Revealing the Seafloor: Exploring Local Knowledge and Interpretations of Benthic Spaces along the Eastern Shore of Nova Scotia, Canada

By

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Submitted in partial fulfillment of the requirements for the degree
of
Master of Marine Management

at

Dalhousie University
Halifax, Nova Scotia

December 2022

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List of Abbreviations

AOI	Area of Interest
BEcoME	Benthic Ecosystem Mapping and Engagement Project
CPAWS	Canadian Parks & Wilderness Society
DFO	Fisheries and Oceans Canada
GIS	Geographic Information System
MPA	Marine Protected Area
NSNT	Nova Scotia Nature Trust
OFI	Ocean Frontier Institute
PGIS	Participatory Geographic Information Systems
TEK	Traditional Ecological Knowledge
WITAP	Wild Islands Tourism Advancement Partnership
WWF	World Wildlife Fund

Citation

Marty, G. (2022). Revealing the Seafloor: Exploring Local Knowledge and Interpretations of Benthic Spaces along the Eastern Shore of Nova Scotia, Canada. *Unpublished master's project,* Dalhousie University, Nova Scotia, Canada.

Abstract

Marine ecosystems are increasingly affected by climate change, understanding impacts, how they might change, or the role they will play in system adaptation is key to protecting the overall marine environment and broader marine socio-ecological systems. The Eastern Shore of Nova Scotia is known for its recreational activities and fisheries, where local identities and ways of life are closely tied to the ocean. The seafloor provides the foundation for many of these activities and is an important factor in determining how people use various areas. This study explored how local recreational and commercial users of coastal and marine spaces engage with and understand the seafloor, through interviews with different user groups. Maps were used to elicit knowledge, and tie observations of place to use and change. Participants spoke about the seafloor structure, composition, features, and species, which varied depending on their purposes, as well as observed changes to marine and coastal environments. The results of this study can contribute to a richer, holistic understanding of the seafloor, as well as how local users experience change. This knowledge can inform decision-making on the Eastern Shore and demonstrates the value of incorporating different ways of knowing, including localized, place-based, and experiential knowledge into marine management.

Keywords: seafloor, benthic ecosystems, Eastern Shore of Nova Scotia, local knowledge, experiential knowledge, place-based knowledge, recreational use, commercial use, coastal and marine change, holistic management.

Acknowledgements

I would like to acknowledge that we are in Mi'kma'ki, the ancestral and unceded territory of the Mi'kmaq People. Dalhousie University sits on the Traditional Territory of the Mi'kmaq. We are all Treaty people.

I would like to thank the wonderful people who have supported me throughout this project. First, to my supervisors, Dr. Sara Spike, Dr. Patricia Manuel and Dr. Claudio Aporta, thank you for your encouragement, advice and guidance with this research. I really appreciate your support over the last year, as well as the opportunity to work on the BEcoME project. This research is part of Work Package 1.1 (Societal Engagement) of the Benthic Ecosystem Mapping and Engagement Project funded by the Ocean Frontier Institute. To the members of my team, Fes Simmons, and Leah Fulton, thank you for your assistance with GIS, for your writing advice, insights, and friendship.

I would like to acknowledge and thank the participants who shared their time and knowledge to make this study possible.

Thank you to Dr. Hannah Harrison for accepting the role of second reader for this project, and to the Marine Affairs Program for their support. I am grateful to have shared the last year and a half with my fellow MMM classmates, thank you for being so welcoming and inspiring.

Thanks, as always, to my family and friends for their continued support.

I am so grateful to have had the opportunity to paddle, surf and explore the Eastern Shore.

Chapter 1: Introduction

The seafloor is somewhat of a mystery, revealing parts of itself during low tide, but largely staying hidden from human view, compelling us to wonder what lies beneath the surface of the sea. Benthic zones are the lowest regions of marine systems, including the sediments and organisms found on the seafloor (USGS, 2019). They are important areas for nutrient cycling as well as habitat, which support marine biodiversity. The seafloor supports sea life, including the many fish and invertebrates harvested by coastal communities for millennia. Changes to benthic environments, including increases in bottom temperatures due to global warming, are predicted to alter the thermal ranges of bottom-dwelling, high-value commercial fish and crustaceans like lobster (Rheuban *et al.,* 2017). Understanding how the seafloor and its conditions are changing can help managers and fishers adapt to new climate realities and support the survival of culturally and economically important industries and practices through ecosystem-based approaches (Link *et al.,* 2010).

Benthic environments are often poorly mapped and are increasingly threated by climate change and other anthropogenic factors (Borfecchia *et al.,* 2019; Brown *et al.,* 2011). Although the data needed to create detailed seafloor maps may be difficult to collect due to cost, time, technology and resources, benthic maps are important in the planning of marine and coastal management and resource activities (Galparsoro *et al.,* 2014; Brown *et al.,* 2011). These maps can also be used to characterize and model the impacts of climate change on benthic zones, which is needed to better understand how these ecosystems are changing and the associated impacts on complex socio-economic and ecological systems. Acoustic survey technologies, like side scan sonar systems and multi-beam echosounders allow us to capture high resolution imagery of the seafloor, which can be compared to ground truthing methods (e.g., bathymetric photos), but despite the available technologies, and improvements to them, much of the seafloor is not mapped, or visualized (Brown *et al.,* 2011). As the seafloor around Nova Scotia is being mapped using acoustic survey technologies, the documentation of local observations and experiential knowledge can be valuable to inform management and decision making, especially due to threats of climate change.

Exploring other perspectives and knowledge of the seafloor, which focus on human interaction with ecosystems, as well as socio-cultural knowledge, can address gaps and can contribute to a holistic understanding of the seafloor (Beaudreau & Levin, 2014). This master's research project seeks to record and analyze how local people, including recreational and commercial users engage with and talk about benthic spaces along the Eastern Shore of Nova Scotia, which will contribute a unique form of knowledge to our understandings of the seafloor in the area.

1.1 Management Problem

Despite covering over 70% of the Earth's surface, marine environments are some of the least understood ecosystems. A richer understanding of the seafloor is needed, alongside the adoption of holistic views which incorporate different ways of knowing the ocean. This may include experiential knowledge as well as technological and scientific studies. Local and traditional knowledge greatly enrich our understandings of terrestrial environments and are incorporated into the management approaches of land and aquatic systems (Thornton and Maciejewski, 2012; McKenna *et al.,* 2008). Engagement with local communities is also used to understand benthic environments and to document and record observations of aquatic plants, marine animals, fish and resource use by various stakeholders and rightsholders (e.g., lobster fishers, organisms like sponges, corals) (Levine & Feinholz, 2015). Community knowledge has been integrated with scientific data to identify important areas for marine conservation and management, and traditional knowledge can fill gaps or add new perspectives to our understanding of environments (Ban *et al*., 2009). Local and traditional knowledge can contribute to adaptive, integrated management, and provide holistic understandings of interconnected socio-cultural and ecological systems (Berkes *et al.,* 2007). Documenting and recording local geographic knowledge can provide insights into how human interactions with place are influenced by perceptions of one's environment (Smith *et al.,* 2015).

This research is part of Work Package 1.1 (Societal Engagement) of the Benthic Ecosystem Mapping and Engagement Project (BEcoME). BEcoME is a multidisciplinary project funded by the Ocean Frontier Institute (OFI), aiming to study the role that benthic habitats play in changing species diversity and distributions due to climate change in the Northwest Atlantic Ocean (BEcoME, 2020). Research teams are using broad and fine scale mapping technologies like multispectral multibeam sonar, as well as engagement with local and Indigenous communities to identify how seafloor maps can be created and used for different purposes, including to develop a holistic understanding of the benthic environment. The findings and products of this research project can guide the protection of benthic habitats, the management of marine activities and inform the management and mitigation of climate change impacts.

1.2 Research Aims and Objectives

This research sought to understand and document local perspectives of the seafloor along the Eastern Shore of Nova Scotia. It explored the question: how do local recreational and commercial users of coastal and marine spaces engage with and talk about benthic spaces? Sub-questions included how the methods employed in this research and its outputs can help gain insight into how we can capture local knowledge and perspectives about the seafloor to record observations and change. Documenting local knowledge will be useful to integrate community and participatory mapping into benthic ecosystem mapping, as well as guide the inclusion of local, experiential knowledge in marine management decisions in Nova Scotia.

Chapter 2: Background Context

2.1 Eastern Shore Communities

The Eastern Shore region of Nova Scotia encompasses the areas east of Halifax Harbour to the Strait of Canso, divided between the Halifax Regional Municipality and Guysborough County (Figure 1).

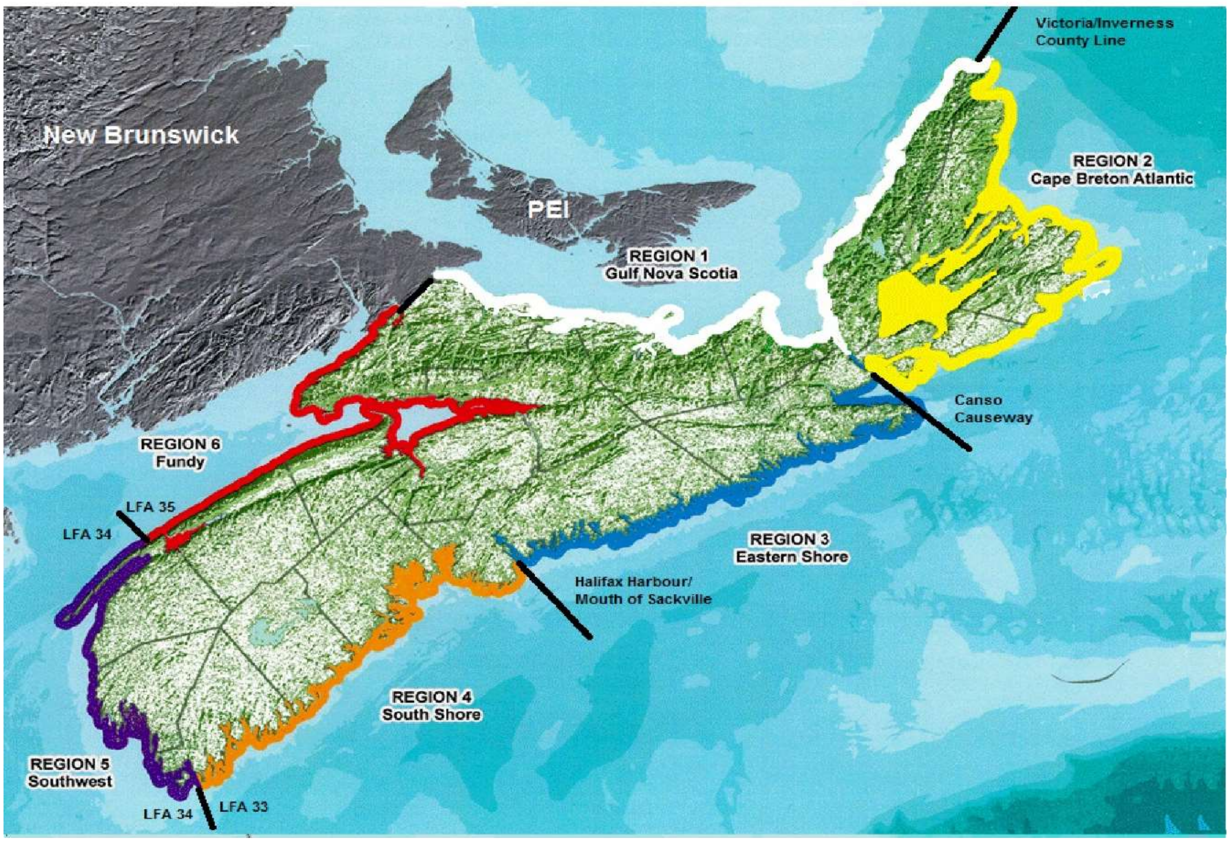

Figure 1. *Map of Nova Scotia, showing the Eastern Shore Region outlined in blue (Province of Nova Scotia, n/a).*

Nova Scotia's coastline is characterized by harbours, bays, coves, islands, sandy beaches, estuaries, headlands, and marshes, this unique natural environment is shaped by the ocean, which alters physical and biological components and influences climate (Nova Scotia, 1986; Neily *et al.,* 2004). The rugged coastline experiences high precipitation, strong winds, salt spray, and heavy fog (Davis and Brown, 1996). The Eastern Shore's coastal forests are exposed to harsh climates and disturbances and are dominated by coniferous stands comprised of black spruce, balsam fir, red maple, white birch, and white spruce (Neily *et al.,* 2004). The rocky coast, estuaries, salt marshes, tidal zones and islands along the Eastern Shore host diverse plants and animals, which migrate between coastal and marine environments (Spike, 2019).

The Eastern Shore is known for its archipelago, provincial parks, sandy beaches, historically themed attractions and more, which attract both tourists and locals to its shores (Province of Nova Scotia, n/a). Many provincial parks are found along the coast including Rainbow Haven Beach, Lawrencetown Beach, Martinique Beach, Clam Harbour, Owls Head, Taylors Head, Marie Joseph, Tor Bay and Black Duck Cove (Province of Nova Scotia, n/a). These parks are popular for an array of recreational activities, and Lawrencetown, Martinique and Clam Harbour are known as surfing beaches.

The Eastern Shore has been the focus of a number of conservation efforts. The Martinique Game Sanctuary is a coastal wetland protected since 1961 for waterfowl and bird conservation (Amyot, 2011; NSDNR, 2011a). Owls Head Provincial Park Reserve obtained legal protection in 2022 after a period of conflict between government, communities, and conservation groups due to a proposed golf course development (CPAWS-NS, 2022). However, much of the attention in recent years has focused on the Eastern Shore Islands, a coastal archipelago of more than 700 islands between Jeddore Harbour and Liscomb (Figure 2).

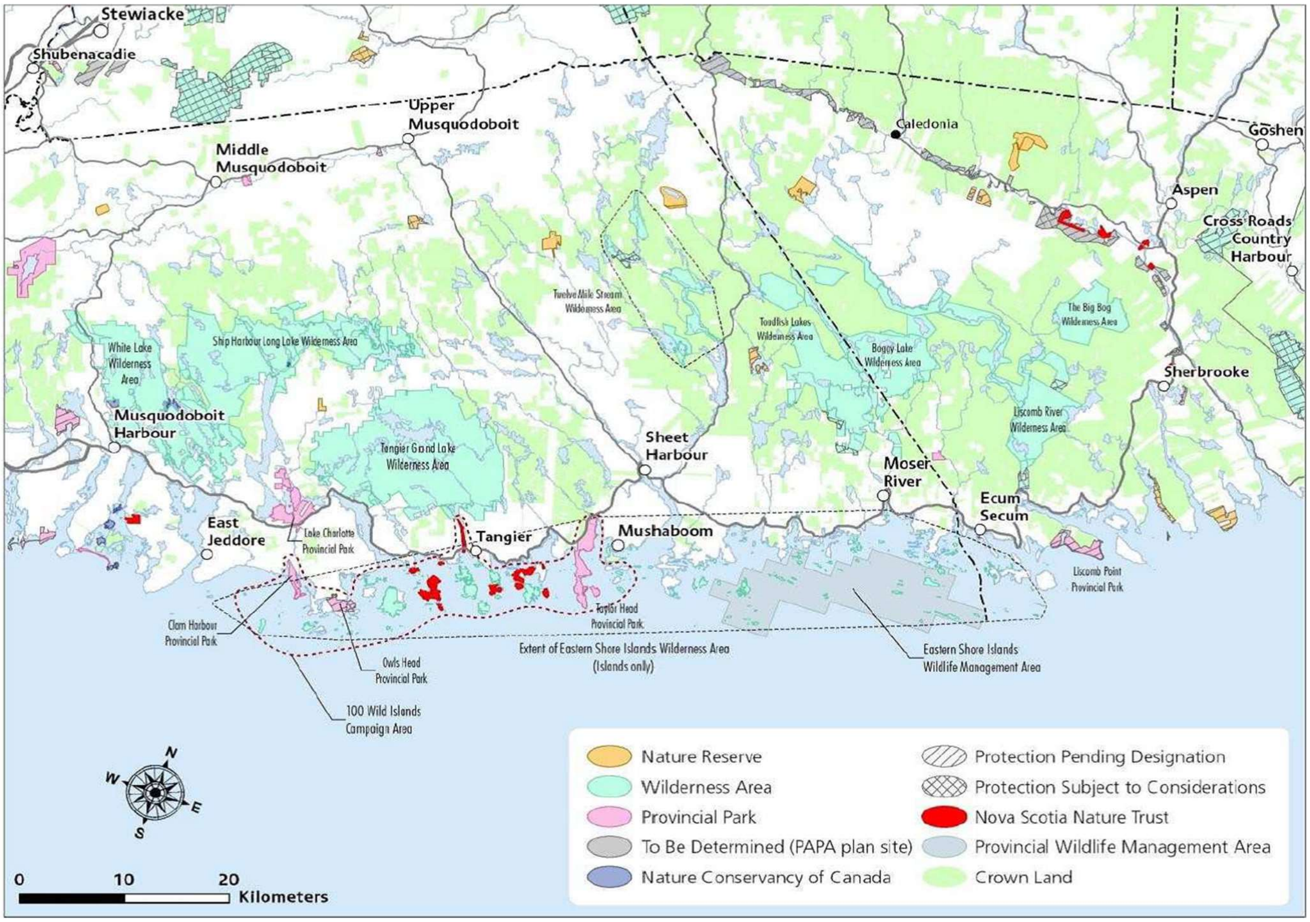

Figure 2. *Map of the Eastern Shore Islands courtesy of WITAP, showing land ownership and protected areas (EDM Planning Services Ltd., 2018).*

In addition to privately owned lands, the area within the archipelago encompasses the Eastern Shore Wildlife Management area, a provincially designated bird sanctuary since 1977 and the Eastern Shore Islands Wilderness Area (Province of Nova Scotia, 2011; EDM Planning Services Ltd., 2018). A portion of the Eastern Shore Islands and its coastline have been the focus of the 100 Wild Islands Legacy Campaign, spearheaded by the Nova Scotia Nature Trust (NSNT, 2017). The aim of this initiative is to ensure the protection of these highly biodiverse islands, home to diverse ecosystems including saltmarshes, eelgrass and kelp beds, boreal forests and temperate rainforests (DFO, 2021; NSNT, 2017). This is one of many community-led conservation initiatives in the area, where local stewards are advocating for the protection and continuation of their environments and place-based identities, which are impacted by changing environmental conditions, management decisions and economic activities (Rainville *et al.,* 2016). The region has also been designated the Eastern Shore Islands Area of Interest (AOI) (Figure 3), identified by the DFO in 2018 for its ecological importance and as a first step in the Marine Protected Area (MPA) establishment process (DFO, 2021).

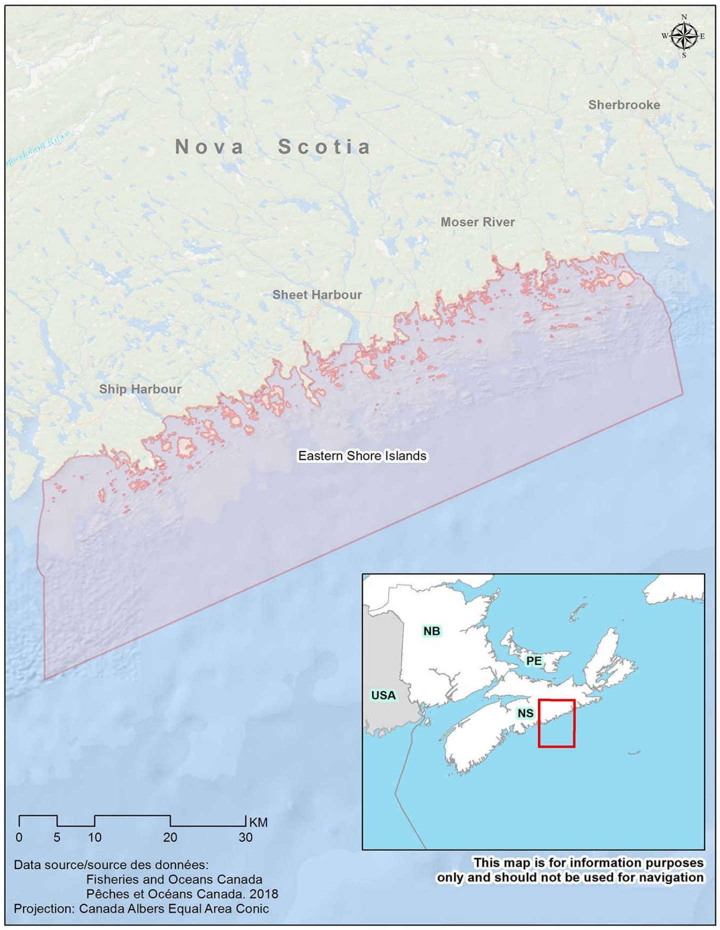

Figure 3. *Eastern Shore Islands Area of Interest proposed by DFO, Nova Scotia, Canada (DFO, 2021).*

The Eastern Shore Islands are described by the DFO as being "*a unique and complex archipelago system that has low human impact and a high degree of naturalness*" (DFO, 2021). Although these islands are ecologically significant, diverse, and unique, they are part of a multi-use, multi-user coastal area (Warrior *et al.,* 2022). The Eastern Shore's coasts, islands and waters are closely tied to the Mi'kmaq and non-Indigenous communities that have lived there for millennia. Connections between land and sea have always played an important role in the identity of communities along the Eastern Shore, fostering a sense of place (EDM Planning Services Ltd., 2018). Coastal communities along the Eastern Shore have relied on the resources provided from the seafloor and ocean and have in turn shaped these spaces through use. From small fishing shacks or "cabanes" to infrastructure such as wharves, fish stores, boat slips, and lobster and clam canneries, coastlines show the history of the fishing industry on the Eastern Shore and the connections between people and the sea (Spike, 2019; Eastern Shore Archives, 1955). Some of these fisheries include lobster, clam, and groundfish like cod, haddock and pollock (Eastern Shore Archives, 1955; Spike, 2019). The fisheries on the Eastern Shore, along with much of Atlantic Canada, were industrialized in the early 1900s, with the acceleration of trawlers and the development of commercial fishing technologies, but many of these operations declined with the collapse of the groundfish fisheries, primarily the cod fishery around the 1990s (Rainville *et al.,* 2016; Higgins, 2009). The region is also known for its nature and tourism opportunities which include birding, surfing, sailing, recreational fishing, kayaking, camping, and boating (Sneddon, 2018).

Tourism and recreation are being explored through initiatives like the "Wild Islands Tourism Advancement Partnership" (WITAP), which aims to support community development and ecotourism opportunities in the region, including innovative and sustainable industries and adventure tourism (WITAP, 2022; Rainville *et al.,* 2016). In addition to historical and archaeological research and documentation, this project has included an Ecological Inventory and Analysis and a Recreational Inventory and Analysis (EDM Planning Services Ltd., 2018). Information on recreation and traditional uses was identified through reviewing previous data, community interviews and public consultations (EDM Planning Services Ltd., 2018). These workshops used mapping as a tool to document knowledge, significant locations and resource uses throughout the Eastern Shore Islands. Participants were asked to identify the activities currently taking place around the Eastern Shore Islands, as well as how business and economic growth could be compatible with the preservation of ecological values in the area (EDM Planning Services Ltd., 2018). Some of the identified recreational activities included: clam digging, mackerel fishing, scallop diving, mussel gathering, beach going, boating, wildlife watching, camping, hiking, hunting and several non-recreational activities (e.g., commercial lobster fishing). Balancing conservation objectives and economic opportunities was important to participants, who expressed that ecological value was important to managing recreational use (EDM Planning Services Ltd., 2018).

2.2 Oceanographic and Benthic Ecosystem Context

The seafloor is a complex ecological and socio-economic system, providing many ecosystem services, influencing how we use these spaces, and the organisms found in them. These ecosystem goods and services, which include marketable goods that are obtained from nature (goods), and the processes that support humans (services) are essential to local and global communities (De Groot *et al.,* 2002). Shallow, coastal benthic ecosystems are easily accessible and support fisheries (lobster, crab, groundfish), are sources of mineral and raw materials (zinc, phosphorous), play a role in coastal protection (biogenic structures and seagrass), cycle nutrients, and provide habitat to primary producers and other marine species (Galparsoro *et al.,* 2014; Kritzer *et al.,* 2016; Forrester *et al.,*1996; USGS, 2019). In addition to its ecological and economic importance, the structure and biology of the seafloor is culturally and socially significant, acting as the foundation for marine recreation (e.g., diving, boating, surfing, kayaking), recreational fisheries, traditional harvesting, and other culturally important activities (Sweetman *et al.,* 2017).

The Eastern Shore consists of diverse habitats, classified as a "complex pelagic bay" where the benthic zones are sandy bottoms, mudflats, boulder and cobble fields (Jeffery *et al.,* 2020; Greenlaw *et al*., 2011). The Eastern Shore borders the Scotian Shelf, and is characterized as having a bedrock geomorphology, with strong glacial deposition and erosion influence (King, 2021; Jeffery *et al.,* 2020). A hard bedrock substrate is found between Clam Harbour and Liscomb Harbour, named the "Mahone Bedrock Shore and Islands," part of the "Inner Scotian Shelf" (Greenlaw *et al.,* 2013). The bottom substrate and glacial history of the area have shaped the seabed and species assemblages, which depend on sediment and substrate composition (King, 2021). Muddy flats have favoured the growth of molluscs like clams, while sandy bottomed areas support the growth of eelgrass. There is a relationship between substrate type and organisms, understanding the composition of the seafloor can be used to identify or predict suitable habitat for benthic invertebrates, fish, marine mammals, birds and plants (Jeffery *et al.,* 2020). Water temperatures on the Eastern Shore are generally cooler than in other areas on the southeast coast of Nova Scotia due to the Nova Scotia current, which also transports zooplankton (Bundy *et al.,* 2014).

The area is highly biodiverse, providing important habitat for marine birds, mammals (e.g., seals), algae and marine plants, crustaceans and fish. Rockweed (*Ascophyllum nodosum*), eelgrass (*Zostera marina*) and other kelp (red coralline, brown algae) beds are distributed across rocky reefs as well as intertidal and nearshore areas, providing habitat and grounds for crustaceans and fish like American lobster (*Homarus americanus*) and Atlantic cod (*Gadus morhua*) (Hastings *et al.,* 2014; Greenlaw *et al.,* 2013). Various species surveys have been conducted along the Eastern Shore by government, academics, and non-governmental organizations. The surveys documented observations of seabirds (common tern, common eider, black guillemot, great black-backed gull, herring gull, double-crested cormorants), shorebirds (spotted sandpiper), aquatic plants (rockweed, eelgrass, kelp, knotted wrack, sea gooseberry, green sea fingers), invertebrates (sea cucumbers, sea stars, scallops, clams, urchins, crabs, lobster, sand dollars, sponges, anemones, dogwhelk, periwinkles), fish (sculpins, cod, herring, mackerel), and marine mammals (seals) (Jeffery *et al.,* 2020; Vandermeulen, 2018; CPAWS, 2022.).

Eelgrass beds are found in estuaries and shallow, coastal waters of Nova Scotia, and are declining across their range due to increased anthropogenic nitrogen inputs, pollution, and mechanical damage (Garbary *et al*., 2014; Costello and Kenworthy, 2011; van der Heide *et al.*, 2007). Studies have also linked this decline to the introduction of the invasive European green crab (*Carcinus maenas*), which appeared in Nova Scotia in the mid 1990s (Audet *et al.,* 2003). Green crabs tear and cut apart eelgrass shoots, leaving them "frayed," and disrupt eelgrass beds as they forage for clams (Garbary *et al*., 2014). Research to assess the health and extent of eelgrass beds and kelp on the Eastern Shore is being conducted by academics and CPAWS Nova Scotia. Eelgrass transects surveys were conducted near Owls Head to measure canopy cover, height, shoot density and macrofauna observations, and found that eelgrass beds were in good health (high canopy cover, average height) (CPAWS, 2022). Other research groups at Dalhousie University are using video surveys to assess kelp forests along the Eastern Shore. The surveys revealed that kelp forests (finger kelp and sugar kelp were the most common) were healthier on the Eastern Shore compared to other areas of the province, perhaps due to cooler water temperatures, but research is currently underway to study this hypothesis (Balbar, 2018).

2.3 Jurisdiction and the Seafloor

Healthy oceans, including benthic zones, maintain the well-being of global ecosystems, and the humans that depend on their resources. Nova Scotia's coasts and marine waters are influenced by and fall under the jurisdiction of different levels of government including federal, provincial, municipal, and Indigenous. This governance framework has implications for the management of the seafloor. Marine protected areas and other conservation measures are put in place by the federal government under the Oceans Act (Government of Canada, 1996). These types of protection mechanisms prohibit practices that may disturb or damage marine organisms or habitats, including those found in benthic environments. The federal government, including departments like Fisheries and Oceans, Parks Canada and Transport Canada has control over coastal waters extending from the low water mark to 200 nautical miles towards sea, and certain activities that occur within this space (East Coast Environmental Law, 2018). This boundary is complicated though, with the province of Nova Scotia claiming certain areas past the low water mark as part of its territory (Doelle *et al.,* 2006). The provincial government of Nova Scotia has primary jurisdiction over provincial crown lands, including seabeds and coasts that are not privately or federally owned (East Coast Environmental Law, 2018). Municipal jurisdiction in Nova Scotia extends to the high-water mark and regulates land use and development which may affect the marine environment (Province of Nova Scotia, 2019). These jurisdictional discrepancies complicate the management of coastal lands and waters, including the management of the seafloor and will become more complex with the new provincial Coastal Protection Act.

2.4 Documenting and Visualizing the Seafloor

DFO has identified a lack of comprehensive data on the Eastern Shore, and the need for higher resolution bathymetric data (e.g., multibeam coverage) to better characterize the seafloor and provide more accurate information about species distributions and habitats (Jeffery *et al.,* 2020). Underwater surveys have been conducted by DFO to assess bottom substrate types, as well as species assemblages, using methods like glass-bottom bucket observations (1982) and drop camera surveys (2018) (Moore *et al.,* 1986; Vandermeulen, 2018). Although these types of technology-led surveys provide detailed data on bathymetric features, there is an opportunity for local knowledge and observations to complement and strengthen our understanding of these spaces. Combining different types of knowledge can help create full coverage maps of the seafloor, integrating multiple types of knowledge that can be useful for a variety of uses and planning purposes. Mapping tools like SeaSketch have been used elsewhere in collaborative planning processes, where stakeholders are able to map how and where they use marine space. This data has been applied to understand how user interests may overlap or conflict in the establishment of MPAs (Cravens, 2016). Mapping through participatory tools like Participatory Geographic Information Systems (PGIS), has been used to involve communities in an empowering way (Craig and Weiner, 2002). These tools can be applied to the seafloor, where studies have shown the benefits of including Traditional Ecological Knowledge (TEK) in seafloor habitat mapping by documenting local fishers' knowledge of seabed features, which was coupled with a technical oceanographic survey for MPA planning (Teixeira *et al.,* 2013). Engaging with local and Indigenous communities in participatory mapping processes can help us better understand the seafloor, by capturing and documenting knowledge and observations that would not be considered in conventional ecological or economic based marine assessments and management.

There have been a few community mapping initiatives on the Eastern Shore. DFO led the "Coastal Resources Mapping Project" in 1995-1996, which documented recreational uses of coastal waters and observations of fish and marine mammals across the province, including a collection of 46 maps of the Eastern Shore from Halifax Harbour to Ecum Secum. Additionally, the "Eastern Shore Coastal Communities StoryMap" was created in 2019 by the Lake Charlotte Area Heritage Society and the Seacoast Trail Art Association, with funding from WWF-Canada (Memory Lane Heritage Village, 2019). This interactive map showcases coastal heritage and fishing history collected through a community mapping process with residents. The map presents photographs, testimonies, stories, placenames, and significant locations (Memory Lane Heritage Village, n.d.). The Wild Islands Tourism Advancement Partnership (WITAP) also engaged with local people about their knowledge of the Eastern Shore Islands, which resulted in community asset mapping, including historical and cultural knowledge, as well as ecological and recreational assessments (WITAP, 2022).

Documenting local and traditional ecological knowledge can offer holistic perspectives on benthic ecosystems and can complement the knowledge and data collected through scientific processes to increase our understanding of the impacts of climate change on seafloors. Participatory mapping can be used as a tool for knowledge sharing between different rights-holders and stakeholders, bringing together their perspectives, objectives, and theories in resource management (Bishop *et al.,* 2021; Aporta *et al.,* 2020). Mapping can be an opportunity for knowledge co-production to combine different types of knowledge through community engagement processes, which would benefit all users of marine spaces. The visualizations created through collaborative frameworks could map contextual and qualitative data, based on local and place-based observations (Blake *et al.,* 2017). These visualizations or documentations are important to empower and increase resilience in coastal communities and to better understand the links between benthic zones and climate change from different perspectives.

2.5 Local Knowledge of the Seafloor through Recreation

Socio-cultural knowledge, including local observations and experiences of commercial and recreational users can add value to our understandings of the seafloor. Local users of marine space have distinct and extensive knowledge of the places surrounding their communities (Smith *et al.,* 2016). McKenna *et al.,* 2008 studied fishers' "mental maps" of the seafloor in Lough Neagh, Northern Ireland, gained through experience and intergenerational knowledge sharing. The mental maps were found to be highly accurate when compared to bathymetric surveys and contained selective information that was of value to fishers (McKenna *et al.,* 2008). Local and traditional marine knowledge can provide insights into how people navigate and engage with the seafloor without the use of technology, providing highly localized observations of these areas which can fill gaps in our understanding of benthic ecosystems (Teixeira *et al.,* 2013). Benthic habitat maps were also developed through engagement with Indigenous peoples in Australia to combine traditional ecological knowledge and science for conservation purposes (Davis *et al.,* 2020). Local and traditional ecological knowledge have been studied in relation to documenting and identifying changes to marine species' abundance and health, habitats, and anthropogenic pressures (Beaudreau & Levin, 2014; Levine & Feinholz, 2015; Carter & Nielsen, 2011). Inuit knowledge and perspectives of sea ice, and the effects of climate change on Inuit identities have been captured and documented in Arctic regions using participatory mapping (Aporta, 2011). Studies have focused on cross-cultural collaboration with commercial fishers and Indigenous peoples to document knowledge of the seafloor, but it is also valuable to consider other types of knowledge, for example, knowledge held by recreational users of marine spaces.

Outdoor recreation monitoring is used in Nordic countries to collect information about use and tourism in coastal and marine areas, and this knowledge is integrated into management planning (Hansen, 2016). Recreational divers have gathered knowledge of marine features and organisms through experience, and often participate in citizen science initiatives by providing their local knowledge to add to wider ecological data sets (Hermoso *et al.,* 2021). Local knowledge can also provide insights into how places are changing through continued use and observations of coastal and marine waters. Surfer knowledge in California was recoded using a survey approach to understand the impacts of sea level rise on surf locations (Reineman *et al.,* 2017). Surfers indicated where important surf spots were located, as well as ideal conditions, waves, and tides. This knowledge was analyzed with sea level rise data to predict the effects of climate change on various surf locations (Reineman *et al.,* 2017). Surfer knowledge can be considered a form of local knowledge as surfing communities develop an understanding of the marine environment through use and shared observations (Davis and Wagner, 2003; Reineman *et al.,* 2017). The values associated with surf breaks have also been studied in New Zealand and found that coastal communities have extensive knowledge of their local waters and perceive the importance of areas differently depending on individual preferences (Peryman & Orchard, 2013). This knowledge, as well as local values and objectives, should be integrated with ecological and economic information in coastal and marine management.

2.6 Opportunities for Knowledge Sharing: Local Knowledge and Decision Making

Documenting local knowledge of benthic ecosystems and combining knowledge types provides an interesting opportunity to understand multiple forms of information, how they interact and how they can support each other. Knowledge and information types may include historical and contemporary knowledges, technical and experiential knowledges, ecological/scientific and socio-cultural studies, and qualitative and quantitative data and information. While local knowledge can contribute to a better understanding of ecological significance, it is also important to consider the cultural significance of places based on the knowledge and perceptions of residents, which can be integrated into planning (Manuel, 2003). The results of technical and community-based seafloor mapping initiatives can be used to revise and improve marine plans, especially related to the management of fisheries and climate change adaptation (Bøe *et al.,* 2020). Seascape ecology, when applied to benthic spaces, evaluates the connectivity and the role of context in ecological patterns and processes (Swanborn *et al.,* 2021). Our management of marine environments is closely tied to how people use and rely on marine resources and services; the ways that people engage with the ocean are rooted in specific contexts. Knowledge sharing through the creation of maps can bring together stakeholders and rightsholders, to map their values, interactions and relationships with places, with can help us better understand the socio-cultural dimensions of management decisions (Pearce *et al.,* 2021). Understanding socio-cultural implications of management is especially relevant on the Eastern Shore, where community identity and economies are closely tied to the coast, seafloor, and waters around them.

2.7 Climate Change Impacts

Global climate change is increasingly altering ocean physical, biological, and chemical properties, and the impacts of this change will affect the overall marine ecosystem, and related socio-ecological systems (Bush and Lemmen, 2019). Benthic ecosystems are subject to threats, including anthropogenic stressors and the influence of changing ocean conditions. These impacts include but are not limited to increased water temperatures due to increased CO_2 emissions, hypoxia due to increased nutrient inputs, lowered pH, changes to particulate organic carbon fluxes and altered species ranges, habitats, survival and food supply (Ehrnsten *et al.,* 2020; Huang *et al.,* 2018; Sweetman *et al.,* 2017). Decreases in oxygen concentrations are especially concerning as the diversity of benthic organisms depends on oxygen availability and distribution (Moffitt *et al.,* 2015). Human uses like fisheries (commercial, bottom trawling), mineral deep-sea mining and oil and gas extraction can also alter or threaten ecosystem structure and function. Mining and bottom-trawl fisheries have been shown to severely damage the seafloor, but how benthic communities recover from these types of extractive activities is still largely unknown (Boetius, & Haeckel, 2018). It is becoming increasingly important to keep record of these changes and map benthic ecosystems to provide baselines for management. Mapping species assemblages of benthic communities can help us predict future impacts, as well as identify areas vulnerable to climate change based on these baselines, which can support mitigation and adaptation planning (Frazão Santos *et al.,* 2020).

Chapter 3: Methodology

3.1 Study Area: Eastern Shore Region of Nova Scotia

The geographic scope of this study encompasses the western portion of the Eastern Shore of Nova Scotia, from Cow Bay to Taylors Head Provincial Park (Figure 4). The study is specifically focused on the seafloor of nearshore and intertidal waters in bays and passages surrounding islands. The western portion of the Eastern Shore was chosen as a suitable size for this exploratory study: five provincial parks are found within the area, including Rainbow Haven, Lawrencetown Beach, Martinique Beach, Clam Harbour Beach, Owls Head and Taylors Head. The study boundary also includes part of the Eastern Shore Islands and the whole of Nova Scotia Nature Trust's 100 Wild Islands Legacy Campaign area. This area is important for recreation (it is close to the urban center of Halifax Regional Municipality) and has not been an area of focus for this type of work.

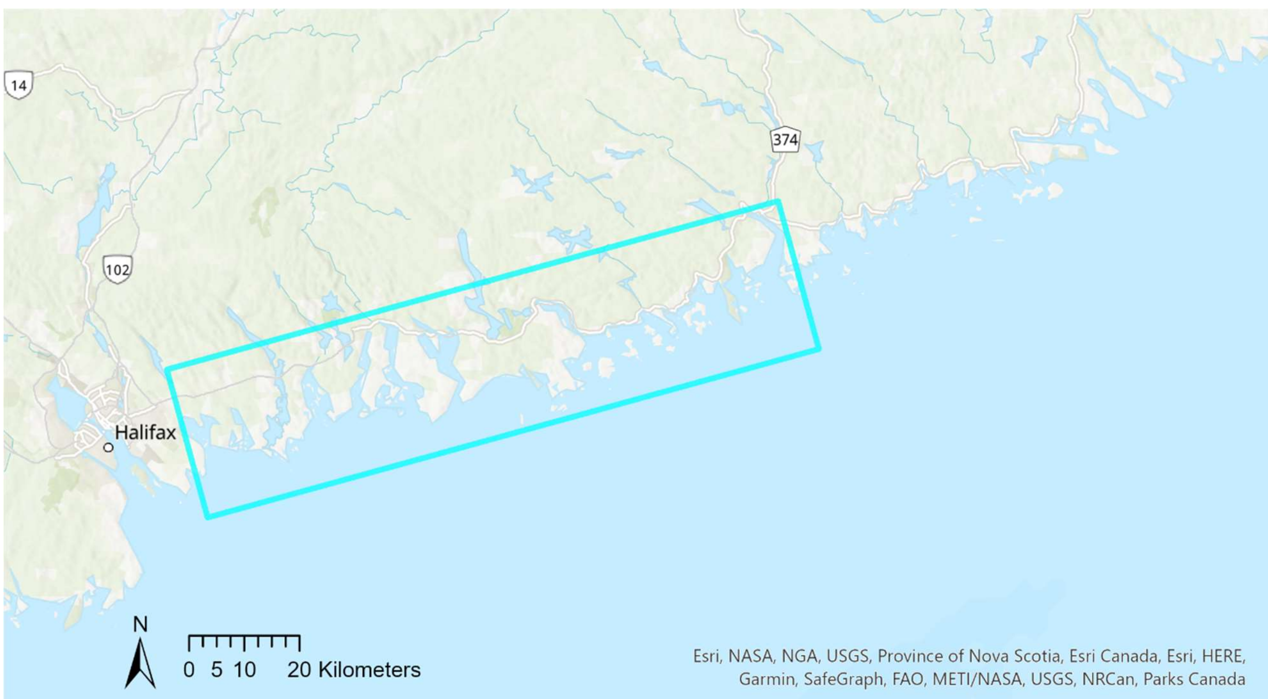

Figure 4. *Map of the study scope outlined in blue from Cow Bay to Taylors Head Provincial Park, Nova Scotia, Canada.*

3.2 Study Design: Semi-structured Interviews and Annotated Maps

This research can be characterized as qualitative, exploratory research, which contributes to a larger mixed-methods research project (the BEcoME project). The qualitative approach employed for this work consisted of a literature review and one-on-one semi-structured interviews. This research received approval from the Dalhousie University Research Ethics Board (REB# 2021-5801). The interviews were conducted and analyzed using a social-ecological theoretical approach. A scoping literature review was chosen with direction from supervisors to identify existing literature on the topic, concepts, and gaps, providing a contextual basis for the work.

Semi-structured interviews were chosen as a method to explore how local people view, speak about, and understand nearby benthic spaces. The study population included people with local knowledge of the Eastern Shore's marine environment developed through recreational or commercial experience in the waters along the coast. These users included surfers, kayakers, tourism operators, commercial clam fishers, boaters, and residents who use the shore and tidal areas for recreation generally. Participant selection was determined using a non-random, purposive sampling strategy (Robinson, 2014; Mason, 2002). Participants were identified and recruited by email and in-person by members of the BEcoME research team who had knowledge of the area and contacts within different user communities. Interviews were semi-structured with open ended questions to allow participants to speak about what they found most important; the interview guides were developed with guidance from the research team. Each interview followed the same format and explored the same themes, but the question guide was designed to be flexible to tailor it to the different types of users (Appendix I). The interview questions centered on the activities people practice and where they practice them, why these areas are important to them, what factors they consider when doing their activities, if and how they thought about the seafloor during their activities, what changes they have observed to the area over time, and knowledge of local use and species composition.

Interviews were conducted during the summer and fall of 2022 and ranged between forty minutes to an hour and a half. Participants had the choice to interview either in person or virtually. In person interviews were held in various locations of the western portion of the Eastern Shore at a meeting place that was convenient for participants, while virtual interviews were conducted using Microsoft Teams.

Maps of the nearshore waters and coast along the Eastern Shore supported the interviews. Interviewees annotated the maps during the interviews, highlighting significant locations. This method was chosen as an elicitation tool, to anchor the conversation, and to document and tie knowledge, memories, and observations to place. These base maps were made using ARCGIS Pro, showing an outline of the coast and nearshore water (Figure 5).

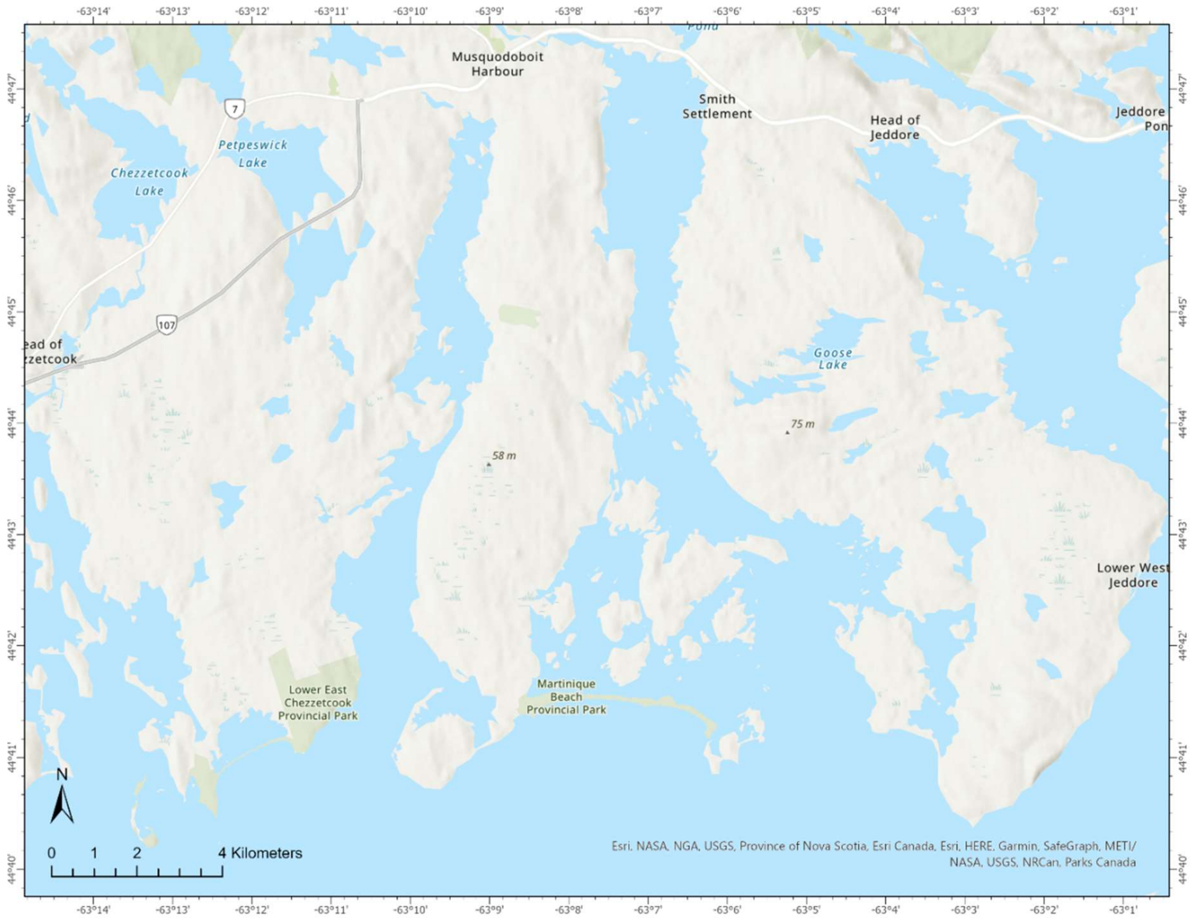

Figure 5. *Example of base map used in semi-structured interviews. This map shows the coast and nearshore waters between the Head of Chezzetcook and Lower West Jeddore (Fulton 2022).*

In person interviews used printed maps. For virtual interviews, screen sharing was used to display the maps, and participants were able to indicate areas or features which were then annotated onto the PDFs by the interviewer. Participants were encouraged to annotate the maps to show important or significant locations, observations of marine life, place names, benthic features, and other relevant information.

3.3 Data Analysis

The interviews were recorded, transcribed, and then analyzed using qualitative content analysis. NVivo 12 Pro was used to organize the data, coupled with a manual review of the transcripts to identify core themes. Key words and subthemes were identified following an inductive coding approach. The maps annotated by participants were used to identify the areas where each type of activity took place. Feature classes for each of the activities (Surfing, Clam Harvesting, Kayak/Boating, Resident) were created using ARCGIS Pro, and the data from the annotated maps was georeferenced according to those classes. The themes identified through the analysis of the interview materials were contextualized according to the literature, especially compared to other studies on local ecological knowledge, and the inclusion of socio-cultural knowledge in decision-making.

Chapter 4: Results

4.1 Interview Participants

Ten interviews were conducted, one of which had two participants (n=10, with 11 participants in total). Table 1 shows the number of interviews per user group. Interviewees were grouped according to their primary use of coastal and marine space. These groupings are: surfing, kayak and recreational boating, commercial fisheries (clam harvesting), tourism, and residents. However, while participants might be aligned with a specific interest, they did not exclusively speak about a single use during their interviews. Participants spoke about a wide range of activities, including the following: snorkeling, research, conservation, beach camping, beachcombing, scuba diving, paddling, recreational fishing and harvesting (bass, clams, scallops), hunting, walking, swimming, photography and art, and coastal observations. Although the interview questions were mainly about the seafloor, the interviews were not limited to talking about the benthic space. Participants spoke about coastal, intertidal, nearshore, and offshore areas in addition to observations and knowledge of the seafloor.

Table 1. *Interview participants by group, and number of interviews per user type.*

Participant Groups	Number of Participants	Number of Interviews
Surfing	4	4
Kayak and Recreational Boating	3	3
Commercial Clam Fisheries	1	1
Tourism	1	1
Resident	2	1

4.2 Geography of Use

In their responses to interview questions, interviewees referred to beaches, coastal parks, harbours and islands between Cow Bay and Taylors Head Provincial Park. Figure 6 shows the distribution of activities over the entire study area, and Figures 7-11 show detailed maps of specific locations, coded according to activities. These locations were plotted based on the hand-drawn and PDF-annotated maps created by participants. It is important to note that not all identified areas were included in these figures due to the sensitivity of information and participant preferences.

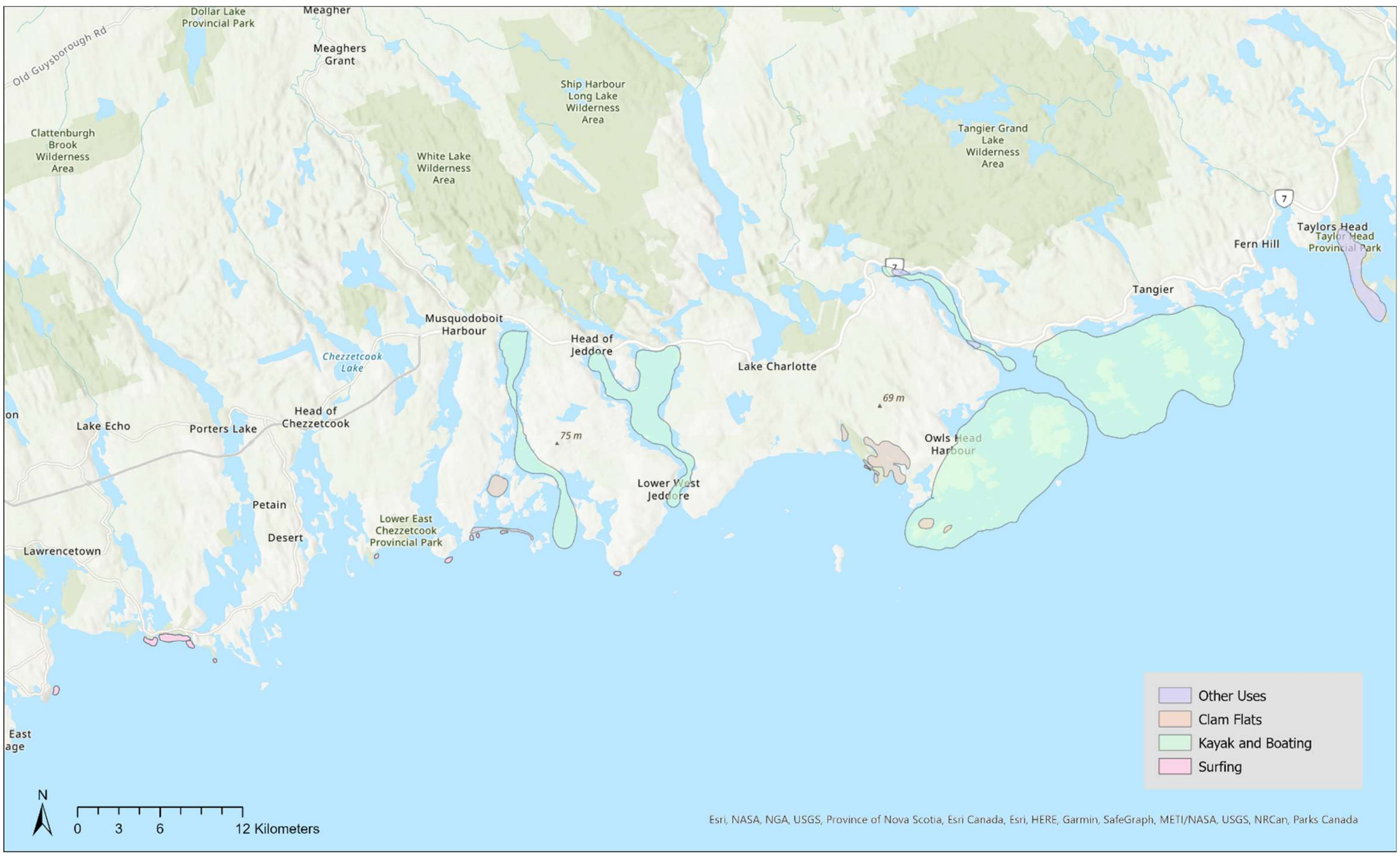

Figure 6. *Distribution of activities discussed by users during interviews, from Cow Bay to Taylors Head Provincial Park, Nova Scotia.*

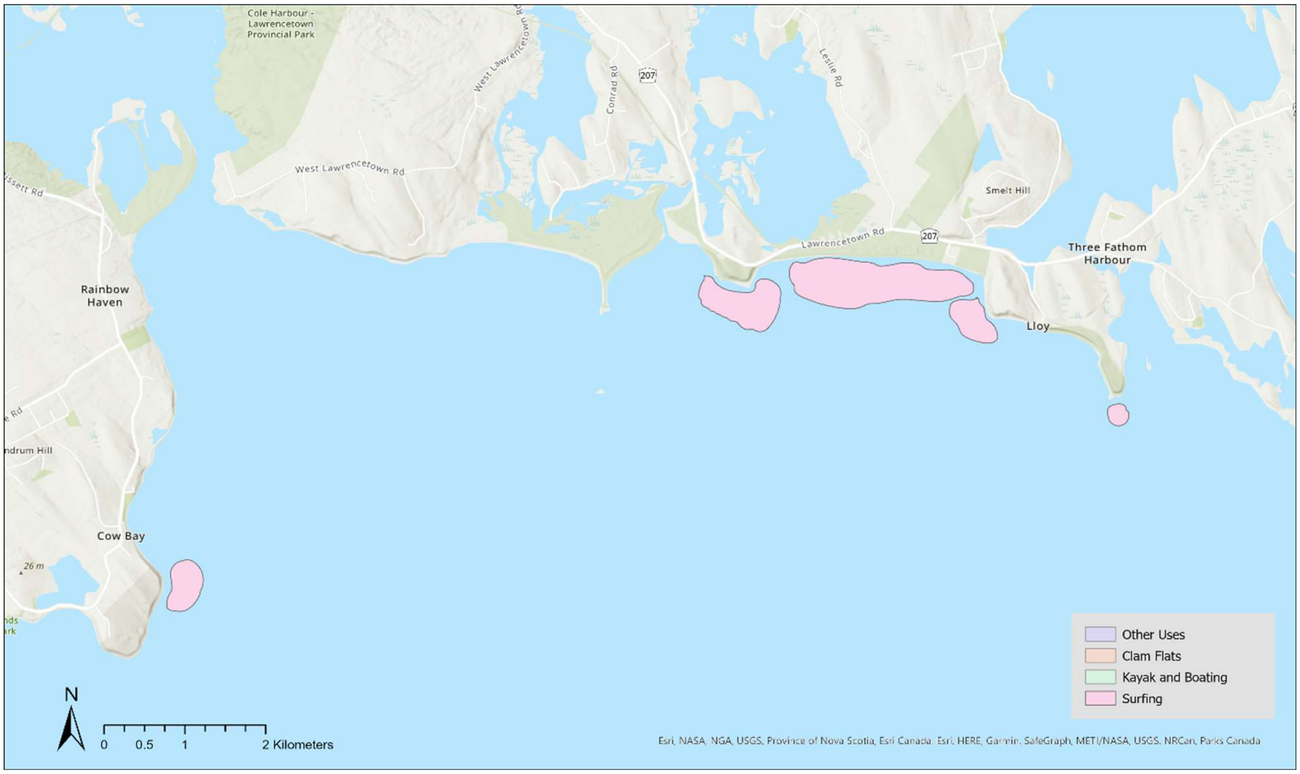

Figure 7. *Distribution of activities discussed by users during interviews, from Cow Bay to Lawrencetown Beach Provincial Park, Nova Scotia.*

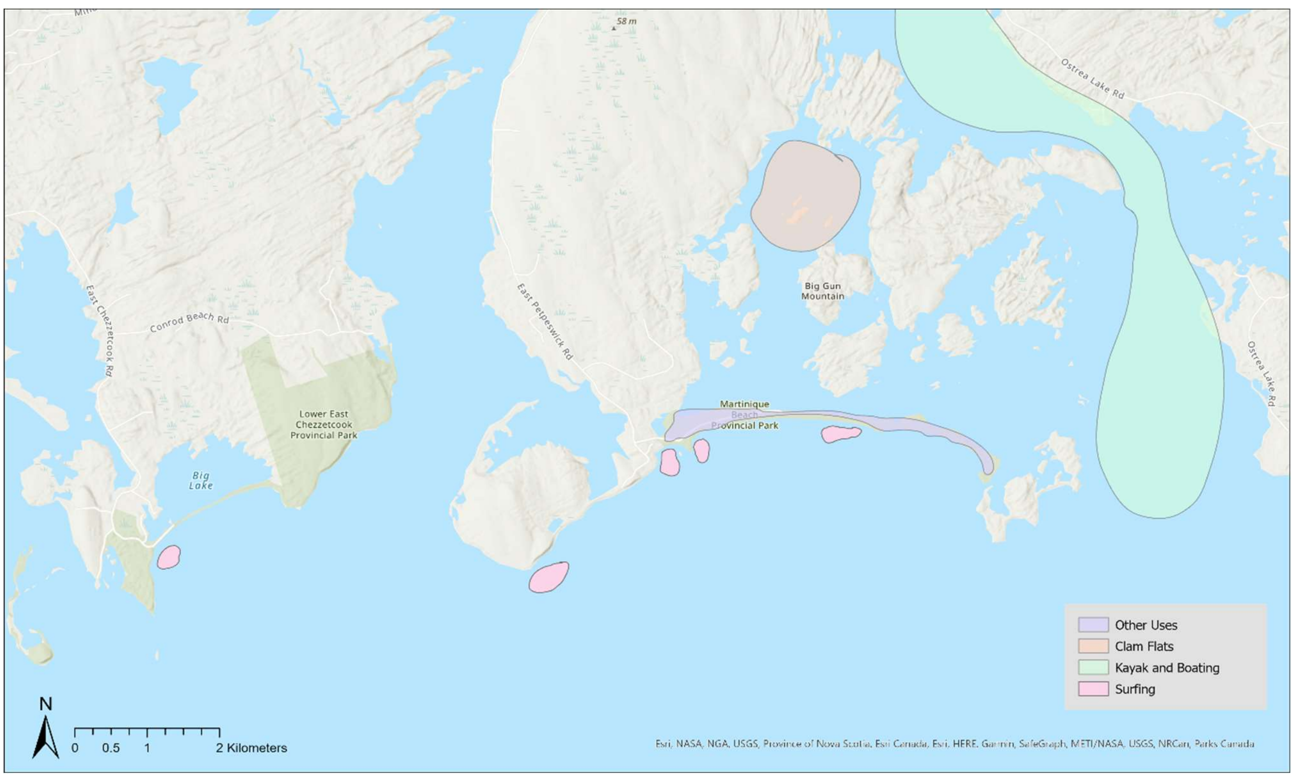

Figure 8. *Distribution of activities discussed by users during interviews, from East Chezzetcook to Musquodoboit Harbour, Nova Scotia.*

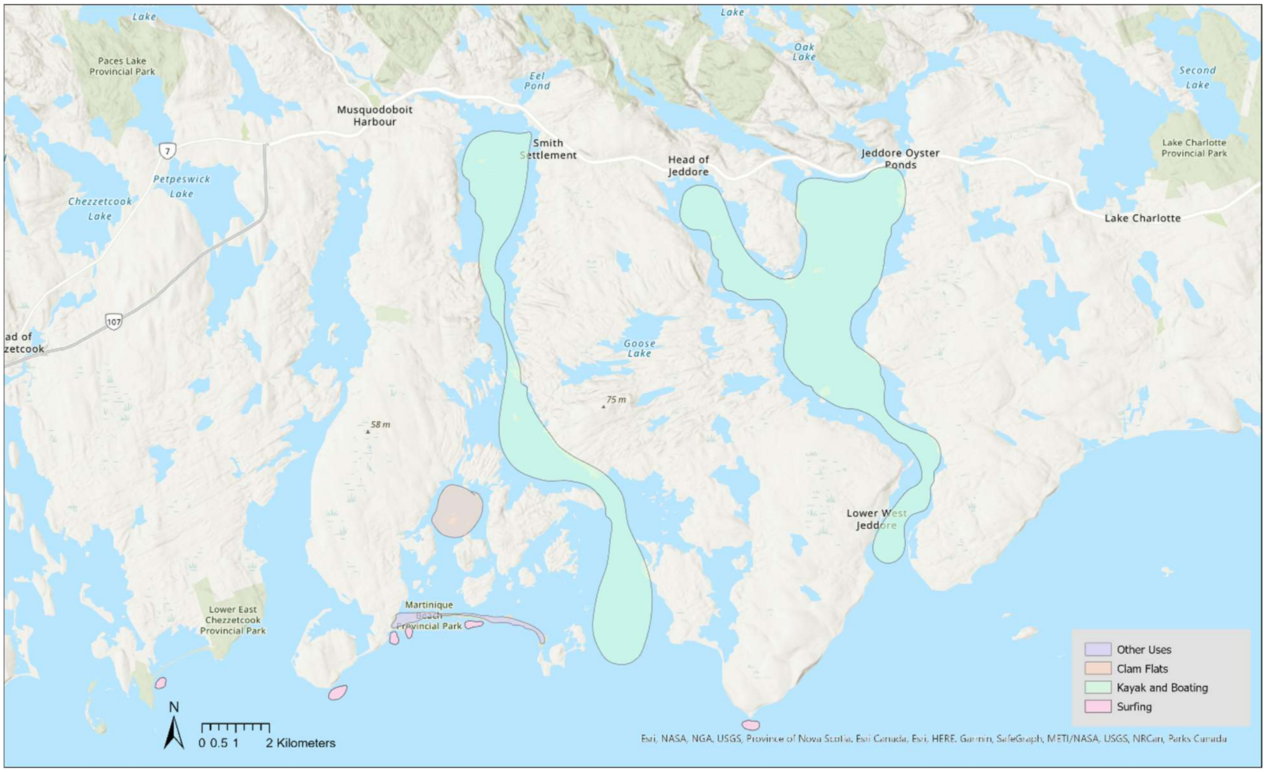

Figure 9. *Distribution of activities discussed by users during interviews, from East Chezzetcook to Jeddore Harbour, Nova Scotia.*

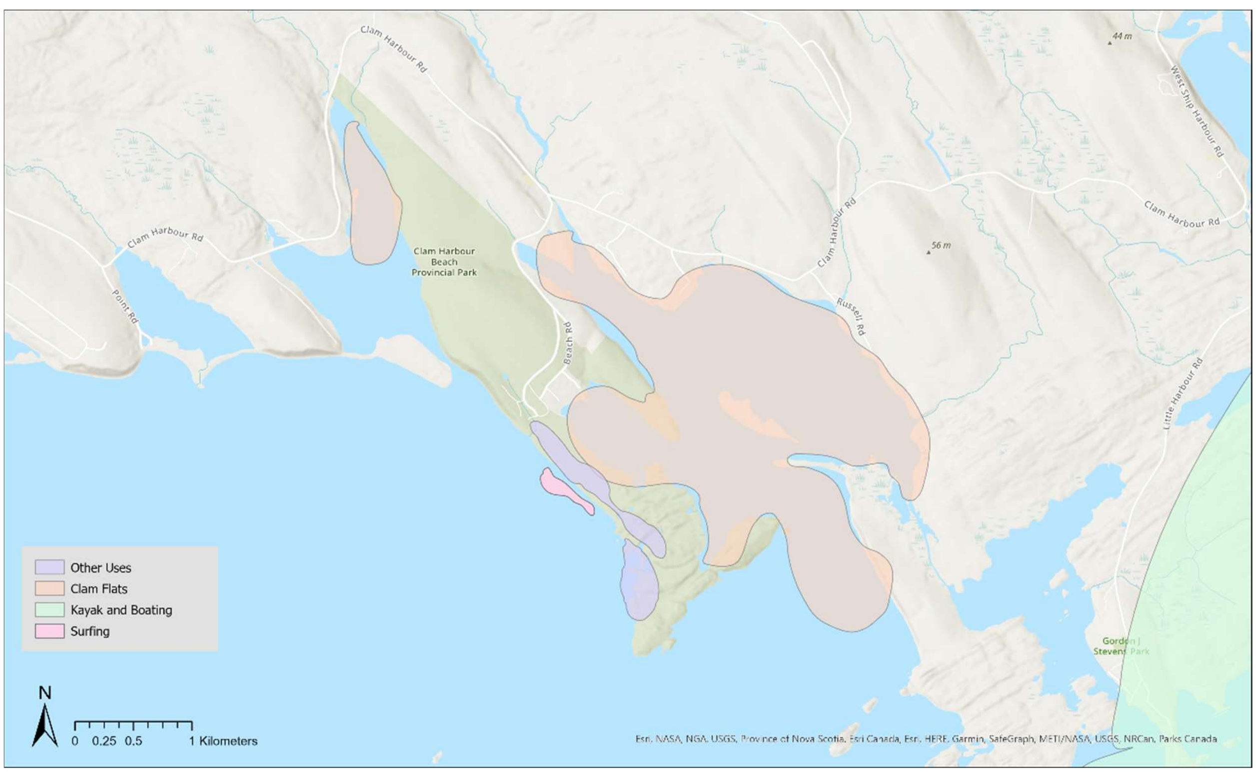

Figure 10. *Distribution of activities discussed by users around Clam Harbour, Nova Scotia.*

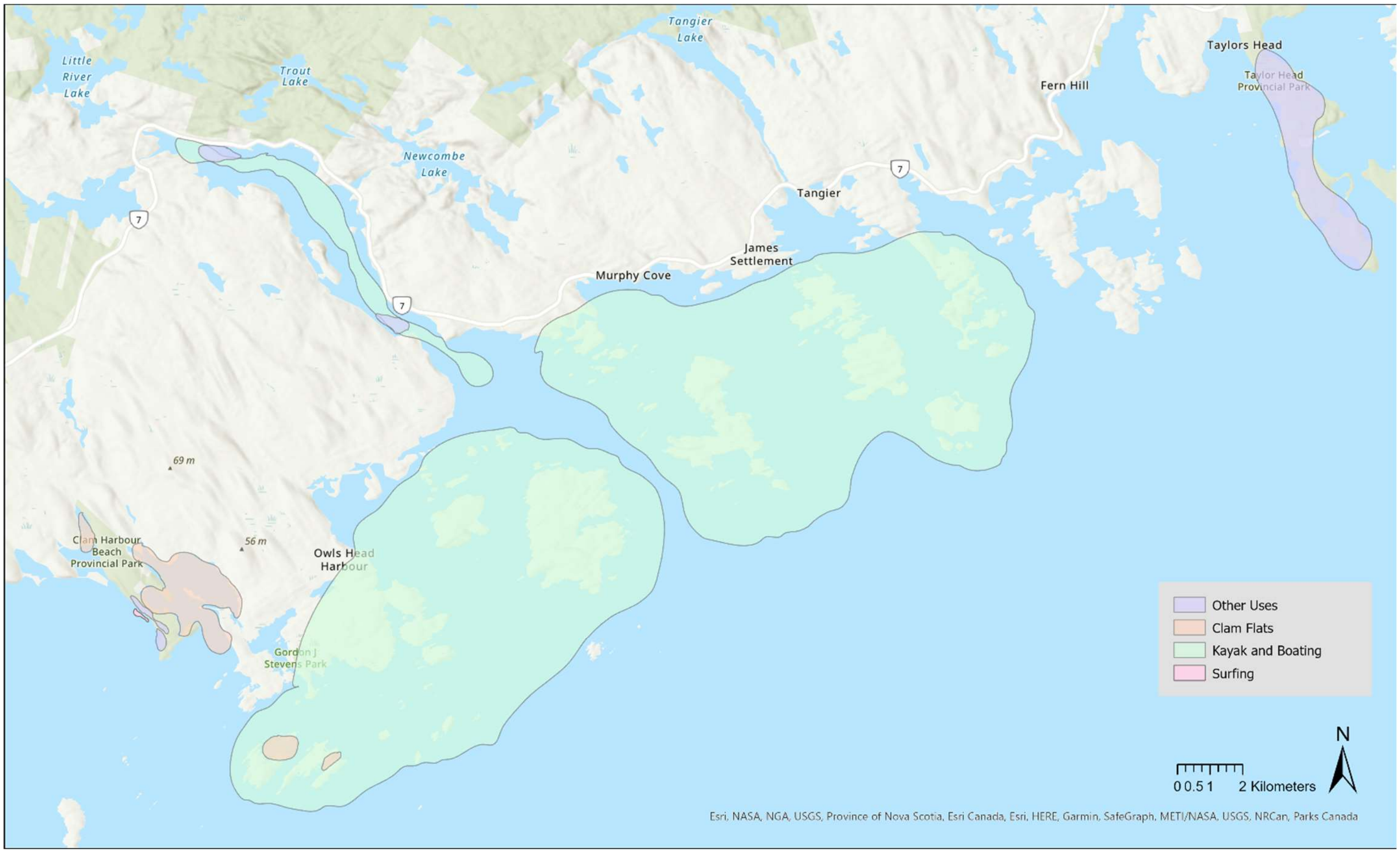

Figure 11. *Distribution of activities discussed by users during interviews, from Clam Harbour to Taylors Head Provincial Park, Nova Scotia.*

4.2 Interview Themes

Users of coastal and marine waters have extensive knowledge of the seafloor. Four key themes emerged from the analysis of the interviews, which were identified based on a thematic analysis of the entire data set and specific coded interview questions (Appendix I). The following sections present the findings of this research to support each theme. The identified themes are:

1. Seafloor elements including structure, composition, features, and species.
2. Activities and ideal locations for the activities as directed by the shape and composition of the seafloor.

3. Coastal, marine, and seafloor change.
4. Coastal plants, wildlife, and marine life.

4.2.1 Seafloor elements including structure, composition, features, and species.

Interviewees described the seafloor in terms of its structure, composition, features, and species. Interviewees referred to elements of the seafloor throughout the interviews, in response to multiple questions, and interviewees focused on different elements based on their given activity. All users were aware of the bottom types (e.g., rock, cobble, sandy bottom, silty bottom, mud). Surfers spoke about water depth, as large swells brought in by storms and hurricanes break in different locations based on depth. For example, it was described that during storm events, waves break at Lawrencetown Beach 800m-1km offshore because the water remains shallow up to that distance. However, in deeper areas like Cow Bay, the swells can come right into the beach due to the water depth, and break once they hit a headland. One surfer described how they use observations of tides when surfing:

> *"Depending on the shape of the ocean floor, a particular spot could be best for certain conditions at a high or low tide. So, we certainly watch tides, there are spots that are best at a high tide, there are spots that are best at a low tide, and incoming tide, outgoing tide."* (S1)

Surfers emphasized the bottom composition (e.g., sandbars, cobbles), structure (e.g., reefs and points) and features (e.g., large boulders). They also spoke about how depth, tides and currents influence waves, as well as how water flows may alter and create channels in sandbars. Surfers did not typically talk about marine plants or animals (other than seals), some of them explained that they prefer focusing on being on the water instead of thinking about what's swimming underneath. An interviewee in the surfer user group described how the shape of a wave can be an indicator of the shape of the seafloor:

> *"I'll always look at the shape of the wave to then to try to think about what the bottom might look like underneath."* (S3)

Kayakers and recreational boaters spoke about water depth, tides and organisms they observed, as well as the location of sandy beaches and exposed rocks. Shallow water depths allow boaters and kayakers to observe the seafloor as they paddle, but may prevent access to certain locations (e.g., boats touching the ocean bottom). Kayakers noted that high tides allow access to certain areas, for example, during high tides, one might be able to paddle through the rocks around islands near Owls Head, something that is not possible at lower tides. Kayakers paddling in shallow coastal waters described searching for sea life as one of their goals (e.g., looking for fish, crabs, sand dollars, sea urchins, eelgrass and other undersea plant life, etc.). Boaters and divers spoke about features like shipwrecks (e.g., a four masted schooner in Ship Harbour), as well as harvesting of fish and bivalve mollusks in the area (e.g., scallops).

Commercial clam fishers spoke about marine fish and invertebrates (e.g., clams), the bottom composition (e.g., mud, sand), structure (e.g., clam flats) and features (e.g., large boulders). Fishers also discussed tides, as well as knowledge about conditions and the history of fisheries in the area. Low tides expose clam flats, and therefore determine when harvesting occurs. An interviewee noted that they leave by boat to start digging when the tide is half down. Tourism operators emphasized the geology of the seafloor, which relates to structure, underwater features, composition (sandy bottom), in addition to tidal patterns and multiple marine species. Tourism operators described that tourists often seek sandy beaches on remote islands along the

Eastern Shore. Tourism operators also emphasized islands and underwater features (i.e., large underwater rocks), describing the topography of the seafloor as underwater islands:

"the islands and, the islands that didn't quite make it." (T1)

Residents spoke about bottom composition (sand, rocks, location of mudflats), underwater features (rocks) and exposed rocks (many of which had local names) and knowledge about fish, birds, and their seasonal migrations. Interviewees spoke about eels migrating up rivers in the fall, mackerel coming into harbours to feed on herring, smelts migrating towards rivers after the ice melts to spawn, and gaspereau coming into Clam Harbour in the spring. Residents shared insights into unique observations of the seafloor, for example, the seafloor in Ship Harbour is largely composed of muddy-soft sediment, built up from the effects of the logging industry. An interviewee described their diving experience in this area, where they never hit a hard bottom and instead just sank deeper into the soft sediment.

4.2.2 Activities and ideal locations for the activities as directed by the shape and composition of the seafloor.

A common theme discussed by participants is that the shape and the substrate of the seafloor influence or dictate the types of activities possible at that location. The shape of the seafloor and of sandbars determines if an area is surfable and influences the type of wave found in a particular area. Interviewees in the surfer group explained that there are three types of wave breaks on the Eastern Shore, and how each are associated with different seafloor structures. Point breaks are pieces of land that extend into the water and are found at Cow Bay and Lawrencetown Beach. Reef breaks are created by large rocks and cobbles that create a reef structure, for example the Lawrencetown reef. Sandbars are present throughout the Eastern Shore's beaches, and are surfed at Lawrencetown Beach, Martinique Beach and Clam Harbour Beach. Point breaks and reef breaks are more predictable and consistent for surfing compared to beach breaks because sand naturally shifts. Waves crash due to friction and drag upon contact with the ocean floor and the shape of the seafloor determines how a wave will crash. Surfers described this interaction between the seafloor and waves as thinking about the slope of the water. A participant described the relationship between surfing and the seafloor as follows:

> *"The shape of the seafloor depicts the shape of the wave. Obviously, waves are energy moving through the water, and what makes a wave crash is friction on the ocean floor. So, the more abrupt that friction or obstruction is, the more abruptly the wave will break, and so that changes the shape of the wave. Of course, it takes more energy in order for those more abrupt breaks to work because they are going from really deep water to really shallow water quickly. What makes a good wave is good ocean floor."* (S1)

Surfers also indicated that they use mapping tools like Google Maps to find new surf spots or identify headlands that may be suitable for surfing. An indication of a potential break is where a point of land sticks out into the water.

Knowledge about the seafloor, including intertidal mud and clam flats, is also central to harvesting clams, as described by a commercial clam fisher. When asked how they know where to dig for clams, a participant explained that:

> *"The flats will tell me where to go."* (C1)

The locations chosen for clam digging depend on where the clams are, and this will change depending on the season, as well as based on previous harvesting patterns. The interviewee explained that they only take clams that are two inches in size, or larger from flats.

The size of clams can be predicted by the way that they "spit.", bigger clams "spit" higher. The interviewee explained how harvesters monitor populations and let flats regenerate and grow to ensure sustainable harvesting practices, which is similar to other fisheries like lobster (i.e., releasing females). Good future harvesting locations are identified at the end of the previous season, where harvesters assess how many clams are remaining in various areas of the flats. This knowledge was passed down from generations of clam diggers, as well as gained from personal observation.

The seafloor influences routes used for boating, kayaking and tourism tours, depending on the features people are interested in seeing (e.g., marine animals, sandy beaches, remote islands) and if areas are accessible. Surfers, boaters, and tourism operators spoke about the seafloor in terms of safety, where knowledge about the structure and features of the seafloor is crucial to safely enjoy marine environments and recreational activities. Awareness of rocks and obstructions is essential to safe boating and surfing, to avoid injuries to humans or damage to equipment. Along the Eastern Shore, there are over 700 visible islands, as well as other landmasses that have not broken the surface of sea level. Some of these submerged rocks, outgroups, or eroded drumlin remnants might be visible at low tide, and as such, the seascape was described as "rugged." Knowledge of where these rocks and obstructions are located was gained from experience boating or surfing. The relationship of these features to local tides and currents is also important when surfing, as rip currents may appear on sandy bottoms when a wave breaks and shifts a sandbar, creating a gap through which a rip current can flow. An interviewee spoke about safety while surfing:

> *"If you're surfing a new spot, you need to become really aware of where the rocks are and where you shouldn't be."* (S2)

Participants expressed that they often search for fine sand beaches, or parts of the seafloor with rich sea life. Knowledge about where the best swimming locations are is also based on the shape of the seafloor; ideal swimming locations are often found in secluded places with sandy bottoms.

4.2.3 Coastal, marine, and seafloor change.

The interviewees described changes to benthic systems, which they have observed through continued use of coastal waters. Interviewees described change both in terms of the routine, seasonal variations of marine ecosystems and cycles, and in terms of the accelerating effects of climate change. Change was noted within the lifetimes of participants and was based on their personal experiences, as well as on intergenerational knowledge. Observations or knowledge of change described by interviewees can be divided into three categories: physical change and the drivers of physical change, biological change, and changes in human use. Participants referred to change to coastal and marine organisms, and many also discussed change to coastal and terrestrial systems.

Table 2 summarizes observations of physical change and the drivers of physical change discussed by interviewees, where the blue boxes indicate which changes were mentioned by each group.

***Table 2**. Physical change and drivers of physical change identified by interviewees from different user groups, indicated by blue boxes.*

<table>
<tr><th rowspan="2">Observations of Physical Change and Drivers of Physical Change</th><th colspan="5">User Group Type/Activity</th></tr>
<tr><th>Surfing</th><th>Kayak and Recreational Boating</th><th>Commercial Clam Fisheries</th><th>Tourism</th><th>Resident</th></tr>
<tr><td>Increased wind</td><td></td><td></td><td></td><td></td><td style="background-color:#b4c7e7"></td></tr>
<tr><td>Sea level rise</td><td></td><td style="background-color:#b4c7e7"></td><td style="background-color:#b4c7e7"></td><td style="background-color:#b4c7e7"></td><td style="background-color:#b4c7e7"></td></tr>
<tr><td>Higher tides due to sea level rise</td><td></td><td></td><td style="background-color:#b4c7e7"></td><td style="background-color:#b4c7e7"></td><td style="background-color:#b4c7e7"></td></tr>
</table>

Movement of points and beaches (including seaward headlands and sandy beaches)					
Increased storm intensity and frequency					
Coastal erosion and beach erosion					
Channels cut into the seafloor due to boats					
Seasonal and yearly changes to sand and sandbanks, or seafloor					
Changes to clam beds					
Loss of sea ice					
Channels in clam flats have been filling in					
Disappearance/creation of islands					

Interviewees described how change is normal and part of the natural dynamics of marine and coastal systems. Interviewees spoke about seasonal and yearly changes, variations to sand and clam flats, as well as other types of change which may be accelerated by climate change. The most common observations of change and drivers of change were increased storm intensity and frequency, sea level rise and coastal and beach erosion. Evidence of these changes was described as shrinking headlands, cliffs being cut away, beaches marching inland, points moving up harbours, breaching of barrier ponds to the sea, and the creation of inlets. These are examples of changes in coastal morphology that in turn will influence the seafloor along with the structure of the coastline and associated features. For example, an interviewee described their observation of this type of change at Marsh Point, in Jeddore Harbour. The interviewee described how Marsh Point has moved up harbour about 50-60 meters over the last 15 years:

"That is a very radical movement of that beach. And it's a sandy beach with cobbles on the leading edge, and it's quite silty on the back edge up harbour. I

had sensed that it had moved, but it wasn't until I looked at the Google Earth images to see how much." (B3)

Change was also observed on Clam Harbour Beach, where the headland has disappeared, and the beach is marching inland. These observations were made by comparing current satellite imagery to photographs from the 1930s. The lagoons in Three Fathom Harbour have also moved 50-60 meters over the last 13 years, causing the beach to be pushed inland, as well as the opening of the lagoons due to erosion. Interviewees described this change as impacting habitat in the lagoons:

"Those breaches would have then caused a really significant change in the habitat in what would have been briny pools, but now they are completely marine." (B3)

Storms were identified as drivers of erosion, which was also discussed in terms of islands including the disappearance or splitting of islands, sometimes forming new, smaller islands. An interviewee spoke about the disappearance of an island on the southernmost point of Chezzetcook, which appeared in photographs in the 1940s, this island had heritage features on it including a house and barn. Interviewees spoke about how winter storm frequency and intensity are increasing, there tends to be one storm per week during the winter:

"Certainly, there are storms that reach 80 to 100 km/h every winter and that is very significant, that is getting close to a Hurricane status." (B3)

Channels in the seafloor have also filled in due to storms, erosion and other factors which has affected species distributions (e.g., clams), and has allowed for the extension and growth of marshy grasses. An interviewee in the clam fisher user group described how a marsh is slowly overtaking Clam Harbour due to channels filling in, which will change clam flats. Channel morphology in Clam Harbour is not as wide or as deep as it used to be; in the past, some channels were 15 feet deep at low tide, but you can now walk across them. In some areas, such as Clam Harbour, the seafloor has become more compact due to the accumulation of sand, and this compaction has made harvesting clams possible in areas where it was not previously. An interviewee described this change as the solidifying of "mucky" areas, allowing them to walk on the clam flats and harvest clams in areas where it wasn't previously possible.

Interviewees in four of the user groups talked about sea level. They spoke about how the rising sea surface is leading to the deterioration of wharves in communities, covering exposed rocks, and impacting vulnerable archeological locations, many of which are located on seaward headlands and sandy beaches. The Eastern Shore coastline was described as "fingers of rock" that stick out into the ocean, creating points and islands, which are being eroded and flattened by sea level rise. Residents observed changes to sea level from land encroachment on their property and were able to measure the change in tide extent based on their fence, where the water reached past where it used to. Participants perceived that tides are higher than they used to be, due to the ocean being higher. The high tide is now reaching places that it has not previously reached due to sea level rise. With the tidal zone shifting landward, areas previously exposed at low tide are now permanently submerged or only exposed during extreme low tides (e.g., submerged clam flats), preventing access to certain areas and changing habitats. An interviewee also described the seasonal change in tides, where tides move quicker in the spring and fall than in the summer, which creates shifts in the ecosystem, changing the flats, and sometimes creating new spots suitable for clam digging.

Interviewees described how sand is always shifting and changing on seasonal and yearly bases. Surfers described that these short-term variations in sand structure affect swell conditions and beach breaks, as they change the shape of sandbars. After an extended period of small swell, the sand will be pushed onto the beach and collect on rocks, but a big storm will retract the sand as the waves crash onto the beach and the water rushes back to the open ocean. Surfers have not observed changes to the underwater reefs, points and rocks that create waves and surf breaks. There was concern that surfing spots, especially beach breaks may change over time due to climate change and sea level rise; however, they also commented that climate change and storms may bring more waves to the area.

Interviewees in three user groups spoke about the loss or decline of sea ice. This change was observed in Clam Harbour, as well as other areas of the Eastern Shore, and was identified as important because ice creates new channels through the seafloor, generates new clam flats, kills green crabs, and promotes the growth of clams. An interviewee described how ice is important for clam growth; cold water drips over the clams as ice melts promoting their growth and protects clam flats over the winter. Freeze-thaw patterns also help mix ecosystems and move the flats around. Sea ice was also discussed in terms of coastal protection, acting as a buffer to winter storms to reduce coastal erosion. In particular, residents observed that there was no longer an ice wall on Clam Harbour Beach during the winter. The recent sea ice in Clam Harbour was described as:

"Not consistent, it'll freeze, but it won't freeze as hard." (R1)

Interviewees in the kayak and boating user group identified an area where boats left marks in the seafloor, which altered the seafloor and removed eelgrass beds. This change is due to human use and impacts both physical and biological components of the seafloor. The interviewee described the change:

> *"You can see the boating channels, especially through Little Harbour, you can clearly see the channels where boats come through, there's no eelgrass there but there is eelgrass on either side."* (B1)

Table 3 summarizes observations of biological change discussed by different user groups; this knowledge was mostly focused on change to marine plants, fish, and invertebrates.

Table 3. *Biological change identified by interviewees from different user groups, indicated by blue boxes.*

Observations of Biological Change	**User Group Type/Activity**				
	Surfing	Kayak and Recreational Boating	Commercial Clam Fisheries	Tourism	Resident
Increased number of green crabs					
Invasive green crabs on eelgrass beds					
Fewer sea urchins, sand dollars, starfish					
Fewer fish (herring, trout)					
Less eelgrass and plants					
More mosquitos					

Interviewees in three of the five groups identified increased numbers of invasive European Green Crabs (*Carcinus maenas*) and fewer native fishes (herring, mackerel, smelts, eels, gaspereau) as observations of biological change, while interviewees in two user groups identified fewer marine invertebrates, such as sea urchins, sand dollars, and starfish. Residents also identified changes to seabirds, increased sightings of bald eagles, and fewer herons. Some participants were more specific with their description, indicating that there were more green crabs on eelgrass beds, and that green crabs covered clam flats. During recent eelgrass surveys around Owls Head, interviewees observed green crabs eating eelgrass shoots. Participants spoke about how they started observing an increase in green crabs around the early 2000s, and that the numbers observed have been increasing since then. The increase was linked in their minds to the loss of sea ice, which usually kills green crabs; however, this is not the only factor which favours the growth of the invasive species. Observations of change to eelgrass were dependent on area: research surveys around Owls Head found that eelgrass beds were in good health, assessed by measuring shoot density and blade length. However, residents and fishers have observed less eelgrass in harbours, as well as the complete disappearance of eelgrass beds in Clam Harbour. It was hypothesized that the decline in sea urchins may have effects on eelgrass, as urchins consume eelgrass blades. When speaking about the decline in fish populations, interviewees speculated that storms might have brought down trees and blocked the channels or rivers used for spawning. Participants of various ages referred to the decline of fish populations in relation to their memories of fish stocks growing up on the Eastern Shore, or to intergenerational fishing knowledge (e.g., there used to be Atlantic salmon near Clam Harbour). An interviewee described the decline in herring in Clam Harbour in comparison to personal observations and knowledge from past generations:

> *"I've seen a few more herring this year, but not like it used to be. At one time in Clam Harbour, you wouldn't see the bottom of the channel, the herring were that thick."* (C1)

Table 4 summarizes observations of changes in human use discussed by interviewees in different user groups.

Table 4. *Changes to human use identified by interviewees from different user groups, indicated by blue boxes.*

Observations of Changes in Human Use	**User Group Type/Activity**				
	Surfing	Kayak and Recreational Boating	Commercial Clam Fisheries	Tourism	Resident
Concern about the effects of increasing human activity and disturbances		■			
Increased number of people using the marine environment	■			■	
Reduced coastal access	■		■		
More development along the coastline	■				

Surfers and tourism operators spoke about how they observed an increase in people using the marine environment for recreational purposes. Interviewees in two user groups spoke about changes to coastal access, where accessing surfing and fishing locations has become a challenge due to the privatization of land along the coast. Interviewees also mentioned their concern for the impact of increased coastal development and human use on ecosystem health, referred to when speaking about the Owl's Head Provincial Park Campaign.

4.2.4 Coastal plants, wildlife, and marine life.

Knowledge and observations of coastal, marine, and benthic organisms was a common theme throughout interviews with all types of recreational and commercial users. Interviewees mentioned various fish, birds, mammals, reptiles, invertebrates, and plants. Their observations were not limited to the plants, fish and invertebrates only found on the seafloor, and included terrestrial, coastal, intertidal, and marine species (including benthic species). Table 5 presents a list of flora and fauna observations, where the blue boxes indicate if a participant group spoke about a given type of organism. Interviewees in three or more user groups spoke about: eelgrass, eagles, green crab, kelp, mackerel, sea run trout, seals, and shorebirds.

Table 5. *Coastal plants, wildlife, and marine life identified by interviewees from different user groups. The blue boxes indicate which organisms were spoken about by each user type/activity.*

	Participant Group Type				
	Surfing	Kayak and Recreational Boating	Commercial Fisheries	Tourism	Resident
Birds					
Barn swallows					■
Black backed gulls		■			
Blue jays					■
Cormorants		■			■
Dark eyed junco					■
Ducks			■		■
Eagles		■	■		■
Eider		■			
Geese					■
Goldfinches					■
Herring Gulls		■	■		
Ospreys		■			■
Plovers		■			
Ravens					■
Sanderlings					■
Sandpipers		■			■
Seabirds		■			
Shorebirds		■	■		■
Terns		■			■
Warblers					■
Yellow crowned heron					■
Fish					
Atlantic Salmon					■
Bass	■				■
Eels			■		■
Flat fish					■
Gaspereau (Alewife)					■
Herring			■		■
Mackerel		■	■	■	■
Ocean sunfish	■				
Schools of fish	■				

Sculpins					
Sea run trout					
Sharks					
Smelts					
Triggerfish					
Tuna					
Invertebrates					
Bar clams					
Clams					
Dog whelk					
European green crab					
Jellyfish					
Lobster					
Moonsnails					
Mussels					
Periwinkles					
Portuguese man o' war					
Quahog clams					
Razor Clams					
Rock crab					
Sand dollars					
Scallops					
Sea anemones					
Sea urchins					
Soft shell clams					
Starfish					
Surf clams					
Mammals					
Deer					
Dolphin					
Foxes					
Otters					
Pilot whales					
Porpoises					
Seals					
Plants					
Eelgrass					
Kelp					
Marsh Grass					
Rockweed					
Reptiles					

Leatherback sea turtle					

An interviewee described how high and low tides affect birds in intertidal zones, especially linked to their behaviours and how they feed during low tide cycles:

> *"It really changes the landscape from high tide to low tide on our Harbour because there are mudflats that are exposed at low tide, and then when that happens that changes the behaviours of birds, you'll see herring gulls and black backed gulls going after crabs."* (B3)

Birds were described according to their habitats as well (e.g., mudflats, sandy beaches), and interviewees indicated how different areas and tides favour different species:

> *"Eagles will perch on the mudflats because it's a convenient location. We have terns and cormorants and sometimes eider, and they behave differently according to the tides, and certainly the smaller shore birds, like the plovers and sandpipers, they like it when the tide is going out, especially when it goes out quite a ways."* (B3)

Residents also described how some of these fish and invertebrates (e.g., triggerfish, Portuguese man o' war) are not native to the Eastern Shore and Nova Scotia and come up with warm currents.

Chapter 5: Discussion

The results of this study demonstrate that users of coastal and marine spaces have localized knowledge of the seafloor along the Eastern Shore, in areas where they are involved in recreational and commercial activities. The locations where these activities take place are linked to the seafloor, and interviewees spoke about different elements of the seafloor depending on their activities, including observations of structure, composition, underwater features, and species. This knowledge was gained through experience and continued use of marine environments, which also allowed users to observe changes to coastal and marine spaces.

5.1 Connections between coastal and marine systems

In their interviews, participants spoke about many different areas of coastal and marine environments, including the connections between the coast and intertidal, nearshore, offshore and seafloor spaces. These linkages were further extended to the relationships between freshwater, estuarine systems, and the sea, as some participants spoke about rivers feeding into harbours, and the ways in which streams cut channels into the seafloor or are used as spawning habitat by fish. Participants also spoke about a wide range of fish and marine animals, including how they migrate between sea and freshwater, reflecting the interconnection of land-sea interfaces. Change was primarily spoken of in terms of coastal ecosystems (erosion, sea level rise), and changes to sand on beaches. Participants hypothesized that sediments from the coast likely end in up the ocean as material lying on the seafloor due to erosion on cliffs and points. The boundary between marine and terrestrial ecosystems can be described as a transition zone, where both systems interact and influence each other (Talley *et al.,* 2003). Throughout their interviews, participants spoke about the seafloor in relation to other coastal, marine, and terrestrial resources, organisms and areas which reflects the dynamic boundary of benthic zones.

Valuable species and landscapes or seascapes identified by people can act as boundary objects, providing alternatives to the hard boundaries used in traditional marine management (Zurba, 2022). It is important to recognize the system-wide interactions and interconnectedness of coastal and marine spaces, as well as the permeable boundary, or lack thereof, of the seafloor as described by local users of coastal places. Interviewees spoke about how sediment from the coast may be deposited on the seafloor due to erosion, how fish move from salt to freshwater, and how certain birds inhabit both land and sea. These are examples of how local users and residents interpret and view marine space, and determine their own boundaries based on experience and observations. In this case, boundaries do not divide and categorize ecosystems, but instead reflect the fluidity and interactions between coastal and marine spaces.

5.2 Marine and coastal species as indicators of benthic change

Participants spoke about their observations of marine and coastal plants, animals, fish, invertebrates and more, providing insight into where these are found in different parts of the benthic environment, from tidal to offshore zones. There is a relationship between sediment type and megafaunal communities, where different species are found on distinct bottom substrate types (e.g., hard substrates like rocks, soft substrates like mud, silt) (Lacharité & Metaxas, 2017). Plants were identified during interviews as associated with certain bottom substrates or seabed features; for example, eelgrass was observed on sandy bottoms and rockweed was found on rocky features and shores. The findings of this study demonstrate that people make observations about their local environments and recognize change. Change in visible parts of the seafloor, for example to marine flora and fauna or shape or sediment or ocean conditions, may be an indicator of possible change in deeper benthic areas, or could at least signal that change might be happening there too. Declines in fish populations (herring, smelts, gaspereau, mackerel, eels) and eelgrass beds were mentioned, which could be due to changing seafloors, or human use, all of which could alter the functioning of habitats and the survival of species. Additionally, a link was made between increased numbers of green crabs found on eelgrass, and the potential negative impacts of this species on eelgrass beds. The impacts of green crabs have been studied, where green crab foraging and tearing of eelgrass shoots has led to declines in eelgrass abundance (Garbary *et al*., 2014). Participants started to observe green crabs around the late 1990s and early 2000s, which aligns with the timelines found in literature on the invasion of the species in Nova Scotia (Audet *et al.,* 2003). Local observations of plants, fish, invertebrates, and animals can be used to determine the composition or structure of the seafloor and act as indicators of change.

5.3 Impact of change

Change, and the effects of climate change, were central themes discussed by all the interview participants. Sea level rise, increased storm intensity and frequency and increased coastal and beach erosion were the most prevalent observations of change or drivers of change. Climate change projections and future scenarios can help us predict change to marine and coastal environments through biological and physical studies, while local knowledge can illustrate how change is happening and its effects on vulnerable groups (Naess, 2013). On the Eastern Shore, change affects marine resource users, as well as the economies and culture of coastal communities. Benthic environments, including estuaries and mud flats are highly productive areas and are increasingly affected by climate change. Studies have shown that sea level rise could negatively impact primary productivity in estuaries due to reduced light penetration to the seafloor, however, this may be offset by the expansion of intertidal zones inland (Douglas *et al*., 2022). Interviewees identified similar changes to the bays and harbours around the Eastern Shore, where sea level rise has resulted in certain clam flats being permanently submerged, as well as the encroachment of tides onto properties. The ecological knowledge and observations of change documented throughout this research project can provide insights into how climate change is affecting the environment, and its associated impacts on residents and local users.

The local knowledge collected in this research provides an understanding of how change is affecting the identity, wellbeing and livelihood of people on the Eastern Shore, describing how people perceive and experience change to their local environments. As described during interviews with boaters, islands are being washed away by erosion, and participants expressed that they do not know where the islands go once they disappear from the surface of the water. It was suspected that some of the sediment gets washed out to sea, while stones might settle into the sand, with boulders vanishing into the smaller sediment around them. The landscape of the Eastern Shore changes as a result and may lead to the loss of cultural and heritage sites (Spike, 2019). A participant described the effects of storms on heritage sites:

> *"There would certainly be underwater archeological resources that are being affected by the change in storms and the progression of time."* (B3)

Erosion is a natural process but is accelerated in part by sea level rise and increased storms, which will affect ecological, economic, social, and cultural aspects of the Eastern Shore. Sea level rise means that waves can reach areas which were not previously affected by erosion, altering shorelines and tidal habitats. Participants spoke briefly about the threat of storms on community wharves and infrastructure, and the need to address and mitigate community vulnerability to climate change impacts. Awareness of change in storm events on the Eastern Shore was apparent, and participants voiced their concerns. For example, *"The change in the strength of storms, I think that some people are aware of that, I think that they should be more aware of that really, the abundance of storms and the strength of them, I am sure is increasing, and that will change life."* (B3)

Understanding how change is observed on the seafloor and coasts by local users can help communities better adapt to climate change. Recording and documenting this change, including the findings of this research project can be useful for climate change adaptation measures.

5.4 Bringing together knowledge to gain a better understanding of the seafloor

As seen by the findings of this research, users emphasize different areas and elements of the coast and seafloor. Combining the experiential knowledge of various users and their observations acquired through recreational and commercial activities can create holistic and richer understandings of how people perceive the features and the conditions that are important for their activities, as well as the change they observe to these systems. These understandings can fill gaps in current marine and coastal management practices, and present different ways to perceive and manage these places. Although the seafloor is being mapped using different types of technology, data sets are incomplete and we still have a limited understanding of these ecosystems (Brown *et al.,* 2011). Documenting traditional and local ecological knowledge can help address and fill this gap, as well as contribute a different type of information which can not be captured using technology (e.g., socio-cultural dimensions). Studies have shown the benefits of engaging with fishers to create maps based on both scientific and traditional or local ecological knowledge (McKenna *et al.,* 2008; Teixeira *et al.,* 2013), but this research suggests that extending engagement to other types of users including recreational users and residents is valuable to develop a holistic understanding of the seafloor.

Mapping can facilitate knowledge co-production and can be used as a tool to include local knowledge in decision-making. Cross-cultural knowledge sharing through mapping and engagement has been used as a method to bridge Indigenous and Western knowledge, where both forms of knowledge are respected and valued side-by-side (Davies *et al.,* 2020). Similar knowledge sharing methods can be used with non-Indigenous local knowledge, which can provide new perspectives and lead to a richer understanding of human-environment relationships and the state of marine environments. This research provides valuable information on how local people use and engage with coastal and marine space and resources, as well as how they observe change to these ecosystems.

Participants identified uses, where these activities take place, and ecological components. The types of activities and organisms identified are similar to the findings of the WITAP project related to recreational uses of the Eastern Shore Islands (EDM Planning Services Ltd., 2018). Combining these datasets would bring together knowledge and observations from different areas of the Eastern Shore and would visualize where uses may overlap. Documenting local knowledge can also be important and relevant to communities. Many interviewees noted that their knowledge was gained through a combination of personal observations and intergenerational knowledge, passed on from family or community members. Some of the topics mentioned, like past fish stocks and heritage fisheries are not within living memory anymore. It is hoped that the local knowledge recorded through this study will be useful to the interview participants, as well as to Eastern Shore communities, acting as a record of local marine and coastal knowledge.

5.6 Relevance to decision-making

The Eastern Shore has a complicated relationship with conservation and management decisions, especially those focused on marine protection initiatives which overlap with important economic activities (e.g., lobster fisheries) (Withers, 2019a; Moreland *et al.,* 2021). Community mistrust and opposition is rooted in historical conflicts between the Government of Canada and local people, originating from the proposed establishment of a national park in Ship Harbour, and continuing around DFO's Eastern Shore Islands Area of Interest (Moreland *et al.,* 2021; Froese-Stoddard, 2013; Hammond, 2018). Understanding how people speak about and interpret coastal and marine environments as well as the value of these places to local identities and livelihoods can help managers better tailor decision-making to the realities and objectives of communities. During interviews, participants identified the locations of various plants, marine life and wildlife, their uses of the seafloor and the coast, and change to significant species and places. This research documented localized marine knowledge of the Eastern Shore, as well as how communities are observing change. Local knowledge and observations should be included in how we plan and implement the management of seascapes and resources along the Eastern Shore and elsewhere.

5.7 Gaps and future areas of study

This research project focused on interviewing recreational users and commercial users. Although it provided insight into how local users speak about and engage with benthic spaces, it does not encompass all user types and perspectives found on the Eastern Shore. Conducting similar work with other with recreational users such as divers and sailors would deepen understandings of the seafloor from other perspectives. Exploring participatory mapping workshops with multiple people belonging to the same user group could also be interesting to see how or if knowledge overlaps, and how people speak about these spaces amongst each other. In particular, commercial fishers other than clam harvesters would contribute an important perspective on the seafloor. When speaking about the lobster fishery on the Eastern Shore, a resident described how they remembered that a lobster fisher in the community "*would have the whole seafloor in his head.*" (R1). They spoke about fisher knowledge of the seafloor:

> *"The benthic layer with respect to lobster, there is another invisible map. And everybody knows where it is, but its not marked down anywhere."* (R1)

This is consistent with studies on fisher knowledge of the seafloor, and traditional knowledge of fish and invertebrates based on observations *(*McKenna *et al.,* 2008; Teixeira *et al.,* 2013*).* The BEcoME project team will continue this work and hopes to interview commercial fishers (e.g., lobster fishers) on the Eastern Shore in 2023 and beyond.

Maps were used in this research to anchor stories and as a visual tool to help elicit knowledge during interviews. They helped support the ways in which people spoke about coastal spaces and the seafloor. The use of maps was especially effective during in person interviews, where participants were able to draw on maps as they spoke about different uses, species and significant features and areas. Annotating maps did not work as well during virtual interviews (via screensharing on Microsoft Teams), as it was harder to draw lines and point to areas. These maps can be used to show local knowledge and use of space, in a way that can be overlayed with other forms of data (e.g., ecological and physical data), and can contribute cultural and social dimensions to decision-making. There is an opportunity to create digital maps based on the findings of this research project, to visualize the knowledge and observations of marine and coastal users using GIS software. The information could also be overlayed with other data sets. Interviewees spoke about coastal landscapes and different parts of marine ecosystems (e.g., intertidal, nearshore) in their answers to interview questions, further research could be conducted to explore the boundaries of benthic spaces as viewed by local users and residents.

This research was focused on local perspectives of individuals, regardless of their cultural or ethnic background. Mi'kmaw perspectives in relation to the seafloor are being explored by the BEcoME project in other parts of the province in collaboration with Mi'kmaw organizations. Additionally, the BEcoME project seeks to bring together the material collected by various academic and non-academic projects by assembling many types of information and knowledge about the benthic environment along the Eastern Shore into a single product, which will be publicly available in the form of an ESRI StoryMap. The knowledge collected in this graduate project will be included, in addition to heritage fisheries datasets, the products of the WITAP project (2018), DFO's Coastal Resources Mapping Project (1990s), Dr. Sara Spike's Eastern Shore Islands Heritage Research Project (2017), the Eastern Shore Coastal Community Mapping Project (2018) and more.

Finally, the number of interviews was limited to ten due to the short time frame of this research project, participant availability and interruptions due to Hurricane Fiona. Hurricane Fiona at the end of September 2022 impacted data collection: some interviews were cancelled either because travel to the Eastern Shore was not possible, interviewees were no longer available (dealing with storm impacts), or prolonged power outages interfered with using virtual meeting platforms. There was not enough time to reschedule interviews once power and access had been restored to communities. Meeting after the storm could have been an opportunity to speak to people about some of the changes they observed to the seafloor after the storm.

Chapter 6: Conclusion

Recreational and commercial users of coastal waters have localized knowledge of the seafloor along the Eastern Shore, which is specialized to the needs of their interests and uses. They pay attention to the seafloor because their vocations and activities rely on it. They emphasize different elements, ranging from observations on structure, substrate composition, underwater features, and species. The shape of the seafloor influences where marine activities may best be undertaken in different parts of the ocean and coast. Recreational and commercial users spoke about the changes they have experienced or observed related to the physical and biological elements of the coast, sea and seafloor. Additionally, they spoke about observations of plants, wildlife and marine life, and the links between terrestrial and marine ecosystems. Local, experiential knowledge can provide a better understanding of the seafloor, and how it is used or perceived by different users. It is important to find ways to document this knowledge, and consider it in decision-making pertaining to coastal, marine, and benthic environments, especially due to the increasing impacts of climate change on the world's oceans. Climate change is affecting local economies and activities, as well as peoples' experiences of place. Local users and residents of the Eastern Shore understand the lands and waters surrounding their communities, which stems from their place-based livelihoods and identities; capturing and documenting these understandings is valuable to both communities and management.

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Appendix I – Interview Questions

Research question: How do local recreational and commercial users of coastal and marine spaces engage with and talk about benthic spaces along the Eastern Shore of Nova Scotia, Canada?

1. How long have you been out on the Eastern Shore, and using the marine environment?
    - What type of activities do you do in marine spaces?

2. Along the Eastern Shore's coast and waters, where do you spend time? What beaches, harbours, islands etc. do you go to?

3. How do you decide where you want to go for a given activity?

4. How often do you spend time in the area? Is it seasonally dependent?

5. How did you first discover or start using this area?
    - Are these areas well known in the community?

6. Do you have a favourite area or spot? Why?

7. Why is this area important to you?

8. Do you follow specific routes or trails when you go out on the water?

9. How do you consider the seafloor when you go out boating/harvesting/fishing. How are you aware of it?
    - How does the seafloor impact how you do a given activity?
    - Where/how did you gain knowledge about the seafloor?

10. Based on your experience, can you identify seafloor features, benthic species, or other features? Where are these places on a map?
    - Species, seabed composition, features, depth

11. How are you aware of tides, currents, and waves?

12. Have you observed changes in the area through time? What changes?
    - Related to habitat, species present and characteristics, human activities?
    - Are there areas of concern? Climate change?

13. Do you use the area for other recreational of commercial uses?
    - Do you know of other uses in the area?

14. Is there anything else you would like to touch on?

Appendix II – Interview Participant Codes

List of individual interview participants, and associated codes which are used for in-text quotes.

Code	User Group
B1	Kayaking and recreational boating
B2	Kayaking and recreational boating
B3	Kayaking and recreational boating
C1	Commercial clam fishing
R1	Resident
R2	Resident
S1	Surfing
S2	Surfing
S3	Surfing
S4	Surfing
T1	Tourism