 | 0 | ╳ |

Finally, the impact of using a moderate and more extreme sea level rise estimate was assessed. When modelling the newly surveyed site location and boundaries on the LiDAR topographic dataset, the two sea level rise estimates, RCP 4.5 (median) and RCP 8.5 (95%), had no measurable impact on the results, likely due to the fact the two scenarios have a difference of only 9 cm (Table 2.15).

*Table 2.14: Vulnerability classification change using the moderate and extreme sea level rise estimates.*

| Vulnerability | Eroding in the field | RCP 4.5 | RCP 8.5 |
|---|---|---|---|
| High | 42 | 48 | 48 |
| Moderate | N/A | 3 | 3 |
| Low | 17 | 8 | 8 |

## 2.5 Discussion

With 71% of sites surveyed already being impacted by coastal erosion, and another 10% expected to be inundated by 2025, archaeological sites in the Bonavista Bay region are clearly at risk. Compared to other areas of the province where the CARRA model was applied, the results indicated that an average of 65% more sites are at risk in Bonavista Bay by 2025. In addition, there was almost 50% more sites eroding in Bonavista Bay than in any other study area. The combination of sea level history and cultural history of the area resulted in a high concentration of archaeological sites along the coastline. Many sites were repeatedly used. This is evident by the number of multicultural sites that include some of the earliest Maritime Archaic Indian material as well as artifacts as recent as the Beothuk and Euro-Newfoundlander complexes. With the landscape subsiding and sea level rising shortly after the last glaciation in Bonavista Bay, prehistoric cultures settled the same areas over and over again, living on top of the previously occupied sites. This means that extensive archaeological history will be lost with as little as 1 m of sea level rise. Bonavista Bay is classified as a submerging landscape.

### 2.5.1 Impact of Data Resolution on the Desk-Based Vulnerability Assessment

During the 2014 field season, field observations identified 71% of archaeological sites as being eroding. Comparatively, using the highest resolution data available for the project, the CARRA model indicated that 81% of sites would be vulnerable to the risk of sea level rise by 2025.

Site location and boundary proved to be a determinant in the accuracy of the model. Modelling the PAO site location vulnerability in comparison to re-surveyed site location and boundary increased the number of high-risk sites from 29 to 48 respectively. Of particular concern, the majority of sites not identified as high risk using the PAO location were assessed as low-risk sites. This discrepancy in identified site vulnerability is due to the newly surveyed sites, with the area of the archaeological site more accurately determined than by using single point locations of sites. Re-surveying the archaeological sites indicated a median shift of 102 metres from the PAO point to the centre of the re-surveyed site location. Of the 59 sites re-surveyed, 38 were closer to the active coastline, while 21 sites were further away. Understanding site boundaries is integral to accurate site vulnerability assessment. An archaeological site is not a single point, but a landscape; it is an area occupied and utilized by past cultures. Representing sites as they exist on the landscape is required for an appropriate vulnerability assessment. A single point may not be inundated for 50 years, but the seaward side of the site may currently be tidally inundated with essential aspects of archaeological significance being submerge. It is vital that heritage managers get a holistic view of the risks to archaeological resources. Not only does having the appropriate data on a site extent and location improve the accuracy of the vulnerability assessment, but it also allows for further questions to be asked to understand inundation risk at the site better. For instance, the total area of a site which may be inundated was calculated. This further demonstrated that of the 48 high-risk sites, 11 would be entirely submerged by 2025. Knowing the exact site location and a general estimation of the extent of damage/sea level rise will provide the most accurate assessment of vulnerability when using a desk-based modelling approach. Site extent is not the only high-resolution dataset required.

High-resolution topographic datasets, especially for a model addressing risk faced by inundation of rising sea level, are important for creating an accurate site vulnerability model. This paper only addressed two extremes in topographic resolution: the CDED and LiDAR data. It was evident in the results that the CDED was not a suitable resolution for conducting this type of inundation site vulnerability assessment. Although the number of high-risk sites identified is relatively similar, six sites were identified as low risk, even though they are actively eroding. Heritage managers must be able to determine with some confidence which sites are at risk, and where to focus their resources to best protect or salvage cultural resources. It is suggested that high-resolution data such as LiDAR is needed to represent the coastline better and assess the risk of archaeological resources to storm surge and millimetre scale sea level change. The site vulnerability assessment identified 48 sites as eroding in comparison with the 42 sites identified in the field. Sites that were identified in the model, but not during fieldwork, were characterized by being slightly higher in elevation, on bedrock coastlines, or in sheltered areas protected from current wave action.

Applying two different relative sea level rise estimates to the site vulnerability illustrated that although there are many different estimates for sea level rise in the next 10 years, the difference between the two SLR values used in this paper had no bearing on the results of the site vulnerability. It may be preferential to use a more extreme estimate of sea level rise to better prepare for the worst-case scenario, although this is not always justifiable.

Localized differences in storm surge estimates may have a large impact on the vulnerability model. It is important that localized data be collected when running the model. The two sea level estimates had no impact when modelling the newly surveyed site boundaries using the LiDAR topographic data. This is because the two sea level rise estimates are only marginally different (8.5 cm) by 2025. There was a larger difference between the sea level rise estimates at 2100 (59 cm), but this did not impact the site vulnerability assessment. The results of the two RCP sea level estimates illustrate that regardless of a more conservative approach to site vulnerability, coastal archaeological sites are at risk to inundation.

### 2.5.2 Implications for desktop modelling and heritage managers

The CARRA model was developed to be utilized by heritage managers in light of the data requirements of existing models. It provides a first step towards the identification of coastal archaeological sites threatened by sea level rise. It is crucial to understand the impacts of data resolution on the vulnerability assessment. To accurately assess vulnerability, sites' locations and spatial extents must be known. Going forward, archaeological site visits should include updated site location and preferably GPS coordinates delineating the boundaries of the site. It would also be beneficial for archaeologists to collect information about the surrounding area, particular in coastal zones. This could include the seaweed line, to identify marine inundation, driftwood line, to identify storm surge reach, and tree line, to determine where there is ground stabilization. Each of these datasets can be used within the model to better understand the vulnerability of a site on a case-by-case basis. Heritage managers should also evaluate the impact of terrain resolution in their study areas. In Bonavista Bay, high-resolution topographic data was important for the successful identification of archaeological sites at risk due to the variability in elevation. LiDAR elevation data may not be required for all types of landscapes, particularly those characterized by very little topographic variability. Some communities may also have their own commissioned digital topographic data that could be suitable and available to heritage managers at a lower cost. Drone surveys are a potential method for collecting high-resolution digital elevation data for small areas. The accuracy of desk-based site vulnerability assessments is likely to change based on the data available. This research does not consider many other factors that can influence coastal archaeological site vulnerability, and therefore should not be taken as a final assessment. Once sites have been identified as at risk by 2025, site visits are integral to help further assess factors influencing the site and its vulnerability. Heritage managers can then begin to prioritize management.

## 2.6 Conclusion

Coastal archaeological resources are at considerable risk to the impacts of climate change impacts. Developing methods helping heritage managers to identify and address these risks on a broad scale can help mitigate those risks.

Using the CARRA model, sites in Bonavista Bay were evaluated to determine the potential risk of sea level rise. Sites identified as currently at risk were compared to field-based data and proved to be accurately characterized. The second objective of the work was to evaluate the impact of data resolution on the three key datasets used to identify sites at risk, 1) archaeological site data, 2) terrain data, and 3) regional sea level estimates.

Fieldwork identified that archaeological site data not only needs to include refined data on location but also on the extent of the site, to model risk at each site. The improved dataset yielded more comparable results to the field observations when modeled using the LiDAR topographic dataset and the more extreme RCP 8.5 sea level rise estimate. Comparison of site vulnerability using the two different digital elevation models, CDED and LiDAR, indicated that higher topographic resolution resulted in a more accurate assessment of site vulnerability. The role of sea level rise estimates was the dataset with the least influence on the outcome of the assessment. In this study, the values for sea level rise by 2025 for both RCP 4.5 and RCP 8.5 were only 9 cm apart. However, understanding the factors that influence sea level rise estimates and the role each might play in a particular study area (e.g., subsidence in Newfoundland) is important for developing a site vulnerability assessment. Sea level rise estimates can provide an idea of vulnerability, but also when combined with up to date site location boundaries can inform the percentage of the site at risk of inundation.

One of the most important findings is that high-resolution topographic data may not allow for a complete assessment of the risk if the site is not accurately located and if site boundaries are not known. A single point is not sufficient to allow an assessment of the risks posed by sea-level risk to a site. Although heritage managers may not be able to get out in the field with a DGPS, GPS should be a requirement as part of archaeological fieldwork. It may also benefit future heritage managers to model vulnerability of sites that cannot be revisited by digitizing an assumed boundary based on field reports and recorded site size.

Further testing of the impact of data resolution on the assessment should be conducted using the bathtub model to further refine data requirements, particularly in terms of topographic data. The model presented here can also be developed to include the impact of erosion, looking at sediment and slope, the impact of wave energy and fetch, as well as impacts from visitors at the site. Although the CARRA model is by no means an extensive site vulnerability assessment, it gives a general indication of sites at risk and provides insights into the minimum required data resolution for an effective assessment. Conducting a comprehensive site vulnerability assessment that is accessible to heritage managers with varying spatial resolution is critical. Climate change is a threat to coastal cultural heritage. Developing methods to assess and address this threat is important for its management.

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# **Chapter 3: Current p**ractices in the prioritization of at-risk archaeological resources for management action and their application to eroding coastal sites in Bonavista Bay, Newfoundland.

## Abstract

The effective management of coastal archaeological resources requires an understanding of the impacts of climate change and a method for identifying site vulnerability. Current literature suggests that archaeological sites are prioritized based on current risk (e.g., based on whether a site is eroding or not). In the face of climate change, basing archaeological site priorities on current risk is no longer sufficient. Heritage managers need a strategic plan for dealing with multiple cultural resources at risk. In Canada, heritage managers are mandated to protect and preservecultural heritage. Through a review of current practice, methods for determining site priority are evaluated. Two main methods are identified; physical risk and the values-based approach. These two methods are combined, and a framework for site prioritization is suggested. This framework is then applied to vulnerable sites in Bonavista Bay, Newfoundland. The results of this assessment did not identify one high priority site, but four most significant sites, reducing the overall site list from 59 to 4. To apply this method, each value required specific questionsto help utilize the limited data available and determine site significance. The framework proposed provides heritage managers methods for addressing multiple sites at risk. We also suggest further improvements to the framework taking into account local history and priorities.

## 3.1 Introduction

Archaeological resources are at risk (ICAHM, 2015). Globally, millions of sites are under threat from impacts such as urban expansion, erosion, and sea level rise (Erlandson, 2012; Blankholm, 2009; Reeder-Myers, 2015). Billions of dollars are being invested into climate change research globally to help determine best practices for development and protection of properties; however, archaeological resources are not one of the main concerns in these studies (Erlandson 2008;2012). Many agencies struggle to deal with this issue due to the magnitude of the problem (Erlandson, 2008). In Canada, heritage managers are tasked with the preservation and protection of at-risk archaeological sites (Heritage Property Act [NS], 1989; Historic Resources Act [NL], 1990; Ontario Heritage Act, 1990; Heritage Conservation Act [BC], 1996; Denhez, 2000; Historic Resources Act [YK], 2002). With a large inventory of vulnerable sites that require protection and limited resources, managing archaeological sites is a difficult task, and not all sites can be saved. For the purposes of this paper, vulnerable sites will be those that are exposed to threats. This includes sea level rise and storm surges. Developing methods for prioritizing sites for protection can help heritage managers focus their resources on specific archaeological resources. Two main approaches have been used for prioritizing archaeological sites (Moratto and Kelly, 1976; Deeben et al., 1999; Walton, 1999; Robinson et al., 2010, Reeder et al., 2012; Reeder-Myers et al., 2015; Hambrecht and Rockman, 2017). The most commonly used approach aims to prioritize sites based solely on an assessment of existing or imminent threat exposure. A site that is threatened by coastal erosion, for instance, can either be actively eroding or susceptible to future erosion. Such a prioritization approach can help heritage managers rank susceptible sites based on their threat expusre level ranging from currently eroding (extreme level) through imminent (high level) to distane future (low level). In practice, assessing the future vulnerability and current condition is useful when only a few sites are being designated for action. It doesn't not, hoever, help the manager in his/her decision-making when multiple sites face a similar threat exposure level (Erlandson, 2012; Dawson et al., 2013). In such a case, additional ranking or prioritization is required.

Another method, commonly referred to as 'values-based,' uses the perceived significance of a site to prioritize response by heritage managers (Moratto and Kelly, 1976; Schiffer and Gumerman, 1977; Moratto and Kelly, 1978; Darvill, 1995; Poulios, 2010). Moratto and Kelly (1978;1) raised some moral concerns with a values-based approach, arguing that archaeological resources are "…being methodically conserved or obliterated depending on their adjudged significance." Nevertheless, they suggest that significance can be utilized as a managment tool given that it can be applied in a structured manner.

Developing methods that can strategically and systematically apply this "values-based" approach can help heritage managers prioritize among sites at equal physical risk. Utilizing current practice and literature on archaeological site management, a framework that can help heritage managers prioritize vulnerable sites is proposed. This framework combines threat expisure and site significance to prioritize sites. Using this framework, archaeological resources in Bonavista Bay, Newfoundland are assessed to determine the operability, effectiveness and sensitivity of the framework.

## 3.2 Existing methods for identifying high priority sites

Various methods have been proposed to help prioritize sites at risk for management decisions. On the east coast of the United States, Robinson et al. (2010) used a shoreline retreat model to identify potentially eroding sites along the coast of Georgia. Once the study sites were selected, historical air photos and shoreline analysis were used to determine the average rate of coastal erosion. These average rates were used to estimate future shoreline retreat rates. Of the 21 sites studied, 11 were considered as being eroding (i.e., shoreline retreat indicated an average loss per year). Those sites were then ranked based on their respective rates of erosion (Robinson et al., 2010).

In California, Reeder et al. (2012) assessed the threats of urban expansion, sea level rise, and coastal erosion to coastal archaeological resources. A coastal vulnerability map was created using multiple datasets, characterizing the vulnerability of sites close to the coast. These datasets included areas of low relief slope, easily erodible material (i.e., sandy beaches), wave heights, and historical rates of erosion. Once sites vulnerable to sea level rise and coastal erosion were identified, they were assessed to determine the vulnerability to urban expansion based on population prediction models for 2050. This provided researchers with an opportunity to identify sites at risk to both increasing populations and coastal threats.

In addition to assessing site vulnerability, the ‘Scotland’s Coastal Archaeology and the Problem of Erosion’ (SCAPE) program developed criteria to help evaluate site significance based on available site data collected in the SCAPE assessments (SCAPE, 2010). Archaeologists used the physical threat of erosion, the condition of the site, and site significance to identify high priority sites (Heritage, 2012). Poulios (2010) referred to this type of analysis as the 'values-based approach'. SCAPE (2010) and Dawson (2013) adopted similar assessment standards when prioritizing coastal archaeological sites affected by erosion. An on-going program developed by SCAPE called *Shorewatch* aims at facilitating the use of public opinion, combined with current condition, detailed site field assessments, and local priorities when determining archaeological site significance and prioritization (SCAPE, 2010).

A review of the literature (e.g., Moratto and Kelly, 1976; Schiffer and Gumerman, 1977; Moratto and Kelly, 1978; Darvill, 1995; Deeben et al., 1999) identified seven key factors of significance that can be used for site prioritization: Future Vulnerability, Current Condition, Rarity, Public Significance, Recreation and Tourism, Scientific Significance, and Historical Significance. Together these seven factors of significance provide a holistic evaluation of archaeological resources.

### 3.2.1 Method 1: Physical Risk

A first method used to prioritize archaeological sites for management assesses risks faced by each site (Moratto and Kelly, 1976; Deeben et al., 1999; Walton, 1999; Robinson et al., 2010, Reeder et al., 2012). Risks can be anything that may alter or infringe on any aspect of the site, from urban expansion to sea level rise or increased erosion (Robinson et al., 2010; Westley et al., 2011; Reeder et al., 2012; Bickler et al., 2013). These risks may be current or anticipated. Determining the physical risk of a site is typically done by evaluating the current integrity of a site in the field or by modelling the future vulnerability of the site to risk.

#### *3.2.1.1 Future vulnerability*

Assessing risks, particularly future risks that could impact archaeological sites, is typically done using Geographic Information System (GIS) tools and appropriate datasets (Robinson et al., 2010; Westley et al., 2011; Reeder et al., 2012; Bickler et al., 2013; Reeder-Myers et al., 2015). Utilizing GIS, regional models of site vulnerability can be developed to assess the impact of various threats, including potential impacts from climate change (Westley et al., 2011; Daire et al., 2012; Reeder et al., 2012; Bickler et al. 2013).

Westley et al. (2011) used desk-based modelling to determine sites at risk to sea level rise, coastal erosion, and increased storm surge in three study areas along the coast of Newfoundland. A similar study conducted by Bickler et al. (2013) in New Zealand also took into account landbased threats, particularly landslide risk. These efforts, along with many others, prioritize archaeological sites based on the exposure risk of the site andin cases like Robinson et al. (2010), the vulnerability of a site over time, ranking sites based on how soon they will be impacted.

#### *3.2.1.2 Current site condition*

An assessment of the current condition of a given site is one of the most common factors used to determine which sites should be a priority for heritage managers (Westley et al., 2011; Bickler et al., 2013; Reeder-Myers, 2015).  A site already impacted by coastal erosion would, be at high risk for total loss and therefore have a higher priority for management action. Deciding how to deal with multiple eroding sites can be a challenge for management. A site not currently eroding may have a lower priority than other sites eroding at any rate. While it is not adequate to develop a prioritization method based solely on physical risk, it does identify sites that should be further prioritized. Much of this work is done through field observations. The current condition of a site may be collected by an academic institution, a governing agency, or volunteers. Projects like SCAPE and ALERT ('Archéologie, littoral et Réchauffement Terrestre' translated as 'Archaeology, Coasts, and Global Warming') mobilize the public through volunteer events and mobile apps to determine current condition (SCAPE, 2010; Daire et al., 2012).

The current condition of a site may influence how other values of significance are assessed. If a site is in acceptable condition and its archaeological materials remain in context, then the site could yield more data, which could fulfill the scientific, historical and recreational significance. A site that has already been substantially altered would have less opportunity to provide data to heritage managers, making it potentiallyless significant. To avoid prioritizing sites not currently at risk, it is suggested that a site's current condition be a pre-requisite for determining management priorities.

### 3.2.2 Method 2: Values-based Approach

A second type of method discussed in the literature is the 'values-based approach' which uses different criteria for determining the significance (value) of a site. Here, five values commonly discussed in the literature are presented. While described in no particular order, a structure for evaluating these significance (value) factors is suggested when applied to the specific case of Bonavista Bay.

### *3.2.2.1 Rarity*

Rarity is a factor that determines how uncommon a particular type of site or affiliated culture is in a study area (Moratto and Kelly, 1976; Deeban et al., 1999). Such assessment can be complex, especially if little is known about the site, which is common in archaeology few sites have been fully excavated. It requires an understanding of local, regional, national, and potentially global archaeological resources as a site may be locally, regionally, nationally and/or globally rare (Deeben et al., 1999). A site can be considered rare if it is part of an under-represented culture or site type in the region, and can inform heritage managers of local history and contribute to local knowledge. An example of a site that is both nationally and locally rare is L'Anse aux Meadows, located on the Great Northern Peninsula of Newfoundland, only confirmed Viking site in Canada.

### *3.2.2.2 Public significance*

Public significance is one of the most difficult aspects to quantify when assessing the significance of an archaeological site. It is often understood as how important a site is to local communities (Moratto and Kelly, 1976; Darvill, 1995). In this study, public significance will represent areas or sites that are essential to local communities based on intrinsic, not necessarily monetary, values. Public significance refers not just to local communities, but to all stakeholders. An example of this is the Cabot Tower in St. John's, Newfoundland. Cabot Tower not only represents an historical commemoration of the arrival of John Cabot in Newfoundland, but it is also a community symbol of St. John's, and a place of recreation. Data informing public opinion can be quite difficult to obtain. In many case, communities may not even be aware of the archaeoloigcal sites in their area. It is important a consultative process be taken with communities both near the site and abroad to inform the significance of a site in the public opinion.

#### *3.2.2.3 Recreation and tourism*

This may include the value of the site for entertainment and education, or as a tourist attraction (Darvill, 1995). The importance of a site for recreation can be equally crucial for tourism (Schiffer and House, 1977; Darvill, 1995; Deeben et al., 1999). Tourism may also include the value of the site as an economic driver. This does not only mean income from admission fees, but relates to the resulting economic impact from tourism. For example, while the site of L'Anse aux Meadows has monetary value (i.e., admission revenue), the appeal of the site to visitors also supports local businesses in the area (e.g., restaurants, accommodations). The site may also provide the community with job opportunities, such as tour operators or actors. Site significance should consider not only the role it plays in the historical and scientific record of the area, but also how the site is currently impacting the local community, both positively and negatively.

#### *3.2.2.4 Scientific significance*

Scientific significance of a site is commonly defined as the potential of cultural resources to establish reliable generalizations concerning past societies (Moratto and Kelly, 1976; Darvill, 1995; Deeben et al., 1999). Determining the potential of a site to answer current research questions or fill knowledge gaps is the most challenging aspect when determining scientific significance. This is especially true for archaeological sites with limited data available. Another issue is understanding what data are required to answer a research question (Schiffer and House, 1977). A scientifically significant site does not necessarily need to relate to archaeological research questions and could also inform anthropological, paleoenvironmental, or even technical or methodological questions (Schiffer and House, 1977). The Beaches site in Bonavista Bay may be considered a scientifically significant site due to its continuous occupation from the MAI to the Beothuk, and the significance of the area to sea level and erosion history (Carignan, 1974; 1975).

#### *3.2.2.5 Historical significance*

Historical significance is assessed based on whether the site can be linked to an individual event or another aspect of history (Moratto and Kelly, 1976). To determine historical significance, archaeologists may perform site surveys. If a significant amount of the data returned can be linked to a particular period, event, or person, it can be seen as being historically significant (Groover, 2013). Another method that can be used for evaluating the historical significance of a site does not require the site to be directly linked with an historical event, but rather evoking some memory of the past (Darvill, 1995; Deeben et al., 1999). For instance, the site may be related to myths and legends, or play a role in the perception of the landscape. Deeben et al. (1999) argue that the first definition of historical significance should always warrant preservation. Often historical significance is used to determine priorities for the conservation of built heritage. This may be used with prominent sawmill sites or landscapes in Newfoundland and Labrador. One example is Salton's Brook Site in Terra Nova National Park,which was designated a historically significant site. It can be directly linked with Thomas Turner and Sons, ( local merchants from Happy Adventure), who started the sawmill in the early 1900s (Major, 1983; Curtis, 2007).

## 3.3 Developing a framework for prioritizing archaeological resources for management

To develop an effective framework for heritage managers, each site must be carefully evaluated. Determining sites' significance has proven to be a complex process (Schiffer and Gumerman, 1977; Darvill, 1995; Deeben et al., 1999; Walton, 1999; Samuels, 2008). Part of this is due to the ambiguity when assessing a given site's value. The significance of a site often directly relates to the priorities set by the agency addressing the issue, priorities that can change with political and social influences (Moratto and Kelly, 1978).

Using the criteria discussed in the previous section, it is suggested that sites identified as having a high-risk through an assessment of physical risk (Method 1; current condition and future vulnerability) be further evaluated to determine the overall significance (Fig. 3.1).

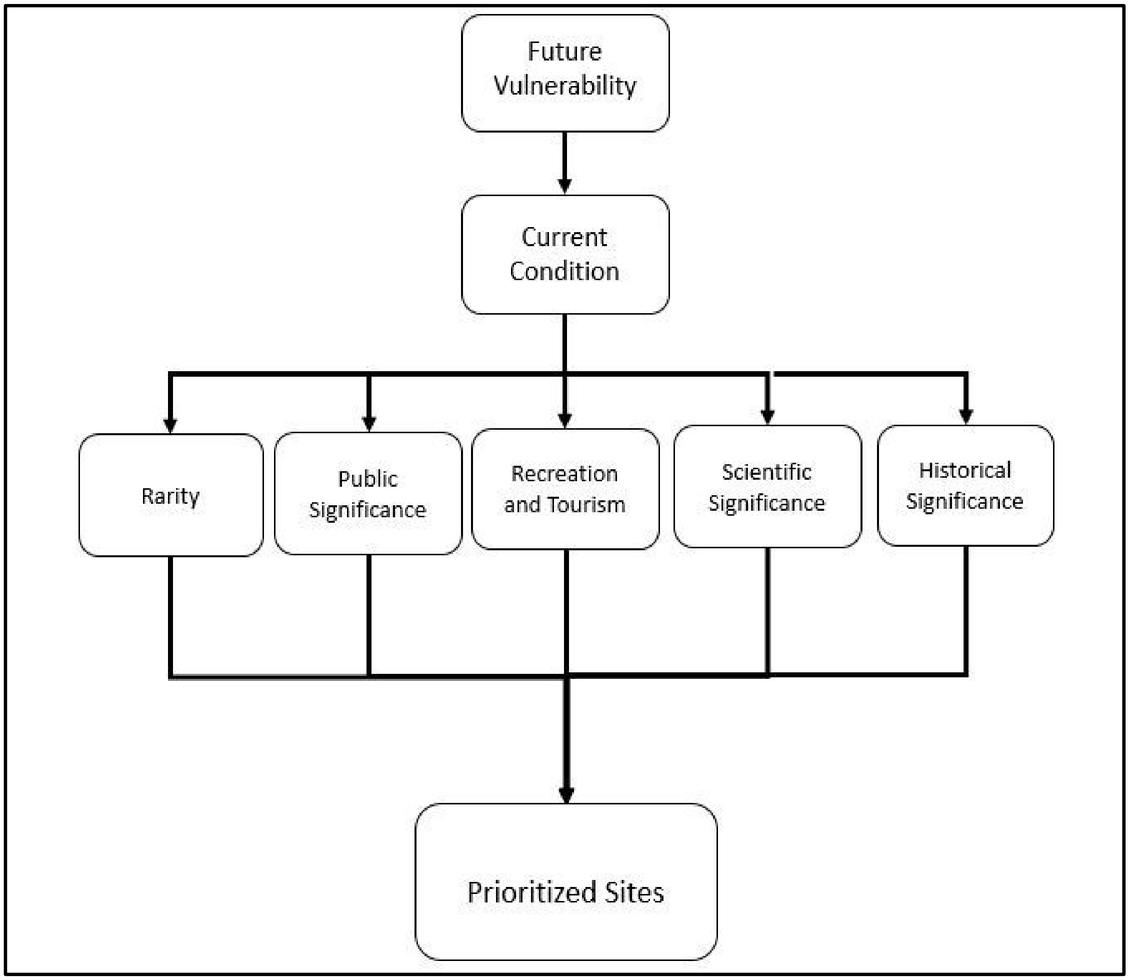


*Figure 3.1*: *Framework for utilizing the values-based approach for prioritizing archaeological resources at risk.*

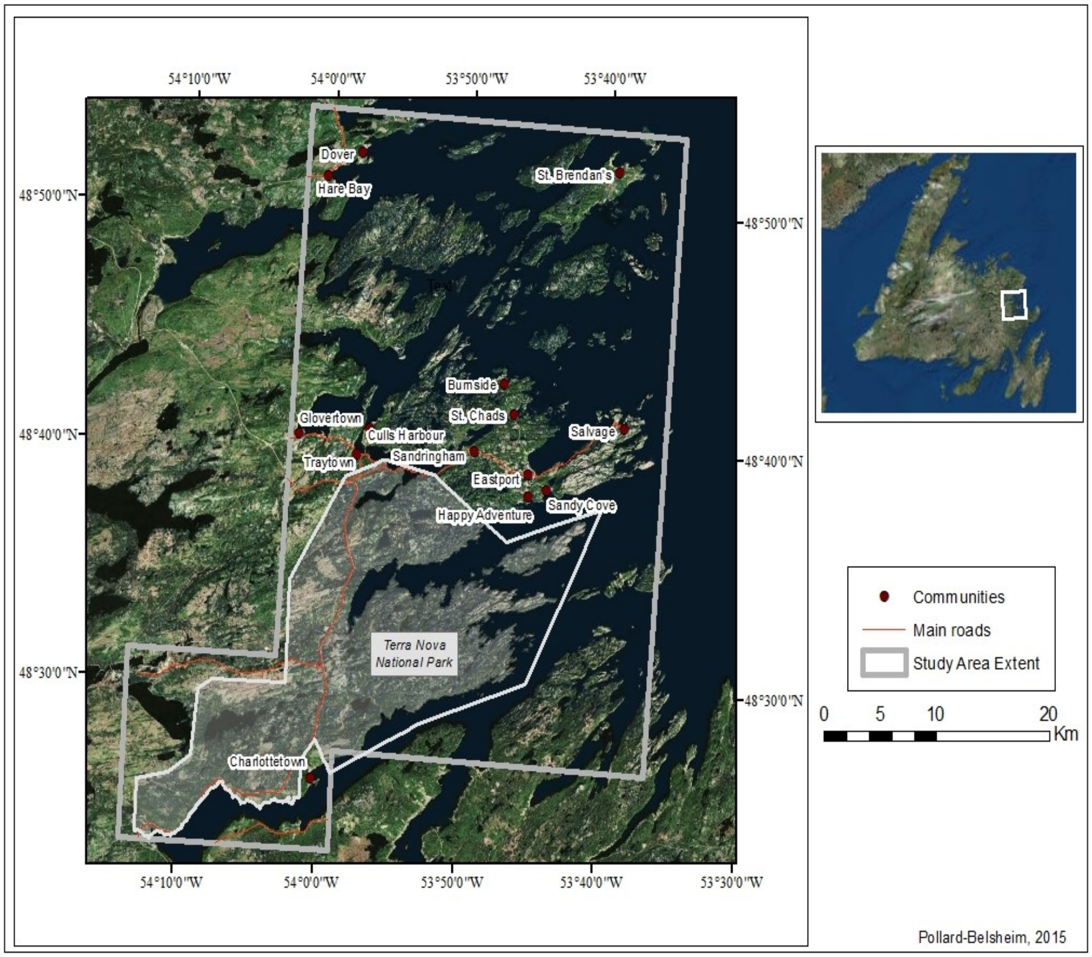
It is difficult to make and defend recommendations for prioritization without an explicit methodology for comparing archaeological values across different sites (Walton, 1999). By first identifying sites vulnerable to sea level rise and then determining which of those sites are actively being impacted, a basis for heritage managers is established. It is proposed that future vulnerability be assessed before current condition, as it provides a methodical assessment. As it is not usually possible to address all vulnerable sites at once, assessing current condition can establish those sites currently impacted. Applying the values-based approach to identify the most significant at-risk site and prioritize management is suggested. In this study, all the significance factors were weighted equally, allowing subsquent adaptation based on the priorities of the local heritage managers.

## 3.4 Case study in Bonavista Bay, Newfoundland

The method for prioritizing archaeological sites at risk described above was applied to archaeological sites in Bonavista Bay, Newfoundland. One of the most common challenges when prioritizing archaeological sites is the variability in available site information. The requirements and types of data recorded in site record forms are continuously being updated by the Provincial Archaeology Office (PAO). Such a range in data quality makes it difficult for heritage managers to efficently compare two sites, especially if the structure of site record forms is different. Sites that have been visited multiple times or have had test excavations done may have more information than a site only visited once decades ago and where only surface finds were recorded. Sites must be evaluated using questions that can be applied to sites with variable amounts of data. To assess the sensitivity of each significance factor to site data, an assessment of archaeological sites within the Bonavista Bay study area was completed. This assessment was carried out to address both the sensitivity of the factors to available site data and the applicability of these factors for effective prioritization.

### 3.4.1 Geography

Bonavista Bay, Newfoundland, is a coastal region dominated by deep inlets and numerous islands (Fig. 3.2; Environment Canada Atlantic Region, 1993). Inlets are characterized by steep bedrock flanks and gravel beaches. Much of the soil is shallow, acidic, and is being eroded by wave action. The vegetation along the coast is typical of the Boreal Forest environment, with coniferous trees and low growing shrubs. Species include spruce, alder, pine, and larch, such as common juniper, crowberry, and heath vegetation (Ryan, 1978).



Pollard-Belsheim, 2015

*Figure 3.2: Bonavista Bay study area, Newfoundland, and Labrador.*

Erosion in Bonavista Bay can be seen along most of the coastline (Fig. 3.3). High winds, a broad fetch, and shallow soils over gravel or bedrock beaches create conditions susceptible to erosive processes. The area was mainly classified as having moderate to high coastal sensitivity to the impacts of sea level rise by Catto (2011). This sensitivity assessment considered sea level change, topographic relief, mean annual maximum wave height, rock/sediment type, landform type, shoreline displacement, and tidal range as influences (Shaw et al., 1998; Catto, 2011). More importantly, the coastal erosion sensitivity of Bonavista Bay varies. Farther inland, the beaches are more protected and have low to moderate sensitivity to coastal erosion, such as Little Content Cove, Beaches Cove, and Matchim Cove. More open coastlines, such as Sandy Cove, St. Brenden's, and Eastport, are more susceptible to coastal erosion (Catto, 2011). Although there are regional assessments of coastal erosion impacts in Bonavista Bay, local effects cannot be generalized through broad-based assessments (Shaw et al., 1998). Local topography, wave dynamics, sediment flux, and even built structures influence the impact of tidal exchange, storm surges, and sea level rise (Catto, 2011).  The low-lying coves, coupled with high bedrock cliffs, provided landscapes suitable for marine subsistence oriented cultures to establish camps.

*Figure 3.3: Photographs of the Bonavista Bay coast: A) Gravel beach with sparse vegetation at the Bank Site; B) Shallow heath vegetation on a bedrock coastline at the Moss Site; C) The view from the quarry site at Bloody Bay Cove*

### 3.4.2 Cultural History

The Maritime Archaic Indian (MAI) were the first cultural group to occupy Newfoundland around 5500 years ago. The majority of MAI sites date between 4600 and 3200 BP (Bell and Renouf, 2004). Sites are typically coastal, with a few sites also identified along major waterways (Bell and Renouf 2004). The MAI occupation on the island seems to have ended approximately 3200 years ago. Evidence suggests the arrival of the Groswater Pre-Inuit culture approximately 2800 years ago in Newfoundland (Rast et al., 2004; Curtis, 2008).

For the purposes of this paper, the traditional Palaeoeskimo has been changed to pre-Inuit (Whitridge, 2016). The Groswater Pre-Inuit culture was also heavily marine focused.

Across the island, Groswater Pre-Inuit seem to have relied far more heavily on seal hunting, with terrestrial animals supplementing their main subsistence. Sites are commonly identified along the coast in areas with expansive views for monitoring the water (Renouf, 2000). The end of the Groswater Pre-Inuit tradition coincided with the arrival of the Dorset Pre-Inuit tradition. The two groups are assumed to have overlapped for a short period before the Groswater Pre-Inuit tradition disappeared from the archaeological record. The arrival of the Dorset Pre-Inuit has been dated to approximately 2000 BP. In Bonavista Bay, they are not identified until 800 years later, around 1200 BP (Renouf, 2000; Curtis, 2008).

In Newfoundland, Dorset Pre-Inuit sites are primarily located along the coast to capitalize on marine animals for subsistence, predominantly harp seal (Major, 1983; Renouf and Bell, 2008). Although both cultures were marine adapted, the Dorset Pre-Inuit's focus on harp seal indicates a specialization in subsistence preferences (Renouf, 1993). Due to this marine focus, Dorset Pre-Inuit sites are typically located on exposed headlands with good viewscapes of the ocean, presumably for seal hunting. Contemporary with the end of the Dorset Pre-Inuit occupation, the Recent Indian phase, which lasted from 2000 BP to 200 BP, began (Erwin et al., 2005, Curtis, 2008; Renouf and Bell, 2008). The Recent Indian occupation is composed of three different traditions: Cow Head, Beaches, and Little Passage (Holly, 2000; Holly, 2013; Erwin et al., 2005). These complexes rely on a mixture of terrestrial and marine subsistence resources (Renouf and Bell, 2008). Unlike the Dorset Pre-Inuit population, Recent Indian sites can be found in a variety of locations both along the coast and inland. This illustrates a more general subsistence strategy utilizing both marine and terrestrial resources. The Beothuk complex is also referred to under the Recent Indian period but is linked to post-contact or the historic period. European encounters and historical documents provide information on the Beothuks (Holly, 2000).

With the colonization of Newfoundland in 1497 AD, these European encounters became more prevalent. The European occupation of Bonavista Bay began in Salvage around 1672 AD, with the English migratory fishery (Major, 1983; Curtis, 2008). Permanent settlement in the area was not established until the end of the 18th and beginning of the 19th.century, fishing stages, sawmills, and scatters of European artifacts mark their presence on the Bonavista Bay landscape, with one of the more dominant site types being the Sawmills found in Terra Nova National Park. The impact of the industry can be seen across the area through deforestation and built dams (Curtis, 2008).

## 3.5 Application of the Values-based approach in Bonavista Bay

Previous studies done in Bonavista Bay provided a basis from which to study the vulnerable sites. The site vulnerability model developed by the Coastal Archaeological Resource Risk Assessment (CARRA) project identified 71% of sites were currently eroding. This was substantiated by the field observations from both the author and local archaeologists.

### 3.5.1 Data Sources

The PAO of Newfoundland and Labrador maintains the records of each archaeological site identified in the province. Each site is documented using a standardized site record form. These forms include information such as site name, location, dates visited, site description, condition, and size (Appendix 1). Since the Historic Resources Act of Newfoundland was applied in 1985, archaeological studies across the island have been monitored by the PAO, with completed site record forms being mandatory. The data collected and archived in the site record forms is the extent of the standardized data available to assess the significance of an archaeological site. One of the major issues is the variability in the recording. This is exacerbated by the dispersion of sites in Newfoundland and Labrador and the difficulties related to accessing sites and re-visiting them at regular intervals. Site reports and grey literature provide further insight and better inform site significance assessments.

Using the 59 sites re-surveyed during the 2014 CARRA field season (Pollard-Belsheim et al., 2014; Belsheim, 2018a), each site record form was evaluated. The cultures and site types identified at each of these archaeological sites were identified (Table 3.1).

*Table 3.1: Re-surveyed Archaeological sites in Bonavista Bay, NL.*

| Site Name | Borden Number | Culture | Site Type |
|---|---|---|---|
| Ashley Baker Island | DcAk-02 | GP; DP | Habitation |
| Babstock | DeAl-23 | PC | Lithic Scatter |
| Bank Site | DdAk-05 | MAI; GP; DP; RI | Habitation |
| Barachois Beach (413A) | DdAl05 | EN | Sawmill |
| Beaches | DeAk-01 | MAI; GP; DP; RI | Habitation |
| Bloody Bay Cove 1 | DeAl-01 | MAI; DP; RI | Habitation & Lithic Scatter |
| Bloody Bay Cove 2 | DeAl-06 | DP; PC; EN | Habitation & Lithic Scatter |
| Bloody Bay Cove 3 | DeAl-05 | PC | Habitation & Lithic Scatter |
| Bloody Bay Cove Overhang | DeAl-18 | PC | Lithic Scatter |
| Bloody Bay Cove Summit | DeAl-09 | PC | Quarry & Lithic Scatter |
| Bloody Bay Point | DeAl-10 | PC | Quarry |
| Bread Cove 1 | DcAl-02 | EN | Sawmill & Habitation |
| Bread Cove 2 | DcAl-03 | PC | Lithic scatter |

| | | | |
|---|---|---|---|
| Broad Cove Harbour | DeAk-04 | PC | Undetermined |
| Brown's Beach | DeAl02 | MAI; DP; RI | Habitation & Lithic Scatter |
| Brown's Meadow | DdAj08 | UP | Undetermined |
| Bruce Cove | DeAl-07 | DP | Habitation |
| Buckley Cove (414A) | DdAl06 | EN | Habitation |
| Butler's Cove | DfAl08 | EN | Undetermined |
| Cary Cove | DeAl-03 | RI | Undetermined |
| Chandler Reach (Minor Drainage) | DcAk-01 | PC | Lithic Scatter |
| Chandler Reach 1 | DdAk-10 | MAI | Lithic Scatter |
| Chandler Reach 2 | DdAk-11 | PC | Lithic Scatter |
| Chandler Reach 3 | DdAk-12 | PC | Lithic Scatter |
| Chandler Reach 4 (412A) | DdAk19 | MAI; RI | Spot Find |
| Chandler Reach Long Islands | DdAj-02 | DP; RI | Habitation |
| Chapple Tickle | DdAj-01 | DP; EN | Undetermined |
| Charlie Site | DeAl-11 | MAI; UP; RI | Quarry & Lithic Scatter |
| Charlottetown Point | DcAm-01 | PC | Lithic Scatter |
| Clode Sound 1 | DdAk-03 | MAI; GP; DP | Multi-Component |
| Clode Sound 2 | DdAk-04 | MAI | Habitation |
| Culls Harbour Narrows | DeAl-19 | PC; RI; EU | Undetermined |
| Daisy | DeAk-13 | PC | Lithic Scatter |
| Dock Cove French Cemetery | DfAj-01 | EU | Graveyard |
| Fox Bar | DeAk-03 | MAI; DP; RI | Habitation |
| Fox Bar Burial Site | DeAk-02 | RI | Graveyard |
| Grassy Pond Sawmill | DcAl-04 | EN | Sawmill |
| Howard | DeAl-12 | UP; RI; PC | Quarry & Lithic Scatter |
| King Site | DdAl04 | EN | Sawmill & Habitation |
| Little Content | DfAl-01 | DP | Undetermined |
| Long Island, Bonavista Bay | DdAj-03 | MAI | Habitation |
| Lou Island Tickle | DeAk-08 | DP | Undetermined |
| Matchim | DdAk-01 | GP; DP; RI; EN | Habitation |
| Minchin Cove | DdAl-02 | EU | Undetermined |
| Moose Pasture | DcAk-03 | MAI; GP; EU | Multi-Component |
| Moose Pasture Sawmill | DcAk-04 | EU | Sawmill |
| Moss | DeAk-12 | RI | Undetermined |
| Platters Picnic Area | DcAl-01 | EU | Habitation |
| Sailor South | DeAj-05 | UP; EU | Undetermined |
| Sailors site | DeAj-01 | MAI; DP; RI; EU | Habitation |
| Saltons Brook | DdAl-01 | EN | Habitation |
| Sandy Cove 1 | DdAk-02 | MAI; DP | Habitation |

| | | | |
|---|---|---|---|
| Squire's site | DeAl-20 | PC; EN | Sawmill & Habitation |
| Stroud's Point Graveyard | DeAm-03 | EN | Graveyard |
| Swale Island | DdAk-08 | UP; RI | Undetermined |
| Terra Nova River | DeAm-02 | UP; EU | Undetermined |
| Unnamed Site | DdAj-04 | MAI; DP | Habitation |
| Wicks' Site | DeAl-21 | PC | Undetermined |
| Wiseman's Cabin | DfAk04 | EN | Habitation |

EN: Euro-Newfoundlander
MAI: Maritime Archaic Indian
GP: Groswater Pre-Inuit
DP: Dorset Pre-Inuit
PC: Pre-contact
UP: Unidentified Pre-Inuit
EU: European
RI: Recent Indian

Out of these 59 sites, 11 had two different cultures identified in the PAO records, nine sites had three cultures, and four sites had four cultures identified. Site types were less variable, with 14 sites having multiple types and the remaining 45 having only one site type recorded. The majority (40%) of these sites were habitation sites. Sites were marked as being either excavated or not excavated based on the site record forms. Sites were dominantly unexcavated (40 sites out of 59; 68%), with only 19 (32%) having excavations noted in the site forms. The sites in Bonavista Bay used in this case study are a sample of the archaeological landscape of the area. These data were used in the application of significance factors to determine high priority sites for heritage managers to focus on.

### 3.5.2 Methodology

Using Bonavista Bay Newfoundland as a case study, five of the seven significance factors taken from the previous literature were used to evaluate site priority. The two factors not utilized were the historical significance and the recreation and tourism significance, due to the lack of available data. These five factors were applied to the 59 sites surveyed as a part of the Coastal Archaeological Resource Risk Assessment project (CARRA) project in the summer of 2014.

To establish future vulnerability, the desk-based site vulnerability model, developed by CARRA was used. The model indicated which sites were at risk from the impacts of sea level rise and increased storm surges (Pollard-Belsheim, 2014). Using site location, digital elevation models, and projected sea level rise estimates, sites anticipated to be inundated by 2025 due to sea level rise and storm surge were identified in Bonavista Bay, Newfoundland. Additionally, these 59 sites were also re-surveyed, and the current condition recorded as part of field work associated with the CARRA project. The current condition was classified as evidence of erosion using a binary value (i.e., yes or no).

Public Significance was, due to data limitations, determined using areas of significance rather than individual sites of significance. The two constraints used to define areas of significance were the boundary of Terra Nova National Park, and the sites monitored by the Burnside Heritage Foundation. All sites within the boundaries of these areas were considered publicly significant.

Assessing the rarity of an archaeological site is a complex process. For the case study in Bonavista Bay, site types that were part of a category with less than 50 representative sites across the island were classified as an underrepresented site type. These site types included those classified as multi-component, workstation, sawmill, quarry, hunting, lithic workshop, and lithic or surface scatter. Another aspect of rarity for this study was the evaluation of rare or under-identified cultures on the island. In this case, when less than 150 sites of a particular culture were identified throughout Newfoundland, the culture was considered rare. Rare cultures,  include the Recent Indian, Beothuk, Early Pre-Inuit, and Pre-Inuit, as well as the ‘undetermined’ type. These values were determined using the natural breaks method. Cultures or site types are based on what options or terms were recorded in the site record forms maintained by the PAO. This does not necessarily represent the appropriate cultural term. Recent Indian could be Cow Head, Beaches, or Little Passage, but these cultures are not always identified in the PAO forms.

To assess scientific significance, three criteria were established. The first one helped determine whether the site had been previously excavated or not, based on site record forms. This assumed that if a site had not been excavated, it held potential to further add to knowledge gaps in the archaeological history of the area, whereas sites that had already been excavated had already contributed to the larger body of knowledge and may not have the same potential to contribute further to it.

The next two criteria were similar. The first one helped establish if a site had multiple cultural affiliations identified. The more cultures identified at a site, the higher potential the site has for filling knowledge gaps. The second criteria indicated if multiple site types were identified at the site, highlighting the potential of the site to inform on significance. The assessment of the scientific significance of a site is multi-faceted. Based on the data available in the site record forms provided by the PAO, sites in Bonavista Bay were determined to be scientifically significant through the assessment of three factors. The first factor assesses if a site has multiple cultures associated with it. More cultures identified are presumed to lead to more data, possibly filling gaps in the literature. The second factor assesses if the site has multiple types associated with it. The final factor was to determine whether the site had already been excavated or if there is potential for excavations to reveal new data. Assessing sites based on these three questions allows for the determination of how scientifically significant a site is.

The final framework was made up of the five values, and eight questions (Fig 3.2).

| Future Vulnerability | Current Condition | Public Significance | Rarity | Scientific Significance |
|---|---|---|---|---|
| **1.** Is the site indicated to be at risk from sea level rise by 2025 according to the CARRA site vulnerability model? | **1.** Is the site currently eroding as indicated in the CARRA 2014 field work ? | **1.** Is the site located in an area of public significance? | **1.** Does the site represent an under-represented culture in Bonavista Bay? | **1.** Has the site been excavated or not? |
| | | | **2.** Does the site represent an under-represented site type in Bonavista Bay? | **2.** Does the site have multiple cultures associated with it? |
| | | | | **3.** Does the site have multiple site types associated with it? |

*Figure 3.4: Proposed values-based approach to determine site significance in Bonavista Bay.*

### 3.5.3 Results

Archaeological sites in Bonavista Bay were prioritized by first assessing the physical risk faced (i.e., existing and predicted) and further prioritized based on the assessed significance based on three different values (Appendix 4). Of the 59 sites re-surveyed in Bonavista Bay, 48 (81%) are thought to be vulnerable to the impacts of sea level rise by

2025. Of these 48 highly vulnerable sites, 40 are currently eroding, as indicated from field observations. Those 40 sites were then further prioritized based on significance.

Out of the 40 sites, 21 sites (53%) were identified as being rare in the study area. Fourteen sites (35%) were identified as belonging to one of the under-represented cultures, and 19 (48%) were identified as one of the under-represented site types. Four (10%) sites were considered rare when assessed using both under-represented culture and under-represented site type. Thirty (75%) of the sites fufilledone or both of the factors of rarity used in this case study.

When assessing the public significance, 33 (83%) sites were identified as being significant. The determination of scientifically significant sites indicated that a total of 10 (25%) sites have multiple site types, 15 (38%) have multiple cultures identified, and 30 (75%) sites have not yet been excavated. Only 2 (3%) sites meet all three factors used for assessing scientific significance, whereas 13 (33%) sites meet two of the three factors. In Bonavista Bay, all 40 sites (100%) met at least one of the three factors.

The application of a values-based approach to archaeological resources in Bonavista Bay did not result in the identification of one single high priority site (Fig. 3.4).

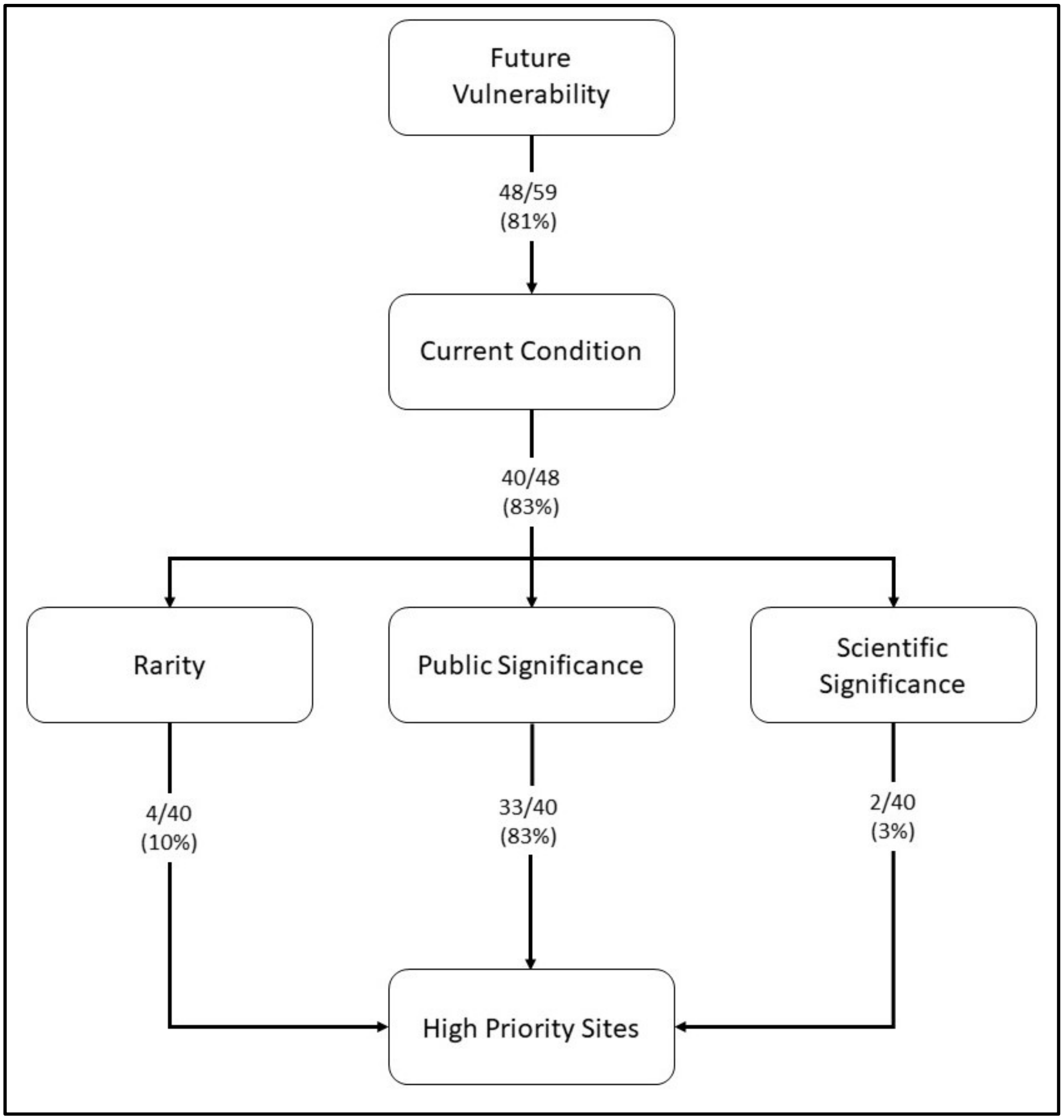


*Figure 3.5: Results of applying the values-based approach on the archaeological sites in Bonavista Bay, Newfoundland.*

In an attempt to isolate a high priority site, the framework was adjusted slightly. Instead of weighting the three values equally, each significance value was weighted by how many questions were asked of the data. This means that future vulnerability, current condition, and public significance were weighted as one each, rarity was weighted as two, and scientific significance as three.  This method identified four high priority sites, having fulfilled 7/8 criteria in the values-based approach (Fig 3.4). This apporach illustratedthe flexibility of the framework in allowing adjustmentbased on local priorities.

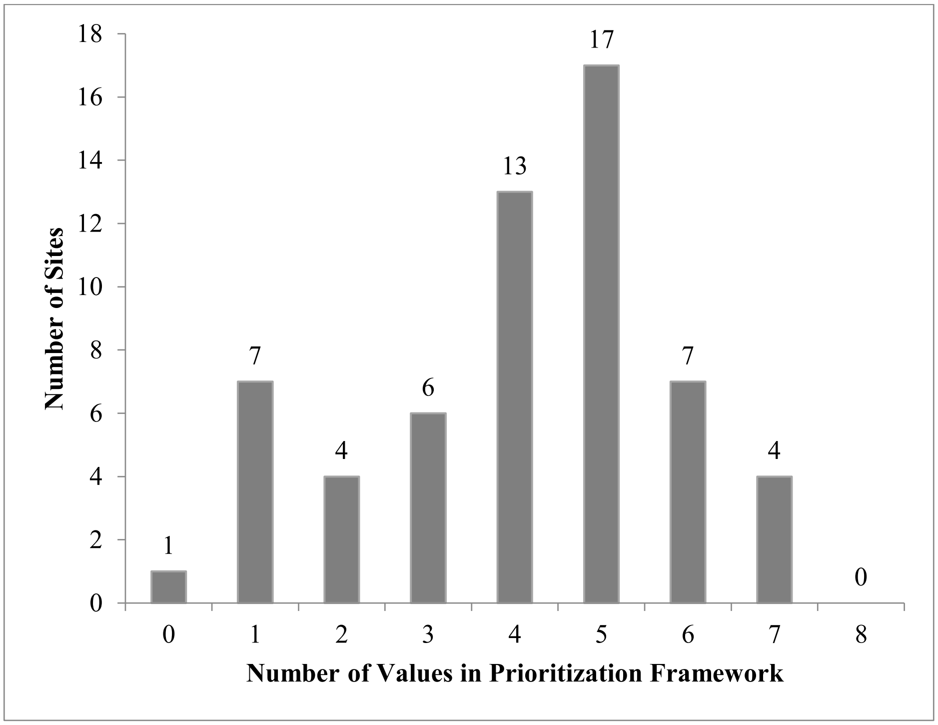


*Figure 3.6: Chart illustrating results of the equal-weighting application of the framework proposed. Notice that four sites were fulfilled 7 of 8 values.*

## 3.6 Discussion

Applying the values-based approach can be difficult when the data available are limited. Assessing the factors most relevant to a study area is an important requirement of this approach, which should be done by professionals who understand the landscape and cultural history of the area. Understanding the sensitivity of each factor can aid heritage managers to determine high priority sites. Ultimately, the evaluation of future vulnerability, current condition, and significance factors can assist heritage managers in the determination of site management priorities.

### 3.6.1 Sensitivity Analysis of Significance Factors in Bonavista Bay, Newfoundland

In this analysis, a significance factor can be considered useful if it helps heritage managers define a manageable list of high priority sites. Assessing future vulnerability of a site is an important component of prioritization. Although this does not necessarily help heritage managers narrow the list of sites in need of protection, it helps inform on local vulnerability. This is evident in the results of the CARRA vulnerability assessment. Of the 59 sites re-surveyed, only 11 were not considered to be at risk from sea level rise by 2025. By addressing current conditions, a refined list of high priority sites was created, including 40 sites. Prioritizing sites based on physical risks alone (Method 1) may help heritage managers develop an initial list of high priority sites. In some cases, this list may create a reasonable base for heritage managers depending on their area of concern and concentration of archaeological resources. In situations where further refinement of a high priority list is required, it is suggested that the values-based approach is utilized.

Rarity proved to be a useful factor for prioritizing sites in the case of Bonavista Bay, reducing the number of sites from 40 to 4, when both factors were considered. When only one of the two values for assessing the rarity of a site was required to identify a site as rare, the number went up to 30 (75%) sites. Although this does not reduce the number of sites for prioritization below 50%, it does provide heritage managers the opportunity to begin assessing sites based on how rare they are on a local to provincial scale. More focused questions could be asked if the data available can answer the same question for all sites under assessment.

Public significance may also be a helpful factor when prioritizing archaeological resources. However, it requires a more in-depth understanding of each site and discussions with local community members. In the case of Bonavista Bay, the evaluation of public significance on archaeological sites was difficult due to data limitations. Since public significance was defined as broad areas rather than individual sites, it was not very useful at reducing high priority sites, only bringing the number of sites from 40 to 33. These areas of Bonavista Bay included Terra Nova National Park, for which the assumed significance was based on the fact it is a national park, and the Burnside Heritage Foundation study area, since a local community group has shown interest in fundraising for the protection and promotion of the sites in that area. Whether each site within these two areas had the same significance within local communities was not determined. Heritage managers need to be able to be involved with the local communities actively and receive feedback from stakeholders on what sites and what areas are publicly significant and why. This result indicates that public significance is highly sensitive to the types of data used to determine if a site is significant or not.

Like rarity, scientific significance was also useful when two or more questions were used to identify the site as being significant or not. Out of the 40 sites located in the study area that are at risk and eroding, only two were determined to be scientifically significant. To establish these two sites as scientifically significant, all three questions were fulfilled: multi-site type, multi-cultural, and not excavated. Based on the current questions asked of the data for scientific significance, assessing archaeological sites based on only one question was not shown to be useful. In this case, the questions asked to determine scientific significance may not be defined enough to reduce the number of sites to help heritage managers organize resources and protection efficiently.

Although this study did not use all suggested factors due to data availability, heritage managers can and should evaluate the most effective factors in their specific context, based on the type of archaeological resource they are working with, the data available, and their management capacity. Factors were ordered in a specific manner in this study in order to help prioritize sites. This provided an example of how such an approach can be used, but the same method could be applied using different factors arranged differently in the prioritization process, depending on the specific context of the study.

### 3.6.2 Methods for developing an individualized framework

In areas presenting a risk, future vulnerability and current vulnerability to various threats are two obvious factors to apply that can reduce the number of sites heritage managers need to focus on. Although these factors can be applied as yes/no questions, there can also be variability in the interpretation of the result. A site that is just starting to erode may be less at risk from complete destruction than a site that has already been identified as primarily eroded.

Desk-based assessments, such as the ones developed within the CARRA project, can help heritage managers assess the vulnerability of remote sites. Sound knowledge, in combination with site monitoring, provides insight into the priority assigned to a given site. The interpretive factors - rarity, public significance, and scientific significance are more challenging to utilize when determining site significance.

The effectiveness of the significance factors for identifying high priority sites for heritage managers depends on what data is available. When sites in Bonavista Bay were evaluated using factor of equal importance, no sites were identified as being of high priority for heritage managers. One issue with equally weighting each significance factor relates to how each factor is established. It is difficult to evaluate public significance and scientific signifcance as equal when sites are classified as publically significant based on one criteria and scientific significant on multiple criteria. Therefore, it is suggested that the questions used to ascertain significance are determined by regional experts create significance factors and weighted by the governing agency.

### 3.6.3 Framework within the Literature

The framework proposed in this study is by no means comprehensive for all heritage managers. It is recommended that the premise of this framework be adapted based on local cultural resources, data, and priorities. The purpose of this research was to assess current literature regarding archaeological site prioritization and develop a framework that could be applied to archaeological sites at risk. Current literature discusses all the factors of significance proposed in this framework but does not indicate how they may be utilized given data limitations. The questions developed to inform on rarity and scientific significance demonstrate a method in which to answer these questions of significance in a strategic manner and provide the opportunity to apply this framework on at-risk archaeological sites.

## 3.7 Conclusion

Coastal archaeological sites are facing diverse threats (Erlandson, 2008; Brimblecombe et al., 2006; Erlandson, 2012; Dawson, 2013), prompting management actions to help preserve cultural heritage around the world. Developing tools to assist heritage managers is important. In this study, we looked at methods for utilizing current literature on archaeological site management to propose a framework for prioritizing archaeological sites at risk. The application of the values-based approach, currently identified in the literature, had both positive and negative implications. Although we were able to deduce a small subset of high priority sites, each value had to be weighted differently. The sensitivity of these values had a compound effect on site prioritization.

Future vulnerability and current condition are two values which efficiently help to reduce the number of sites in need of prioritization. Sites that are not anticipated to be (or are not currently being) impacted are immediately removed from the list of sites heritage managers must address. The remaining factors are rarity, public significance, recreation and tourism, scientific significance, and historical significance. They can all be used to help develop a list of top priority sites. Each factor should be evaluated in the same way across all sites, and requires similar available data at each site. In addition, it is essential that heritage managers address the importance of each factor in their management plan. The sensitivity of each factor used in Bonavista Bay was variable and highly data dependent. However, the application of these factors did provide some insight into the significance of sites and possible strategies for prioritization for heritage managers.

The present study does not attempt to suggest a standardized framework for assessing significance; rather it aims to illustrate a potential framework. This framework can provide structure and flexibility for heritage managers facing tough decisions in response to climate change.

Future work should be done to incorporate stakeholder opinions for public significance and provide heritage managers a methodology for engaging and interpreting the results. Methods for determining the recreational and tourism value of a site must also be addressed. As mentioned, this value, along with the historical value of the site were not taken into account in this paper due to data and time limitations. Heritage managers are also under the same constraints. Developing strategies to assess these values quickly and efficiently is important. Time is key. While we spend time assessing the significance of an archaeological resource, sites are actively being lost to coastal erosion and sea level rise.  We must act quickly and efficiently.

While the law may state that all sites are to be protected equally, this is not a feasible management plan. Globally, coastal sites are actively under threat from the impacts of climate change. This process will be exacerbated by sea level rise. Understanding how site significance can work as a management tool and highlighting the strengths and weaknesses allows for heritage managers to make informed decisions. Ultimately, it is these decisions that will allow for the protection of at least a portion of our cultural resources.

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# Chapter 4: Conclusion

## 4.1 Summary

As climate change continues to exacerbate coastal threats, archaeological resources are increasingly at risk. Increasing storm frequency and severity, coupled with rising sea levels, is expected to increasingly impact the integrity of coastal archaeological resources (Sabbioni et al., 2008; Blankholm, 2009; Erlandson, 2012; Fitzpatrick, 2012). The development of strategic plans for heritage managers to effectively assess risks at archaeological sites is essential. This thesis addressed two steps that act as a foundation for a strategic management plan.

The first step was to propose an approach for identifying archaeological sites at risk to the impacts of sea level rise and storm surge. Building from Westley et al. (2011) initial site vulnerability assessment done in Newfoundland, Chapter 2 identified archaeological sites at risk to sea level rise. The results of this vulnerability assessment were evaluated to determine the impact of data resolution on the identification of sites at risk. Identifying the data required to perform an accurate and precise desk-based assessment of coastal archaeological sites at risk and highlighting the importance of site location and appropriate digital elevation model resolution. The second step was to prioritize the at-risk archaeological resources for management (Moratto, 2016). Chapter 3 assessed current literature on archaeological site prioritization and identified key values used to determine site significance (Moratto and Kelly, 1978; Darvill, 1995; Deeben et al., 1999;

Walton, 2002). Understanding how factors of significance can be utilized for prioritizing management and the impact data availability has on determining significance can help to inform heritage managers.

This thesis aimed at meeting three objectives. The first was to determine the impact data resolution has on a desk-based site vulnerability assessment. The second objective was to identify which sites in Bonavista Bay, Newfoundland, are at risk from the impact of sea level rise and increased storm surge by the years 2025, 2050, and 2100. Finally, the third objective was to identify current practices in archaeological site prioritization for management purposes and apply them to high-risk sites in Bonavista Bay. The first two objectives and the way they were reached are summarized in Section 4.2.1. The final objective and how it was reached is summarized in Section 4.2.2.

### 4.1.1 Desk-based vulnerability assessments for heritage management

Coastal site vulnerability models can be helpful for assessing sites that otherwise would not be monitored. Data quality plays a key role in this process. Data of higher spatial resolution, such as LiDAR, helps increase the accuracy of the model for assessing potential impacts of sea level rise along topographically variable coastlines. The value of detailed and accurate site location and boundaries, cannot be overstated. The CARRA site vulnerability model initially identified almost 50% of sites as low risk (using the PAO site location). Evaluating the potential risk faced by a site is entirely dependent on knowing with some accuracy where the site is located. Desk-based vulnerability assessments can be an effective method for monitoring sites when physical access to those sites is challenging. Further research into the data requirements for identifying the impact of the slope, substrate, vegetation, ice push and aeolian erosion on at-risk archaeological resources must be done. The initial model discussed in this paper provides a base from which to start. Identifying the impact of sea level rise is only one part of the puzzle.

Although models that help identify sites at risk to multiple factors exist, such as Westley et al. (2011), more detailed research on data resolution requirements is needed. In this study, LiDAR was the most appropriate digital elevation dataset for identifying the impact of sea level rise to coastal archaeological resources. All of the sites identified as eroding due to coastal processes in the field were also identified as high risk using the LiDAR terrain data. Using such high-resolution data is particularly important in coastal areas with a stark topographic variation such as in Newfoundland.

The role of fetch, shoreline dynamics, and bathymetry may further influence rates of coastal retreat and height of storm surges and therefore should be considered for a more holistic view of site risk. The purpose of this thesis was to identify the level of resolution required to produce an accurate site vulnerability assessment. Striving to provide holistic assessments of risk is important for heritage managers but should not be limited by data acquisition. Preliminary assessments of sea level risk are effective for identifying an initial list of at-risk archaeological resources.

### 4.1.2 Prioritization of at-risk archaeological resources using significance

Prioritizing at-risk archaeological resources based on significance is one method for heritage managers. Identifying sites at risk is the first step. The identification of current condition and future vulnerability provide heritage managers with the first insight into sites in need of management. Following this, the evaluation of scientific, historic, recreational, and public significance, as well as rarity of a site, can help narrow the list of sites for management down to a few highly significant sites. These factors, although not an exhaustive list, are representative of the main aspects of evaluation for determining the significance of an archaeological site (Morratto and Kelly, 1976;1978; Walton, 2002).

As discussed in chapter 3, applying these values to evaluate site significance can be difficult. Making sure each site has appropriate data available for the thorough evaluation of significance is important. The development of a method for determining significance across a region must be compiled by individual heritage management groups based on local priorities and data availability. Then these assessments must be applied. Methods for dealing with data availability and quality issues should be worked through quickly. Each moment that decisions are not being made, sites at risk are being eroded, and valuable information is being lost.

### 4.3 Heritage managers and climate change

Further work must be done to develop and improve strategies for heritage managers dealing with coastal archaeological resources at risk. In the face of climate change heritage managers have a tremendous task in front of them. Coastal archaeological resources are being lost to the sea. Moratto (2016) said it well: “To destroy an archaeological site is to erase the manuscript” (p. 215). We must work as a global community to develop strategies for facing the impact of climate change on our archaeological heritage.

## 4.4 References

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# Appendix 1: Newfoundland and Labrador Archaeological Site Record Form

## NEWFOUNDLAND AND LABRADOR ARCHAEOLOGICAL SITE RECORD FORM

*According to Newfoundland Regulation 143/91 "Archaeological Investigation Permit Regulations under The Historic Resources Act (O.C. 574-91) Section 11. (2)(a) an archaeologist is to submit within* ***30 days after expiration of Research Permit*** *completed Newfoundland and Labrador Archaeological Site Record Forms for all newly discovered sites and for all revisits to known sites*

**USE YOUR MOUSE TO MOVE BETWEEN FIELDS**

*Incomplete and/or incorrectly completed forms will be returned to the Permit Holder*

Permit Number ____________ Permit Holder ____________
Last name, First name

Site Name ____________

Borden Number ____________ Ethnographic Number ____________

Previous Recording Errors ____________

Location

Access ____________

Jurisdiction Provincial Federal Nunatsiavut Private Land Nearest Large Community ____________
Underline one

Major Drainage ____________ Minor Drainage ____________

Map Reference NTS ____________ UTM Military Grid ____________

Latitude ____________ Longitude ____________

Easting ____________ Northing ____________

GPS? Yes No GPS Margin of Error ____________ Elevation ______ Datum NAD1927 NAD1983 WGS 84
Underline one Underline one

Air Photo Reference ____________ Other Map References ____________

Site Description ____________
Not a description of the physical geography of the area. Discuss what evidence indicates an archaeological site is present.

Culture (s) ____________

Phase/Complex ____________

Site Type ____________ Features ____________
Specific site type should be listed for each Culture if the site is multi-cultural. Specific features should be listed for each Culture if the site is multi-cultural.

Period Dates ____________

Lab Dates ____________ Site Size ____________

Condition Assessment
Destroyed = no physical evidence of site remains
Fair = significant disturbance, some remains in-situ
Good = majority of site intact
Excellent = site is pristine, no disturbance
Undetermined = site condition not confirmed
Applies to areas of site not excavated- underline one

Additional Details ____________

Disturbance Assessment
Looting
Gardening
Construction
Trails (e.g. hiking, ATVs paths)
Tree Falls
Rising Sea Level
Flooded
Windblown
Coastal Erosion
Underline all that apply

Other (Please specify) ____________

Risk Assessment Yes No Details (If Yes) ________________________________

Underline one

Vegetation ________________________________

Informant Name and Address ________________________________

Last name, First name

Principal Researcher (s) ________________________________

Last name, First name

Research Date(s) ________________________________

MMDDYYYY numerics only

Archaeological Activity
Conducted Under
Current Permit

Excavation: ___m X ___m = ____m2
Testing: number of test pits ____; size of test pits ___ cm X ___ cm
Trenching: size of area trenched ___m X ___m = ____m2
Surface Collection: size of area surface collected ___m X ___m = ____m2
Non-excavation Recording Activities (site mapping, photography, etc)
Other (Please specify)
________________________________

Complete or underline all that apply

Collection ________________________________

Be as specific as possible, quantity & type

Collection Repository ________________________________

Photo Records ________________________________

Published References ________________________________

Unpublished References ________________________________

Remarks ________________________________

Site Record Form Completed By ____________________ Date ____________

Last name, First name

MMDDYYYY numerics only

MAP OF SITE LOCATION

# Appendix 2: Coastal Archaeological Resource Risk Assessment Site Record Form

CARRA Project
Memorial University of Newfoundland
Email: Carra@mun.ca

CARRA Site Summary
Observer: Ariel Pollard-Belsheim
Date Observed:

**Site Name:**

**Borden Number:**

Photo 1

Direction ↑

Photo 2

Direction ↑

**PAO Site location:**
(Based on 2014 Site Record Forms)

**Re-surveyed location:**
(Surveyed using dGPS, ±30 cm horizontal)

**UTM:** Zone 22

**Distance offset between 2014 PAO site location and geographical center of re-surveyed site boundaries**

**Towards or Away from Coastline?**
(Did the re-surveyed site location move closer or farther away from coastline)

**Re-surveyed distance from site centre to coast:**

**Area:**

**Resurveyed elevation:**
(CVGD28; Surveyed using dGPS, ±15 cm vertical)

**Vegetation:**

**Bedrock:**
(from O'Brian 1992b, 1:50,000 Bedrock Geology map)

**Surficial Geology:**

**Erosion**:

**Level of risk to sea level rise innundation by 2025 (RCP 8.5):**
(as modeled by CARRA (Pollard-Belsheim 2015), using sea level rise projections provided by James et al. 2014)

**Site location data collected during 2014 field season:**

| Photographs | Sketches | Vegetation Line | Seaweed Line | Driftwood line |
|---|---|---|---|---|
| | | | | |

**Map:** (with view point indicators for photos above)

# Appendix 3: Site Vulnerability Results

| | | Provincial Archaeology Office (PAO) Data | | | |
|---|---|---|---|---|---|
| Site Name | Borden Number | CDED RCP 4.5 | CDED RCP 8.5 | LiDAR RCP 4.5 | LiDAR RCP 8.5 |
| Ashley Baker Island | DcAk-02 | High | High | High | High |
| Babstock | DeAl-23 | Low | Low | Low | Low |
| Bank Site | DdAk-05 | High | High | Low | Low |
| Barachois Beach (413A) | DdAl-05 | High | High | High | High |
| Beaches | DeAk-01 | Low | Low | Low | Low |
| Bloody Bay Cove 1 | DeAl-01 | Low | Low | High | High |
| Bloody Bay Cove 2 | DeAl-06 | Low | Low | High | High |
| Bloody Bay Cove 3 | DeAl-05 | High | High | High | High |
| Bloody Bay Cove Summit | DeAl-09 | Low | Low | Low | Low |
| Bloody Bay Cove Overhang | DeAl-18 | Low | Low | Low | Low |
| Bloody Bay Point | DeAl-10 | Low | Low | High | High |
| Bread Cove 1 | DcAl-02 | High | High | High | High |
| Bread Cove 2 | DcAl-03 | Low | Low | Low | Low |
| Broad Cove | DeAk-04 | Moderate | Moderate | Moderate | Moderate |
| Brown's Beach | DeAl-02 | Low | Low | High | High |
| Brown's Meadow | DdAj-08 | Low | Low | Low | Low |
| Bruce Cove | DeAl-07 | High | High | High | High |
| Buckley Cove (414A) | DdAl-06 | High | High | Low | Moderate |
| Butler's Cove | DfAl-08 | High | High | High | High |
| Cary Cove | DeAl-03 | Low | Low | Low | Low |
| Chandler Reach 1 | DdAk-10 | High | High | High | High |
| Chandler Reach 2 | DdAk-11 | High | High | High | High |

| | | | | | |
|---|---|---|---|---|---|
| Chandler Reach 3 | DdAK-12 | High | High | High | High |
| Chandler Reach 4 (412A) | DdAk-19 | High | High | High | High |
| Chandler Reach (minor drainage) | DcAk-01 | High | High | High | High |
| Chandler Reach Long Islands | DdAj-02 | High | High | High | High |
| Chapple Tickle | DdAj-01 | Moderate | Moderate | High | High |
| Charlie Site | DeAl-11 | Low | Low | Low | Low |
| Charlottetown Point | DcAm-01 | High | High | High | High |
| Clode Sound 1 (Zodiac) | DdAk-03 | High | High | Moderate | Moderate |
| Clode Sound 2 (Celt) | DdAk-04 | High | High | High | High |
| Culls Harbour Narrows | DeAl-19 | Low | Low | High | High |
| Daisy Site | DeAk-13 | High | High | High | High |
| Dock Cove French Cemetery | DfAj-01 | High | High | High | High |
| Fox Bar | DeAk-02 | High | High | Low | Moderate |
| Fox Bar Burial | DeAk-03 | High | High | Moderate | Moderate |
| Grassy Pond Sawmill | DcAl-04 | Moderate | Moderate | Low | Low |
| Howard | DeAl-12 | Low | Low | Low | Low |
| King Site | DdAl-04 | Low | Low | Low | Low |
| Little Content | DfAl-01 | High | High | Low | Moderate |
| Long Island, Bonavista Bay | DdAj-03 | High | High | High | High |
| Lou Island Tickle | DeAk-08 | Low | Low | Low | Low |
| Matchim | DdAk-01 | Low | Low | Low | Low |
| Minchin Cove | DdAl-02 | Low | Low | Low | Low |
| Moose Pasture | DcAk-03 | High | High | Moderate | Moderate |
| Moose Pasture Sawmill | DcAk-04 | High | High | Low | Low |
| Moss | DeAk-12 | Low | Low | Low | Moderate |
| Platters Picnic area | DcAl-01 | High | High | Low | Low |
| Sailor Site | DeAj-01 | High | High | Low | Low |

| | | | | | |
|---|---|---|---|---|---|
| Sailor South | DeAj-05 | Moderate | Moderate | Moderate | Moderate |
| Saltons Brook | DdAl-01 | High | High | High | High |
| Sandy Cove | DdAk-02 | Low | Low | Low | Low |
| Squire's site | DeAl-20 | Low | Low | High | High |
| Stroud's Point Graveyard | DeAm-03 | High | High | High | High |
| Swale Island | DdAk-08 | High | High | Low | Low |
| Terra Nova River | DeAm-02 | Moderate | Moderate | Moderate | Moderate |
| Unnamed Site | DdAj-04 | High | High | High | High |
| Wicks' Site | DeAl-21 | High | High | High | High |
| Wiseman's cabin | DfAk-04 | Low | Low | High | High |

|  |  | Re-Surveyed CARRA Site Data |  |  |  |
|---|---|---|---|---|---|
|  |  | CDED | CDED | LiDAR | LiDAR |
| Site Name | Borden Number | RCP 4.5 | RCP 8.5 | RCP 4.5 | RCP 8.5 |
| Ashley Baker Island | DcAk-02 | High | High | High | High |
| Babstock | DeAl-23 | Low | Low | Low | Low |
| Bank Site | DdAk-05 | High | High | High | High |
| Barachois Beach (413A) | DdAl-05 | High | High | High | High |
| Beaches | DeAk-01 | High | High | High | High |
| Bloody Bay Cove 1 | DeAl-01 | Low | Low | High | High |
| Bloody Bay Cove 2 | DeAl-06 | Low | Low | High | High |
| Bloody Bay Cove 3 | DeAl-05 | Low | Low | High | High |
| Bloody Bay Cove Summit | DeAl-09 | Low | Low | Low | Low |
| Bloody Bay Cove Overhang | DeAl-18 | Low | Low | Low | Low |
| Bloody Bay Point | DeAl-10 | Low | Low | High | High |
| Bread Cove 1 | DcAl-02 | High | High | High | High |
| Bread Cove 2 | DcAl-03 | High | High | High | High |
| Broad Cove | DeAk-04 | High | High | High | High |
| Brown's Beach | DeAl-02 | Low | Low | High | High |
| Brown's Meadow | DdAj-08 | High | High | High | High |
| Bruce Cove | DeAl-07 | High | High | High | High |
| Buckley Cove (414A) | DdAl-06 | High | High | High | High |
| Butler's Cove | DfAl-08 | High | High | High | High |
| Cary Cove | DeAl-03 | High | High | High | High |
| Chandler Reach 1 | DdAk-10 | High | High | High | High |
| Chandler Reach 2 | DdAk-11 | High | High | High | High |
| Chandler Reach 3 | DdAK-12 | High | High | High | High |
| Chandler Reach 4 (412A) | DdAk-19 | High | High | High | High |
| Chandler Reach (minor drainage) | DcAk-01 | High | High | High | High |

| | | | | | |
|---|---|---|---|---|---|
| Chandler Reach Long Islands | DdAj-02 | High | High | High | High |
| Chapple Tickle | DdAj-01 | High | High | High | High |
| Charlie Site | DeAl-11 | Low | Low | Low | Low |
| Charlottetown Point | DcAm-01 | High | High | High | High |
| Clode Sound 1 (Zodiac) | DdAk-03 | High | High | High | High |
| Clode Sound 2 (Celt) | DdAk-04 | High | High | High | High |
| Culls Harbour Narrows | DeAl-19 | High | High | High | High |
| Daisy Site | DeAk-13 | High | High | High | High |
| Dock Cove French Cemetery | DfAj-01 | High | High | High | High |
| Fox Bar | DeAk-02 | Low | Low | High | High |
| Fox Bar Burial | DeAk-03 | Low | Low | High | High |
| Grassy Pond Sawmill | DcAl-04 | High | High | High | High |
| Howard | DeAl-12 | Low | Low | Low | Low |
| King Site | DdAl-04 | High | High | High | High |
| Little Content | DfAl-01 | High | High | High | High |
| Long Island, Bonavista Bay | DdAj-03 | High | High | Low | Low |
| Lou Island Tickle | DeAk-08 | High | High | High | High |
| Matchim | DdAk-01 | Low | Low | Low | Low |
| Minchin Cove | DdAl-02 | High | High | High | High |
| Moose Pasture | DcAk-03 | High | High | High | High |
| Moose Pasture Sawmill | DcAk-04 | High | High | Low | Low |
| Moss | DeAk-12 | High | High | High | High |
| Platters Picnic area | DcAl-01 | High | High | High | High |
| Sailor Site | DeAj-01 | Moderate | Moderate | Moderate | Moderate |
| Sailor South | DeAj-05 | High | High | Moderate | Moderate |
| Saltons Brook | DdAl-01 | High | High | High | High |
| Sandy Cove | DdAk-02 | High | High | Moderate | Moderate |

| | | | | | |
|---|---|---|---|---|---|
| Squire's site | DeAl-20 | High | High | High | High |
| Stroud's Point Graveyard | DeAm-03 | High | High | High | High |
| Swale Island | DdAk-08 | High | High | High | High |
| Terra Nova River | DeAm-02 | High | High | High | High |
| Unnamed Site | DdAj-04 | High | High | High | High |
| Wicks' Site | DeAl-21 | Low | Low | High | High |
| Wiseman's cabin | DfAk-04 | High | High | High | High |

# Appendix 4: Values-based approach: Results in Bonavista Bay, NL

| **Formal Site Name** | **Borden Number** | **Future Vulnerability (2025)** | **Coastal Erosion** | **Public Significance** | **Scientific Significance** | | | **Rarity** | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | *Multiple Site Type* | *Multiple Cultures* | *Not Excavated* | *Under-represented Culture* | *Under-represented Site Type* |
| Ashley Baker Island | DcAk-02 | ✓ | | | | ✓ | | ✓ | |
| Babstock | DeAl-23 | | | | | | | | ✓ |
| Bank Site | DdAk-05 | ✓ | ✓ | ✓ | | ✓ | | ✓ | |
| Barachois Beach | DdAl-05 | ✓ | ✓ | ✓ | | | ✓ | | ✓ |
| Beaches | DeAk-01 | ✓ | ✓ | ✓ | | ✓ | | ✓ | |
| Bloody Bay Cove 1 | DeAl-01 | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ |
| Bloody Bay Cove 2 | DeAl-06 | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ |
| Bloody Bay Cove 3 | DeAl-05 | ✓ | | | ✓ | | | | ✓ |
| Bloody Bay Cove Summit | DeAl-09 | | | | ✓ | ✓ | | ✓ | ✓ |
| Bloody Bay Cove Overhang | DeAl-18 | | | | ✓ | | | | ✓ |
| Bloody Cove Point | DeAl-10 | ✓ | ✓ | ✓ | | | ✓ | | ✓ |
| Bread Cove 1 | DcAl-02 | ✓ | ✓ | ✓ | ✓ | | ✓ | | ✓ |
| Bread Cove 2 | DcAl-03 | ✓ | ✓ | ✓ | | | ✓ | | ✓ |
| Broad Cove | DeAk-04 | ✓ | ✓ | ✓ | | | ✓ | | |
| Brown's Beach | DeAl-02 | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ |
| Brown's Meadow | DdAj-08 | ✓ | ✓ | | | | ✓ | ✓ | |
| Bruce Cove | DeAl-07 | ✓ | ✓ | ✓ | | | ✓ | | |
| Buckley Cove | DdAl-06 | ✓ | ✓ | ✓ | | | ✓ | | |
| Butler's Cove | DfAl-08 | ✓ | | | | | | | |
| Cary Cove | DeAl-03 | ✓ | ✓ | ✓ | | | ✓ | ✓ | |
| Chandler Reach 1 | DdAk-10 | ✓ | ✓ | ✓ | | | ✓ | | ✓ |
| Chandler Reach 2 | DdAk-11 | ✓ | ✓ | ✓ | | | ✓ | | ✓ |
| Chandler Reach 3 | DdAK-12 | ✓ | ✓ | ✓ | | | ✓ | | ✓ |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Chandler Reach 4 | DdAk-19 | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | |
| Chandler Reach Minor Drainage | DcAk-01 | ✓ | ✓ | ✓ | | | ✓ | | ✓ |
| Chandler Reach, Long Island | DdAj-02 | ✓ | ✓ | | | ✓ | ✓ | ✓ | |
| Chapple Tickle | DdAj-01 | ✓ | ✓ | | ✓ | ✓ | ✓ | | |
| Charlie Site | DeAl-11 | | | | ✓ | ✓ | | ✓ | ✓ |
| Charlottetown Point | DcAm-01 | ✓ | ✓ | | | | ✓ | | ✓ |
| Clode Sound 1 | DdAk-03 | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ |
| Clode Sound 2 | DdAk-04 | ✓ | | | | | | | |
| Culls Harbour Narrows | DeAl-19 | ✓ | | | | ✓ | | ✓ | |
| Daisy Site | DeAk-13 | ✓ | ✓ | ✓ | ✓ | | ✓ | | ✓ |
| Dock Cove French Cemetery | DfAj-01 | ✓ | ✓ | | | | ✓ | | |
| Fox Bar | DeAk-02 | ✓ | ✓ | ✓ | | ✓ | | ✓ | |
| Fox Bar Burial | DeAk-03 | ✓ | | | | | | ✓ | |
| Grassy Pond Sawmill | DcAl-04 | ✓ | ✓ | ✓ | | | ✓ | | ✓ |
| Howard | DeAl-12 | | | | ✓ | ✓ | | ✓ | ✓ |
| King Site | DdAl-04 | ✓ | ✓ | ✓ | ✓ | | ✓ | | ✓ |
| Little Content | DfAl-01 | ✓ | ✓ | ✓ | | | ✓ | | |
| Long Island, Bonavista Bay | DdAj-03 | | | | | | | | |
| Lou Island Tickle | DeAk-08 | ✓ | ✓ | ✓ | | | ✓ | | |
| Matchim | DdAk-01 | | | | | ✓ | | ✓ | |
| Minchin Cove | DdAl-02 | ✓ | ✓ | ✓ | | | | | |
| Moose Pasture | DcAk-03 | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ |
| Moose Pasture Sawmill | DcAk-04 | | | | | | | | ✓ |
| Moss | DeAk-12 | ✓ | ✓ | ✓ | | | ✓ | ✓ | |
| Platters Picnic area | DcAl-01 | ✓ | | | | | | | |
| Sailor Site | DeAj-01 | | ✓ | | | ✓ | | ✓ | |
| Sailor Site South | DeAj-05 | | | | | ✓ | | | |
| Saltons Brook | DdAl-01 | ✓ | ✓ | ✓ | ✓ | | | | ✓ |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Sandy Cove | DdAk-02 | | ✓ | | | ✓ | | | |
| Squire's site | DeAl-20 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ |
| Stroud's Point graveyard | DeAm-03 | ✓ | ✓ | ✓ | | | ✓ | | |
| Swale Island | DdAk-08 | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | |
| Terra Nova River | DeAm-02 | ✓ | ✓ | ✓ | | ✓ | | ✓ | |
| Unnamed Site | DdAj-04 | ✓ | ✓ | | | ✓ | ✓ | | |
| Wicks' Site | DeAl-21 | ✓ | ✓ | ✓ | | | ✓ | | |
| Wiseman's cabin | DfAk-04 | ✓ | | | | | | | |