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Biophysical and Ecological Overview of the Eastern Shore Islands Area of Interest (AOI)

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Canada

Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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LIST OF ACRONYMS

ADCP	Acoustic Doppler Current Profiler
AIS	Aquatic Invasive Species
AOI	Area of Interest
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CPUE	Catch Per Unit Effort
CSSP	Canadian Shellfish Sanitation Program
DEM	Digital Elevation Map
DFO	Fisheries and Oceans Canada/Department of Fisheries and Oceans
EBSA	Ecologically and Biologically Significant Area
ECCC	Environment and Climate Change Canada
ECSAS	Eastern Canada Seabirds At Sea
EI	Eutrophication Index
ESI	Eastern Shore Islands

ESS	Eastern Scotian Shelf
ESSCP	Ecologically Significant Species and Community Property
FSRS	Fishermen and Scientists Research Society
IBA	Important Bird Area
ITQ	Individual Transferable Quota
LEK	Local Ecological Knowledge
LFA	Lobster Fishing Area
LiDAR	Light Detection and Ranging
MLS	Minimum Legal Size
MPA	Marine Protected Area
MPN	Most Probably Number
NAFO	Northwest Atlantic Fisheries Organization
NLM	Nitrogen Loading Model
OEABCM	Other Effective Area-Based Conservation Measures
PEL	Probable Effects Level
SARA	Species at Risk Act
SFA	Scallop Fishing Area
SSB	Spawning Stock Biomass
TAC	Total Allowable Catch
TEK	Traditional Ecological Knowledge
VME	Vulnerable Marine Ecosystem

ABSTRACT

The Biophysical and Ecological Overview of the Eastern Shore Islands Area of Interest (AOI) summarizes what is known about key physical and biological components of the Eastern Shore Islands ecosystem. These key attributes and description of their ecosystem function can be used to inform the development of Conservation Objectives and management measures, should the study area be established as a Marine Protected Area under Canada's *Oceans Act*. The Eastern Shore Islands is a unique and complex archipelago system that has low human impact and a high degree of naturalness. Diverse habitat types consisting of bedrock, cobble, and sandy substrates, Eelgrass (*Zostera marina*), Rockweed (*Ascophyllum nodosum*), kelp beds, mud flats, and salt marshes are associated with the more than 200 nearshore islands encompassed within the AOI boundaries. These habitats provide important nesting, foraging, and overwintering habitat for large numbers of marine birds, including two endangered species – the Roseate Tern (*Sterna dougalli*) and Piping Plover (*Charadrius melodus*). Eelgrass and kelp beds provide important habitat for juvenile groundfish in this region, including Atlantic Cod (*Gadus morhua*) and Pollock (*Pollachius virens*). Subtidal Rockweed beds in the AOI have higher species richness and abundance of associated fish and invertebrates compared to southern Nova Scotia and areas devoid of Rockweed. The Eastern Shore Atlantic Herring (*Clupea harengus*) spawning area, an important component of the coastal spawning component, overlaps with the western portion of the AOI. Rivers and estuaries leading into the study area provide important migratory habitat for diadromous fishes including American Eel (*Anguilla rostrata*) and Atlantic Salmon (*Salmo salar;* assessed as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC)), which migrate through the AOI to reach feeding and spawning areas. American Lobster (*Homarus americanus*), found throughout the study area, support an important commercial fishery in the Eastern Shore. Other invertebrates common to the area include molluscs, echinoderms, crustaceans, tunicates, and polychaetes that are associated with high habitat heterogeneity. Within the Eastern Shore Islands AOI, Harbour Seals are present and there are two inshore colonies of Grey Seal (*Halichoerus grypus*), but otherwise the area has no recorded significant habitat for other marine mammal species. The area is highly natural, with lower levels of contaminants in the water and sediments, lower human impacts, and fewer invasive species than southern Nova Scotia and the Bay of Fundy. The diversity and complexity of this highly natural habitat, in conjunction with juvenile fish nurseries and extensive marine bird foraging grounds, make this a unique and important ecosystem to the Scotian Shelf Bioregion. Though the full extent of biological diversity has yet to be quantified, it is likely that the unique habitat characteristics of the AOI are associated with a distinctive and diverse assemblage of bird, fish, and invertebrate species.

INTRODUCTION

The Government of Canada has put in place a plan to reach domestic and international marine conservation targets by increasing the proportion of Canada's marine and coastal areas that are protected to 5% by 2017 and 10% by 2020 (ECCC 2016). Fisheries and Oceans Canada (DFO) is leading the development of the national Marine Protected Area (MPA) network on behalf of the Government of Canada. Network development is guided by the *National Framework for Canada's Network of MPAs* (Government of Canada 2011) and is comprised of both Oceans Act MPAs and Other Effective Area-Based Conservation Measures (OEABCM; DFO 2016). As part of this commitment to meet conservation targets, the Eastern Shore Islands was announced as an Area of Interest (AOI) for potential MPA designation on March 22, 2018.

The Eastern Shore Islands are an archipelago spanning Clam Bay, near Jeddore Harbour, to Barren Island, near Liscomb Point and extending seaward to a depth of approximately 100 m (Figure 1). There are 282 islands between Clam Harbour and Mushaboom, with approximately 45% of these being larger than one acre. Many of these islands (approximately 2800 hectares) are protected and managed by the Province of Nova Scotia, the Nova Scotia Nature Trust, and through the 100 Wild Islands Legacy Campaign. The density of islands in the Eastern Shore is three times greater than any other stretch along the Scotian Shelf, with an average of 1.4 islands per kilometre of mainland coastline (Hill et al. 2012). Terrestrial and marine habitats associated with these islands support a diverse and unique assemblage of fauna. The boundaries of the AOI encompass this archipelago and were used to evaluate the biological and physical attributes of the ecosystem. However, in order to ascertain the necessary breadth and scope of information required to describe some ecosystem components, information derived from areas adjacent the AOI within the coastal planning area of the Scotian Shelf Bioregional MPA Network (roughly defined as the area inshore of the 100 m isobath) were also considered.

The AOI was initially identified as part of an Ecologically and Biologically Significant Area (EBSA) (Hastings et al. 2014), principally due to the unique concentration of nearshore islands, its complex coastline, and globally significant concentrations of marine birds. The AOI meets the EBSA criteria for uniqueness (the size and density of the islands is provincially unique), aggregations of marine birds, and fitness consequences (breeding marine birds, seals, and Atlantic Herring) (Hastings et al. 2014). The site was identified as a candidate for AOI designation in 2017 through the coastal network site selection process that evaluated coastal EBSA with reference to MPA network conservation objectives (DFO 2018a). This process prioritized the AOI because of its high naturalness, defined as "an area [that] exhibits a comparatively higher degree of naturalness resulting from little to no anthropogenic pressure" (CBD 2008, Hastings et al. 2014) and unique assemblage of physical and biological characteristics associated with the archipelago. It is noted by Hastings et al. (2014) that naturalness is highly relative and can be difficult to assess objectively, and in order to evaluate the AOI as an area of high naturalness in this overview, comparisons to other coastal regions in the Maritimes were made where the data were available.

OVERVIEW CONTENT

The objective of this overview is to provide information on key physical and biological features of the AOI as they pertain to existing conservation priorities, the subsequent development of conservation objectives, the identification of data deficiencies, and information for the development of management strategies. The key ecological features identified prior to this overview include the high naturalness of the area, complex and unique geomorphology, significant concentrations of kelp beds, Eelgrass, Rockweed, and salt marsh habitat, areas important for several fish and marine bird species including Atlantic Salmon (*Salmo salar;*

Endangered – COSEWIC), Atlantic Herring (*Clupea harengus*), Atlantic Cod (*Gadus morhua;* Endangered – COSEWIC), White Hake (*Urophycis tenuis*; Threatened – COSEWIC), Haddock (*Melanogrammus aeglefinus*), Harlequin Duck (*Histrionicus histrionicus;* Special Concern – SARA), Roseate Tern (*Sterna dougalli;* Endangered – SARA), Piping Plover (*Charadrius melodus;* Endangered – SARA), and the Purple Sandpiper (*Calidris maritima*), as well as a potential juvenile fish nursery (Table 1).

Information pertaining to the AOI, including unique physical and biological characteristics, habitat features, and the distribution, abundance, biology, ecology, and status of the species and/or populations of interest will assist in formulating and/or refining conservation objectives, delineating the proposed MPA boundary (and zones if required), and completing an ecological risk analysis to inform the development of the regulatory approach for the MPA. The information contained within could also inform subsequent advice on monitoring protocols and strategies, identification of information gaps requiring further research, and the development of a management plan for the area.

Overall the objectives for this ecological and physical overview are:

1. To evaluate, describe and map, where possible, the identified conservation priorities and other key biophysical and ecological features of the study area, including:
    a. predominant and/or unique physical and biological oceanographic characteristics;
    b. predominant, unique, and/or sensitive habitat features; and
    c. ecologically, socially/culturally and/or commercially significant species; depleted species; and marine mammals and birds.
2. Where appropriate, to identify relevance of the study area to the life histories of species of interest, species distribution and abundance (and status and trends where available), and the local abiotic and biotic factors influencing these.
3. To identify known sensitivities, resilience, and recoverability of habitats and species of interest within the study area.
4. To identify key uncertainties and knowledge gaps as they pertain to the current understanding of the existing environment and species of interest within the study area, and recommend measures to address these gaps, where possible.

The overview is organized into sections that detail the physical and biological features of the area, summarize these characteristics into a broad ecosystem description, and outline where sources of uncertainty and knowledge gaps exist. The physical features section describes the physical habitat, oceanography, geology, and chemical oceanography attributes of the AOI. The biological features section describes biotic composition of the AOI with detail on the biology and ecology of species of interest, including species of ecological significance and commercial value. The intended scope of this review is to provide a broad overview of the important attributes of the system and, as such, detail is limited to that required to describe existing conservation priorities or to develop conservation objectives.

PHYSICAL SETTING

DIVERSITY OF HABITATS

The Eastern Shore Islands AOI is a unique archipelago consisting of a diverse range of habitat types along a very complex coastline (Greenlaw et al. 2013). This AOI extends nearly 100 km in length and covers 2089 km^2. Bathymetry of the AOI extends from the low tide line to 100 m, approximately 22 km offshore (Figure 2). Greenlaw et al. (2011) classify the Eastern Shore Islands as “complex pelagic bay”, a classification that is otherwise represented by very large bays, such as St. Margarets Bay and St. Marys Bay. The AOI is named after the unique island archipelago that occurs along this stretch of coast. These islands provide important habitat for marine birds and haulout areas for seals. A diversity of benthic habitats are also associated with the archipelago, including sandy bottom, boulder and cobble fields, and mudflats. Nearshore and intertidal habitats include Eelgrass (*Zostera marina*) meadows, subtidal and intertidal kelp and Rockweed (*Ascophyllum nodosum*) beds, salt marshes (Hastings et al. 2014), cliffs, and rocky and sandy intertidal beaches (Greenlaw et al. 2013). This diversity of habitats provides important nursery grounds for demersal fishes, including depleted species such as Atlantic Cod and important habitat for American Lobster (*Homarus americanus*), for which a significant fishery exists. Overall, the area contains a high diversity of substrate types and macrophyte and macroalgae beds representative of Nova Scotian coastal habitats, yet is unique in regards to the density of nearshore islands and rocky reefs within the AOI. All locations referenced within the document are labelled in Figure 3.

COASTAL AND SEABED GEOLOGY

Modified from: King, E.L. 2018. Surficial Geology and Features of the inner shelf of Eastern Shore, Nova Scotia. Geological Survey of Canada Open File 8375.

The nearshore and inner shelf geology is derived largely from interpretations of sparse coverage of seabed-penetrating and seabed sonars, including sparse seismic and local multibeam bathymetric data, topographic relief images generated from Canadian Hydrographic Service spot depths, limited Light Detection and Ranging (LiDAR) bathymetry, grab samples and limited core samples. An understanding of the surficial geology (Figure 4) has implications for benthic habitat understanding, potential pipeline or cable routing, offshore seabed infrastructure and potential aggregate and/or gold resource development.

Bedrock

Seabed character of the inner Scotian Shelf along the open Atlantic coast is primarily governed by the bedrock morphology. The coastline and especially the outer islands along the entire Eastern Shore are primarily bedrock, and this character continues seaward to the paleo-low-stand of sea level at 65 m where sediment cover thickens. Harder, generally sandier beds stand proud of softer slate beds with several metres relief, giving a jagged topography with long ridges and valleys. Occasional faults, jointing and sculpting from multiple glaciations add to this relief. The seabed (Figure 4) pattern of these beds includes broad folds with plunging axes at several kilometres spacing, giving rise to a chevron pattern of V-forms in plain view. Landward of about 100 m water depth, the relief is quite pronounced and highly undulated. This bedrock topography can have a strong influence on the type and distribution and especially the patchiness of surficial deposits where bedrock is not sediment-covered.

Glaciation and glacial deposits

The glacial depositional and erosional imprint is strong in the area. The last continental ice sheet covered the entire Scotian Shelf, depositing a sequence of till and glacimarine mud and a series of moraines upon retreat (King 1970, King and Fader 1986). Repeated glaciations have eroded deep (tens of meters) channels that are generally extensions of the main embayments at the coast and the paths of former rivers. Stea et al. (1994) describe bedrock valleys up to 1 km across and up to 70 m deep, oriented both coast-parallel and coast-normal. These valleys are now largely sediment-filled but vary morphologically as broad smooth-bottomed valleys with unconsolidated sediment infill.

Glacial deposits take the form of isolated deposits of till (gravelly and cobbly diamict or boulder-clay) in the form of blanket deposits, drumlins, and moraines of various scales, and overlying glacimarine mud deposits infilling bedrock topographic lows (Stea et al. 1996, Stea et al. 1994, Stea et al. 1992). The deposits also include sets of large and small moraines marking short-lived still-stands during overall glacier retreat, the most significant of which lies beyond the inner shelf, shown in the geologic profile (Figure 4). The 50 m thick Country Harbour Moraine (King and Fader 1986) extends 70 km parallel to the shore, is 50 m thick, 5 km wide and includes a tongue on its seaward flank representing fluctuations of the ice margin (see Figure 4C). Landward of the moraine are thick glacimarine muds that accumulated while the glacier margin was in the marine realm. These are, in turn, capped with a broad continuous soft mud blanket derived from the erosion products of shallower areas partly eroded at a later time, when sea-level was lower. The Country Harbour Moraine was succeeded by deposition of a series of smaller, sub-parallel moraines, again paralleling the coast, formed parallel to the retreating ice margin. They reach 20 m relief, and some form a broad field of boulder and cobble-topped moraines of small and mid-size (profile and detailed map) lying just seaward of the 70 m depth contour. These moraines lie on top of the drumlins, cross-cutting them approximately normally, to create a complex orthogonal pattern of till outcrop. Ponded between them are pockets of glacimarine mud emitted and transported beyond the glacier margin by meltwater plumes.

Post-glacial sea-level rise and resulting deposits

During the latest low-stand of sea level, when land-based ice sheets stored ocean volumes to the equivalent of approximately 100 m lower than today, and the ice margins had retreated from the continental shelf to the land, the valleys would have maintained rivers. The 100 m deep low-stand on the outer continental shelf becomes shallower in most of the inner shelf zone (Forbes et al. 1991), and more precisely defined locally at about 65 m depth (Stea et al. 1994), reflecting a degree of glacio-isostatic crustal rebound and global sea level rise following glaciation. Stea et al. (1996) suggested this low-stand dates to *c.* 11.6 ka. As sea-level rose and the paleo-coastline transgressed the seabed, the sediment overlying bedrock were subject to high energy shoreline and shallow water processes. As a result, this 65 m water depth marks a change in the seabed sediments—a relatively continuous blanket of glacial and post-glacial sediments below. This contrasts with a higher frequency of bedrock outcrops in shallower areas, with patchy sediment collected or preserved from erosion in the topographic lows. This transgression “washed” at least the top portions of the glacial deposits, concentrating sand and gravel lag deposits across much of the seabed, modifying the texture of immediately underlying diamicts and muds only centimetres below. The glacial mud-filled channels contain a significant sand and small gravel component. Locally the bedrock surface was “cleaned” of the fines, leaving a boulder-gravel-strewn surface while depositing the finer products in the pockets between bedrock ridges. Neither the absolute or relative timing of glacier retreat and sea-level rise is precisely known older than 11 ka, but the seabed erosion is strong evidence for subaerial exposure. There are no indications of a fluvial system, which, had they evolved, would be cut into the channel sands. Such fluvial systems would also have been confined to a narrow zone between the retreating ice margin and the sea and so confined to limited watersheds encompassing the numerous divides between broad channels. The lack of evidence for paleo-rivers is consistent with a low preservation potential and with a similar lack of evidence for drowned coastal features such as beach ridges, bars and tidal channels. A meandering channel emanating from Sheet Harbour appears to be maintained by present-day currents in these mud-dominated deposits. Such features are registered by the LiDAR data, but only in very shallow areas and coupled with the present coastal deposit regime.

Post-glacial deposition in bays and inner harbours

The transgression progresses at the coastline even today albeit at a slower rate. Therefore, in the inner harbours and bays, the coastal deposits (primarily tills) are progressively removed, or partly so. The finer component of the erosional products are largely driven landward to collect in the basinal areas of sheltered harbours and bays. The offshore extensions of these inlets are generally sandier, and the sand and gravel beaches reflect a balance between longshore, offshore, and onshore transport in a continuing sea-level rise scenario. The sandier inlets reflect a greater present day influence by currents than the mud-dominated inlets.

Comparison with the Atlantic innermost shelf

The Eastern Shore inner shelf is characterized by extensive bedrock with patchy till and glacimarine mud, generally topped with sand and gravel, occasionally dissected by glacially cut channels filled with sand and glacially-derived mud, offshore muds (below 100 m), more recent harbour muds derived from coastal erosion, and, where not destroyed by this process, a record of deglaciation preserved in a complex series of moraines and drumlins, partly modified on their surface by paleo-coastal processes (Figure 4). This AOI is relatively representative of the morphologic and geologic character of the innermost shelf along the Atlantic shoreline of Nova Scotia, which has a similar process history (Forbes et al. 1991, Piper et al. 1986, Stea et al. 1994).

Glacial deposits are similar along the entire coast; an end moraine system marks stepwise, non-synchronous still-stands (King 1996) of the retreating ice sheet of which the Country Harbour Moraine, continuing offshore Sheet Harbour, is part. This region of the coast is typical of the Atlantic coast with some exceptions. The glacial deposit thickness and continuity contrasts from east to west in the AOI; 5 to 20 m thickness is typical in the west (below the low-stand position) and much thinner in the multibeam survey area. The dominant morphological influence by the glaciation(s) is the carving of broad valleys emanating from the larger bays and inlets into shallow drowned fjord-like topography. A similar fjord-like topography typifies the Atlantic coast of Yarmouth and Shelburne counties, but the Eastern Shore examples extend far further across the inner shelf, a trait extending east as far as Country Harbour. The bays are much broader across Queens, Lunenburg (except the La Have River valley) and Halifax counties, to St. Margarets Bay.

Nearly all of the South Shore inlets have mud dominant in their sheltered, shallow upper reaches only. However, mud distribution in the Eastern Shore inlets generally floors the harbour basin and extends seaward to the basins adjacent headlands. Another contrast is the presence of barrier beaches of sand, gravel and cobble to the westward of the AOI and not eastward. At the mouths of Cow Bay, Cole Harbour and eastward to Musquodoboit Harbour barrier beaches reduce storm wave energy on the leeward side, permitting mud preservation. This contrasts with Jeddore, Ship, Tangier, Spry, Sheet, Mushaboom, and Beaver Harbours, which lack such barrier beaches. Here, the offshore bedrock islands are far more common and apparently provide shelter, permitting mud deposition outside the harbours. Fewer beach barriers here might also reflect a general paucity of thick tills on land and so a general sand and gravel deficit in the budget supplying such beaches. Another contributing factor to the barrier beaches may be that the thicker glacial sediment blanket west of Jeddore Harbour supplied more sand and gravel there to the sediment budget during post-glacial transgression.

Links Between Geology and Biology

Links between the surficial geology described by King (2018) and the associated biology of the AOI emerged as the distribution of substrate types was better understood. Substrate composition can have an important influence on associated species composition (Seibold and Berger 2017). For example, Eelgrass requires an appropriate depth of sediment (mud and sand) overlying bedrock for its roots and rhizomes to anchor the shoots. In contrast, stalked tunicates (*Boltenia ovifera*) anchor to hard ledge or boulder substrates (Beazley et al. 2017). Links between the geology and seabird foraging areas have also been revealed. In particular, scoters (*Melanitta* spp.) are molluscivores (Beyer et al. 2008) that tend to forage in the muddy inner bays of the AOI on the leeward side of the barrier islands (K. Allard, Pers. Comm.). Knowledge of the distributions of substrate types are, therefore, useful in predicting suitable habitat for benthic fish, invertebrates, and marine birds.

PHYSICAL OCEANOGRAPHY

The Nova Scotia Current (Figure 5) runs offshore of the Eastern Shore Islands, running southwards on the inner half of the Scotian Shelf (Bundy et al. 2014). This current brings cold water with relatively lower salinity from the Labrador Current and Gulf of St. Lawrence onto the Scotian Shelf. In addition to cold water, the Nova Scotia Current transports zooplankton to the Scotian Shelf from the Gulf of St. Lawrence (Herman et al. 1991). Generally, the water temperature is colder in the Eastern Shore than the South Shore and Cape Breton because of the prevailing Labrador Current driving cold water onto the Scotian Shelf (Sephton et al. 2017). Temperature logger data collected by the Coastal Ecosystem Science Division deployed at depths of 5–15 m off Liscomb show the same trend of colder water in the Eastern Shore relative to the South Shore (Figure 6). Large seasonal fluctuations in temperature observed in Liscomb and Fink Bay are the result of upwelling and downwelling that are mainly wind driven. Coastal upwelling occurs when the wind blows from a southwest direction keeping the coast on its left, while downwelling occurs when the wind blows from a north or northeast direction, with the coast on its right. This is consistent along the NS coast from approximately Cape Sable to Canso (Figure 6). This contrasts with Sanford in southwest Nova Scotia where temperature fluctuations are primarily tidal driven and the wind influence is much smaller.

Surface currents within the boundaries of the AOI are highly variable with wind. In the summer months, the prevailing winds come from the southwest, generating coastal upwelling, moving surface waters offshore and replacing them with colder water that is more saline and higher in nutrients. When the prevailing winds travel in the opposite direction, coastal downwelling occurs. Winds are also important through Ekman transport, bringing in offshore deep or surface waters depending on the direction of the wind (Bundy et al. 2014). This allows for flushing of coastal bays in conjunction with tides, wind, and estuarine inflows. Ship Harbour, is a long (10 km), narrow, and deep (maximum 27 m) basin (Strain 2002) that is relatively protected with a high sill (7 m depth), whereas inlets with a less-pronounced sill will undergo high turnover (Platt et al. 1972). Current data collected using an Acoustic Doppler Current Profiler (ADCP) deployed near Liscomb in 2015–17 demonstrate predominant westward currents punctuated by brief reversals in the fall, generally at depths ranging 5 and 55 m (Drozdowski et al. 2018). Diurnal tidal ranges in the AOI boundaries are relatively low compared to the Bay of Fundy, as are all tide ranges on the Eastern Scotian Shelf, ranging from approximately 1.0 – 3.0 m (Greenlaw et al. 2013). This combination of upwelling, currents, and winds introduces and mixes nutrients into the coastal region, playing a significant role regulating phytoplankton blooms in the spring and providing a first link in the coastal food web.

Freshwater inflows are variable within the AOI. In Ship Harbour, freshwater inflows vary from 33.4 m^3/s in April to 7.4 m^3/s in September. Estuarine circulation in this harbour is greater than in Halifax Harbour or St. Margarets Bay despite comparable freshwater inflows as a result of the smaller inlet volume in Ship Harbour (McCullough et al. 2005). The Eastern Shore area has higher than average precipitation, with approximately 1500 mm annually. The Eastern Shore also receives 20% more rain from May to September than coastal areas located to the south (Hill et al. 2012).

Sea ice is common off Newfoundland and Labrador and in the Gulf of St. Lawrence, but it is rare on the Scotian Shelf south of northeastern Cape Breton. The volume and surface area of sea ice has generally declined since the 1970s on the Scotian Shelf, and any significant aggregations within the Eastern Shore Islands is unlikely, though sea ice from the Gulf of St. Lawrence could be transported to the area in the spring. Temporary sea ice does form in inner bays and inlets in the Eastern Shore depending on air temperature throughout the winter. Temperatures at the surface typically stay around 1ºC in winter for the 0–100 m depth range and increase in the summer with some stratification leading to surface temperatures exceeding 15ºC. By the fall, mixing deepens this warm layer. Wind induced mixing, upwelling and downwelling are the primary determinants of temperature and salinity in waters of the Eastern Shore and coastal Nova Scotia.

CHEMICAL OCEANOGRAPHY

Nutrients

The main source of nutrients, such as nitrogen, phosphorus, and silicon, in inshore waters is from an exchange with adjacent offshore waters (Bundy et al. 2014). Inputs from offshore results in high concentrations of nutrients in the coastal zone in the winter, which are then depleted by spring phytoplankton blooms. These nutrients are replenished in the fall when upwelling is predominant. Nitrate is the most rapidly removed nutrient in the spring and summer, limiting primary productivity following phytoplankton blooms. Overall, nutrients including nitrates, silicates, and phosphates have been declining since the 1970s along the Scotian Shelf, which is consistent with global trends (Yeats et al. 2010). While not recorded within the AOI, anthropogenic nitrogen loading has been directly linked to the loss of Eelgrass in other coastal locations (Hauxwell et al. 2003). Increased nitrogen loading in estuaries and coastal zones leads to stimulated algal growth, which limits the light required by Eelgrass for growth, leading to a decrease in shoot density and bed area, and ultimately, bed loss (Hauxwell et al. 2003).

Several sites in the Eastern Shore Islands area receive anthropogenic inputs (i.e., sewage), which can lead to eutrophication. Most data available at the time of this report was restricted to Ship Harbour, which shows evidence of annual eutrophication. In Ship Harbour, nitrate and phosphate is replenished from offshore, while rivers are the most likely input of silicates. In the deep, saline waters of the basin, nutrient concentrations are often elevated in the summer and fall, while oxygen levels are low (see proceeding Oxygen and Contaminants sections). This characteristic is expected to be the result of a shallow sill at the mouth of the inlet, which may prevent complete mixing in this fjord-like system (Strain and Yeats 1999). Moser River, for example, is less eutrophic than Ship Harbour and has no barriers between the inlet and open water, but it is also a less populated area (McCullough et al. 2005). In a review of eutrophication status of coastal inlets of Nova Scotia, Strain and Yeats (1999) record that 6 of the 15 sites sampled with a positive eutrophication index (EI) are within or adjacent to the AOI (Table 2). In contrast, Liscomb Harbour, Beaver River, and Moser River were found to have negative EIs, with Moser River having the lowest EI among the 34 sites sampled. The particularly low EI within the Moser River was linked to a sparse human population and no barrier separating the inlet from the open ocean (Strain and Yeats 1999). It seems that the number of bays with a high eutrophication potential in the Eastern Shore is primarily because of barriers (sills) that separate the harbours and inlets from the open ocean as opposed to point sources produced by large human populations.

Oxygen

Oxygen is introduced to surface waters at the air-sea interface and by photosynthesis of marine macrophytes. Inshore waters are often saturated with available oxygen as a result. Oxygen levels seem lowest in the fall when water temperatures are high and water mixing is low. Studies in Ship Harbour within the boundary of the AOI found that deep waters in this harbour had <50% saturation of oxygen in the fall in addition to elevated nutrient levels, suggestive of oxygen depletion by biological processes (eutrophication). Strain (2002) found that in Ship Harbour, specifically, oxygen demand from August to November is 10–30 mmol/m^2/day, which is similar to other harbours in Nova Scotia at this time of year. The low levels of oxygen in this region were, therefore, attributed to poor flushing characteristics of Ship Harbour rather than high oxygen demand. Ship Harbour was described as an ‘area of hypoxia’ by Bundy et al. (2014). Oxygen depletion could occur in areas with high sewage runoff or other wastes but should not normally occur in the bays and inlets of the AOI. Data is currently lacking to assess inter-annual trends in oxygen concentrations. Yeats et al. (2010) report a broad decline in available oxygen across the Scotian Shelf, which they attribute to a general slowing of ocean circulation. The effects of this decline in dissolved oxygen on specific nearshore regions of the coastal zone are unknown.

Contaminants

Numerous types of contaminants are present in the region, particularly in areas with higher populations such as Ship Harbour and Sheet Harbour. However, it appears that pollutants in general are in lower concentration in the Eastern Shore Islands area compared to other coastal sites in Nova Scotia. Coastal areas that receive influxes from sewage, residential runoff, industries, and acid rain are susceptible to eutrophication. Stewart and White (2001) list potential pollution sources in the coastal zone as municipal effluents, ocean dumping, organic matter and trace metal enrichment from aquaculture, and industrial effluents, including pulp and paper, petroleum, food processing, shipyards, and mining. Trace metal pollution (cadmium, copper, nickel, lead, and zinc) is lower in Ship Harbour relative to more industrialized harbours, such as Halifax, Sydney, and Pictou (Bundy et al. 2014). In Ship Harbour, metal contaminants are at natural concentrations, with the exception of cadmium (Cd), mercury (Hg) and lead (Pb) in some samples (McCullough et al. 2005).

At least 25 species of toxic or potentially harmful phytoplankton (including *Dinophysis spp.*, *Prorocentrum spp.*, *Nitzschia pungens*, and *N. pseudodelicatissima*) have been recorded in Ship Harbour, an area, as mentioned previously, that is susceptible to eutrophication (Keizer et al. 1996, McCullough et al. 2005). The dinoflagellate *Alexandrium ostenfeldii*, which produces a marine phycotoxin known as spirolides, has also been detected in shellfish (wild and farm-raised) in Ship Harbour in the 1990s (Richard et al. 2001).

The Canadian Shellfish Sanitation Program (CSSP) is a federal food safety program jointly administered by the Canadian Food Inspection Agency (CFIA), Environment and Climate Change Canada (ECCC), and DFO. The goal of the program is to protect Canadians from the health risks associated with the consumption of contaminated bivalve molluscan shellfish, such as mussels, oysters and clams. Under the CSSP, the Government of Canada implements controls to verify that only shellfish that meet food safety and quality standards reach domestic and international markets. These controls include classification of areas, which includes an evaluation of pollution sources as well as ongoing monitoring of the classified area for bacteriological water quality and biotoxins, as well as posting of signs and patrol and enforcement of the area. These areas will be open or closed to harvesting based on the monitoring results.

In areas where shellfish are harvested for non-commercial (Indigenous food, social and ceremonial or recreational) purposes, they should come from classified areas that are open and approved to minimize risks to consumers. Consuming shellfish from areas that are closed for contamination can pose a serious health risk. Harvesting from areas that are unclassified is not recommended. Stakeholders harvesting for non-commercial purposes have often benefitted from the co-location (i.e., same bay or harbour) of recreational harvest areas classified for commercial operations. Currently all CSSP resources are fully committed to maintaining the classification of existing high- and medium-priority harvest areas.

Within the AOI, Clam Harbour, Ship Harbour, Cable Island, Sober Island, and Marie Joseph have areas that are open and approved for shellfish harvesting, and the CSSP is fully delivered in these areas. Other areas in the AOI are not currently being monitored for water quality or biotoxins and are closed as a precaution to minimize public health risk, or they are areas that are permanently closed due to ongoing pollution sources. Compliance monitoring in all closed areas continues subject to operational capacity. This includes vehicle, vessel, and foot patrols, as well as the maintenance of closure notifications (e.g., signage and electronic communications) by DFO Conservation and Protection fishery officers. All areas may be subject to temporary closure due to elevated biotoxin levels or increased pollution associated with significant weather events. Harvesters should consult the Government of Canada’s shellfish harvesting and safety webpage for the current state of closures in the AOI.

Gold mining was extensive in Nova Scotia from the late 1800s to the 1940s, which generated more than three million tonnes of tailings (Parsons et al. 2012). Mercury amalgamation was the primary method for extracting gold from ore up until the 1880s, after which gold extraction was supplemented and replaced by cyanidation. Tailings from gold mines were thus heavily contaminated with mercury and arsenic. These tailings were generally deposited into low-lying areas and water bodies (Doe et al. 2017). Mercury, particularly as toxic methyl mercury, causes neurotoxicity and birth defects and tends to bioaccumulate within the food chain, potentially being consumed by humans and other animals over time. Naturally occurring arsenic is often associated with gold ore in the form of arsenopyrite and, due to the gold mining process, thousands of kilograms of arsenic was released into the environment (Doe et al. 2017, Parsons et al. 2012). Mercury and arsenic have long residence times in the environment. Doe et al. (2017) analyzed mollusc tissue samples collected in 2004 and 2005 from 10 sites along the South and Eastern Shores of Nova Scotia, including three sites within the AOI boundaries. Of these samples, sediment and bivalve tissue levels of arsenic and mercury were generally low and below the Probable Effects Level (PEL), a level above which adverse biological effects are likely to occur. However, in Harrigan Cove near Sheet Harbour, sediment levels of mercury exceeded the PEL by over nine times (0.70 mg/kg). Arsenic levels were nearly 10 times the PEL (41.6 mg/kg) at Harrigan Cove and the highest levels recorded were in Wine Harbour, to the west of the AOI boundary. Furthermore, arsenic concentrations from seawater taken at sites in Seal Harbour, Wine Harbour, and Harrigan Cove exceeded the 12.5 µg/L Guideline for Protection of Marine Aquatic Life (CCME 1999); mercury, however, was not detected in water samples except at Wine Harbour (Doe et al. 2017). The bioaccumulation factor for arsenic in bivalves was low in Harrigan Cove (0.03), suggesting arsenic is not in a bioavailable form in this area despite its high concentration within sediments. Nevertheless, within the AOI boundary, Harrigan Cove appears to be an area that is highly contaminated by both mercury and arsenic from historical gold mining. As mentioned, mercury amalgamation has largely been replaced by cyanidation, and while cyanide is toxic and does occur in mining tailings, it does not bioaccumulate in animals.

Other contaminants including arsenic and heavy metals may enter the water naturally, such as through leaching from bedrock and sediments (Breeze and Horsman 2005). Natural contaminants have been implicated in the acidification of many rivers in eastern Nova Scotia and are thought to have led to a decline in Atlantic Salmon populations (see section on Atlantic Salmon). Petroleum residues, from shipping or roadways, are significantly lower in Ship Harbour and Sheet Harbour relative to Halifax Harbour and the Bedford Basin. Petroleum residues have been shown to have a significant negative impact on salmon habitat (Bowlby et al. 2014) and Eelgrass beds (McCullough et al. 2005), both prevalent in the Eastern Shore Islands.

HUMAN IMPACT METRICS

Eight measures of human impact were compiled to assess the relative magnitude of human activity in the proximity of seagrass beds throughout Atlantic Canada (Murphy et al. 2019). Any human-related impact that would potentially influence seagrass ecosystem health, and could be obtained for all sites of interest across the region, were included in this study. Impacts were assessed at the bay scale: 1) percentage of urban dominated watershed land, 2) percentage of agriculture dominated watershed land, 3) watershed human population density, and 4) nitrogen loading rate; and at the seagrass bed scale: 1) percentage of human altered riparian land adjacent to seagrass bed, 2) percentage of over-water structures in close proximity to seagrass bed, 3) water quality, and 4) presence of near-field shellfish aquaculture activity. These bay- and bed-scale impacts were aggregated into a human impact metric to compare among sample sites. Descriptions of how each of the human impacts were compiled for sites along the Atlantic coast of Nova Scotia, two of which (Cable Island and Taylor Head) are located within the Eastern Shore Islands, are provided below. Murphy et al. (2019) also calculated the percent of coastal land protection for each bay examined. This coastal protection includes provincial, national, and private conservation areas.

The extent of invasive species was calculated by Murphy et al. (2019) based on the percent cover of collection plates monitored by DFO's Aquatic Invasive Species (AIS) Monitoring Program. Invasion extent was calculated as the sum of percent cover on plates within the nearest bay to the study sites for each biofouling species, including tunicates, the crustacean *Caprella mutica*, and the bryozoan *Membranipora membranacea*. Values are calculated from a 10-year average of monitoring (2006 to 2015).

Bay-scale impacts

Percentage of urban and agriculture dominated watershed land

Previously delineated watershed boundaries for each bay were provided by the Nova Scotia Department of Environment. In some cases, watersheds required further delineation in order to include all freshwater inputs. For bays that required additional delineation, watercourse drainage patterns were predicted for each bay using hydrographic data and a digital terrain model. Shapefiles obtained from GeoNova were used to classify land use types across the province. Shapefiles were used to clip predetermined watershed areas for each bay and summed the urban and agriculture land use units, respectively, to determine the percentage of urban and agriculture land usage in each watershed.

Human population density

Human population was estimated using the number of civic addresses present in each watershed multiplied by the average number of residents per household (2.3) in Nova Scotia (Statistics Canada 2017). The number of individuals was standardized to watershed area.

Nitrogen loading rate

Nitrogen loadings were modelled from point and non-point sources to each bay (Nagel et al. 2018) using a nitrogen loading model (NLM) originally developed for Waquoit Bay, Massachusetts (Valiela et al. 1997), and previously applied to bays in New Brunswick (McIver et al. 2015) and Nova Scotia (McIver et al. 2018). Point sources of nitrogen included direct atmospheric deposition to the bay surface, discharges from wastewater treatment plants and seafood processing plants, and nitrogen addition from finfish aquaculture (Nagel et al. 2018).

Non-point sources of nitrogen included atmospheric deposition to watershed land, septic systems, and fertilizer addition. Loss parameters were applied to non-point nitrogen sources to account for the loss in nitrogen that occurs while it travels from the watershed to the bay. The loss parameters take into account nitrogen lost to volatilization, vegetation uptake, and transport through the vadose and aquifer zones. After loss parameters were applied, the model provided an estimate of the total nitrogen load entering each bay per year. Final nitrogen loading estimates were standardized to the area of each bay (kg N/ha bay) to account for the differences in dilution expected to occur in large versus small bays.

Seagrass bed-scale impacts

As opposed to the larger bay-scale impacts described above, the seagrass bed-scale impacts included were measured within 2 km of seagrass survey locations. This smaller scale has been suggested as the most relevant scale for assessing impacts to seagrass beds (Shelton et al. 2017) and similar local impact indices have proven useful in differentiating ecosystem health in low and high impact seagrass beds (Iacarella et al. 2018).

Percentage of human altered riparian land adjacent to seagrass bed

Human altered riparian land includes any land that has been altered from human activities, including urban, agriculture, and forestry land use. Riparian land alteration was measured within a 1 km radius of seagrass sites and defined riparian land as the land between 0 – 50 m from the shoreline included in the 1 km seagrass site radius. The amount of human altered riparian land was standardized to the total land area within the 1 km radius of each seagrass site.

Percentage of overwater structures in close proximity to seagrass bed

Overwater structures include any human-made structure that is supported above or floats on the water surface. This includes docks, piers, marinas, ramps, wharfs, causeways, bridges, and other structures that represent the extent of boating activity, shading, and potential alteration to water circulation. Overwater structures within a 2 km radius of each seagrass site were manually classified using Google Earth. The area of overwater structures located within the 2 km radius to the water surface area was standardized.

Water Quality

Fecal coliform monitoring data from the CSSP was used as a proxy for water quality. A 10-year average (2005–2015) of fecal coliform counts (MPN/100 mL) from the CSSP monitoring station closest to each seagrass bed was calculated. On average, the closest monitoring stations were less than 500 m away from the seagrass beds.

Presence of near-field shellfish aquaculture activity

Given that no shellfish aquaculture operations exist near the seagrass beds of interest along the Atlantic coast of Nova Scotia, this value is zero for all sites. Impacts from finfish aquaculture, which for seagrass beds is specifically related to excess nitrogen entering the bays, is accounted for in the NLM described above.

Results

The results of this study (Murphy et al. 2019) show relatively low human impacts at sites in the Eastern Shore relative to Musquodoboit, Sambro, St. Margarets Bay, and the Lunenburg area (Figure 7). Human population densities and the extent of invasive species is much lower in the Eastern Shore relative to these areas well (Table 3). Overall, human impacts were comparable between Cable Island and Taylor Head within the AOI, and Port Joli on the South Shore, though the invasive species extent is much higher in Port Joli (Table 3). Overall, the Eastern Shore had very low impacts from human density, overwater structures, agriculture-dominated watershed land, or near-field aquaculture presence, and only minimal impacts from water quality (fecal coliforms), nitrogen loading, and human altered riparian land (Table 3). These low human impacts reinforce the description of the Eastern Shore Islands area as one that is highly natural and intact relative to other coastal sites in the Scotian Shelf Bioregion.

Sites on the Eastern Shore also had a higher percentage of coastal protection relative to Halifax, Musquodoboit, Sambro, and Second Peninsula (Table 3). In tropical seagrass systems, terrestrial protection adjacent to seagrass meadows has shown positive effects on the condition of the seagrass (Quiros et al. 2017). While the direct effects of coastal land protection on Eelgrass condition in the Eastern Shore has not been quantified, the positive effects observed in tropical systems suggests that coastal protection adjacent to the AOI (e.g., Taylor Head Provincial Park) may complement the effects of an MPA on marine macrophyte beds.

BIOLOGICAL DESCRIPTION

RESEARCH SURVEYS IN THE EASTERN SHORE ISLANDS

Few annual research surveys are conducted within the inshore component of the Maritimes Region. The DFO Summer Research Vessel Survey has been conducted in NAFO divisions 4VWX since 1970, but none of the survey strata encompass the boundaries of the AOI (DFO 2017a). Similarly, the Snow Crab Survey, a fixed station survey that occurs on the Scotian Shelf each year, does not sample this close to shore (Zisserson 2015). Much of the data from this inshore region is collected by the 4VsW Sentinel Survey, Lobster settlement surveys, and individual research projects from within DFO and academic institutions.

4VsW Sentinel Survey

The 4VsW Sentinel Survey is conducted on an annual basis by the Fishermen and Scientists Research Society (FSRS) in co-operation with DFO and local fishers. This survey allows random surveys of sites in the 4VsW Northwest Atlantic Fisheries Organization (NAFO) areas in waters less than 50 fathoms using commercial longliners to access nearshore areas. As of 2004, the number of stations surveyed was reduced from 202 to 53 for economic reasons. In 2012, this survey was further reduced to 18 stations, all of which are inshore at depths <100 m. Data collected at each site includes the total catch, fish lengths, weights, sex, otoliths, stomach contents, water temperature, and CTD profiles. Specific sampling methods require all participants to fish with 1500 #12 circle hooks baited with frozen Mackerel (FSRS 2016). In 2016, one vessel sampled 18 stations with 2 strata in 4W only. The number of Atlantic Cod and Haddock caught in 4W declined following catches of >1400 individuals in 2007–2009 (FSRS 2016). White Hake and Barndoor Skate (*Dipturus laevis*) have not been caught by the survey since 2011, but small numbers (<100) of Halibut (*Hippoglossus hippoglossus*) and Cusk (*Brosme brosme*), a species assessed as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 2012, have been caught regularly by the survey (FSRS 2016). Overall, Atlantic Cod are the most commonly detected species by the Sentinel

Survey (Table 4). The 4VsW Sentinel Survey is currently the only systematic fish survey occurring within the AOI. Continuation of this survey and associated time series of data would be an asset for future monitoring of the Eastern Shore Islands and the coastal waters of the eastern Scotian Shelf.

Settlement Surveys

As part of a systematic monitoring program for American Lobster, researchers and managers from the Northeastern United States and Canada deployed cobble filled bio-collectors in the nearshore environment. These collectors are designed to mimic settlement habitat for juvenile lobster and have been used as an important index of lobster recruitment (Wahle et al. 2013). A variety of fish and invertebrate species also settle onto these collectors and, thus, the regional collaboration of bio-collector programs provided important information on biodiversity in the otherwise understudied rocky subtitle habitats (Hunt et al. 2017). Using settlement data from Canadian bioregional settlement surveys (see Hunt et al. (2017) for more detail), patterns of species richness and community composition in Atlantic Canada were evaluated with a specific focus on locations immediately adjacent to the Eastern Shore Islands. Based on a non-metric multidimensional scaling analysis, communities appear to separate into four distinct faunal groups characterizing the Bay of Fundy, Gulf of St. Lawrence and the eastern and western Scotian Shelf. Locations near the Eastern Shore Islands align most closely with the eastern Scotian Shelf group, but they are clearly differentiated in multivariate space from all stations included in the analysis (Figure *8*). Similarly, species accumulation curves for these regions show that the three sites closest to the Eastern Shore Islands have among the highest species richness and steepest species accumulation curves (Figure *9*).The Bay of Fundy/Gulf of Maine assemblage potentially has higher species richness based on the slope of the accumulation curves, but fewer sites were sampled overall. The primary differences between the Eastern Shore and other sites sampled along the Scotian Shelf is the presence of *Lebbeus* sp. shrimp and Rockling (*Enchelyopus cimbrius*) in the Scotian Neritic, which are absent in the Eastern Shore, and the presence of the Fourline Snakeblenny (*Eumesogrammus praecisus*) in the Eastern Shore, which was absent elsewhere (Table 5).

PLANKTON

Phytoplankton and Other Microbes

Phytoplankton communities in the AOI are typical of those on the ESS, dominated by diatoms and dinoflagellates and showing an increase in overall biomass over the last 15–20 years. While offshore plankton is better studied than inshore, several studies have provided data on inshore phytoplankton and zooplankton in St. Margarets Bay and Ship Harbour (Breeze et al. 2002, Keizer et al. 1996, McCullough et al. 2005). Phytoplankton abundance is typically enumerated through measurements of chlorophyll *a*, and it peaks in spring (March to May) and fall (September to October). A total of 141 phytoplankton species, with the number of individuals ranging from 1–38 per species, have been recorded in Ship Harbour (Keizer et al. 1996). This was comparable to St. Margarets Bay, which also had 141 species of phytoplankton recorded (Keizer et al. 1996).

Zooplankton

Zooplankton range in size from roughly 20 µm up to several centimetres, and include copepods, ciliates, larval fishes and invertebrates, as well as larger taxa such as krill (Euphausiacea) and jellyfish (including *Aurelia* spp. and *Cyanea* spp.). Zooplankton biomass tends to increase from May to October, concomitant with an increase in spring phytoplankton; biomass tends to then decrease in the winter. Species common in all coastal sites in Nova Scotia include the copepod genera *Pseudocalanus*, *Temora*, *Acartia*, *Calanus*, *Centropages*, *Eurytemora*, *Oithona*, and *Tortanus*. Much of the zooplankton on the Scotian Shelf originate from the Gulf of St. Lawrence and are carried onto the Shelf by the Nova Scotia Current (Herman et al. 1991). Zooplankton, especially copepods, are an important component of the food web, providing food for juvenile pelagic and demersal fishes, such as Atlantic Herring and Silver Hake (Herman et al. 1991).

Krill, including *Meganyctiphanes norvegica*, *Thysanoessa inermis*, and *Thysanoessa longicaudata*, are relatively larger macrozooplankton that feed upon smaller phytoplankton and zooplankton; they are important food for cetaceans, fish, and marine birds. Krill are typically found in deeper water, at depths of 100–300 m during the day and migrate to the surface at night. Of these species, *Thysanoessa* spp. are more likely to be found inshore in the upper 50–150 m of water (Sameoto and Cochrane 1996); however, there are no data specific to the Eastern Shore documenting their occurrence.

BENTHIC HABITATS AND COMMUNITIES

Classification of Benthic Habitats and Communities of the Eastern Shore Islands

The Eastern Shore Islands are found within the Inner Scotian Shelf seabed class, which, on average, extends 25 km from shore (WWF Canada 2009). Characteristics of the Inner Shelf include high relief of eroded bedrock, rapid changes between rocky, sandy, gravel, and mud distributions, Rockweed beds and kelps in exposed areas, Eelgrass beds, and marshes in sheltered bays. Red coralline and brown algae and kelp are also abundant. Bottom invertebrates typically include sea cucumbers, sea stars, barnacles, scallops, urchins, crabs, and Lobster. The area is also broadly characterized by the hard bedrock substrate between Clam Bay and Liscomb Harbour, known as the "*Mahone Bedrock Shore and Islands*" classification by Greenlaw et al. (2013).

Summary of Eastern Shore Islands 2007 Video Survey

Nine nearshore sites in the Eastern Shore Islands EBSA, ranging from 1 to 5 m depth, were sampled in October 2007. Each site was sampled by running two to three 100 m transects using towed or diver-held cameras (Figure 10). At each site, frame grabs from the video transects were analyzed at 30-second intervals to characterize habitat structure and diversity. Extracted images were analyzed for percent cover of biotic organisms (algae and epibenthic invertebrates >2 cm) and substrate using a multi-point tool in ImageJ (Abramoff et al. 2004). Due to the nature of the sampling, mobile pelagic species are not well represented.

Biotic and abiotic features were sorted into 19 categories (Table 6). Green and red turf algae (hereafter turf) was the most dominant group at all 9 sites (67.6 ± 19.2%). Kelp and *Fucus* spp. had >10% cover at 7 and 2 sites, respectively, and all other biotic groups made up less than 5% cover at all sites. *Codium fragile* was only recorded at 2 sites: Laybold Island and Harbour Island-A. There was large variation in diversity and dominant algal type within and between sites.

The three most common algal-forming habitat types were turf algae, *Fucus* sp. and kelp (Figure 11). Kelp showed no alongshore gradients in percent cover and was patchily distributed; it had the highest cover at Goose Island (32 ± 25%) and the lowest at Sober Island (1.73 ± 4.33%; Figure 12). *Saccharina latissima* was the most abundant species of kelp (8.19 ± 11%) followed by *Laminaria digitata* (5.48 ± 11.7%). *Agarum clathratum* was only recorded at 2 sites. Turf algae was the most abundant group at all sites with greater than 50% cover at 8 out of 9 sites, being highest at Salisbury Island (78.7 ± 12.1%) and lowest at Goose Island (48.6 ± 19.4%). *Fucus* sp. showed an average cover of 15.92 ± 20.86% at Laybold Island and 17.55 ± 21.62%

at Sober Island, but less than 5% cover at the remaining 7 sites. Bare substrate (boulder, cobble, pebble or sand) made up 10.7 ± 11.2% cover, averaged across all 9 sites.

Summary of Eastern Shore Islands 2017 Drop Camera Observations

The Eastern Shore Islands drop camera survey consisted of 466 samples taken primarily in the western portion of the AOI (see Figures 3 and 4 in Vandermeulen (2018b). Sampling was conducted over 13 days during September and October[1].

From each video sample, a presence/absence classification was obtained (Table 7). The benthic landscape of the AOI was unusually heterogeneous, with the four different substrate types occurring at almost any depth or location. This may be driven by the relatively shallow, reef dominated nature of the bottom, where it was not uncommon to observe depths <30 m deep 15 km offshore. Soft, muddy bottoms with burrows were rarely seen at depth, they were most common in small well-protected bays. This suggests strong wave and current regimes dominate throughout the AOI, agreeing with observations of the survey vessel.

Macrophytic algae dominated, as would be expected in such an energetic hard bottom environment (Table 7). Almost any rock surface of 10 cm or larger had a red algal coralline crust plus some other algal cover. There appeared to be a depth gradient associated with this cover[2]. The shallowest drop locations (<10 m) were dominated by kelps (*Alaria*, *Saccharina*, *Laminaria*, *Agarum*) with a red algal canopy mainly composed of *Phyllophora* sp. At 20 m or slightly deeper, *Agarum* was usually the only kelp left, with the red canopy switching to *Ptilota*. By 40 m depth, all kelps and *Ptilota* were gone, with only coralline and other red algal crusts remaining, along with a few small red blades (possibly *Turnerella*). Coralline crusts were the only algae present at >50 m. The relatively dense algal cover at 10–20 m obscured smaller, cryptic benthic invertebrates and impeded their classification.

The tunicate *Boltenia* sp. is distinctive and large enough to be observed within an algal canopy and was found widely (although sparsely) throughout the survey area associated with its preferred hard substrate with rough angular ledges. Sponges, anemones, and sea stars were quite common on hard surfaces at all depths, but they were most likely missed by the video camera under dense algal cover in the shallows. Sand dollars were often seen on sand in the shallows, with brittle stars on that substrate at greater depths.

Lobsters were not frequently observed (which is normal for this type of drop camera survey) and tended to occur most often at 10–20 m depth on sandy bottoms dominated by algal drift material piled in distinctive parallel ‘windrows’ many meters long. Rock crabs were not added to the classification in Table 7, but they were observed more commonly than Lobster, preferring a sandy bottom at <20 m depth. Scallops were rare and at depth on cobble or gravel bottoms. Sea urchins were very rare and cryptic (usually only about 3 cm in diameter) in crevices at depth. Cunner (*Tautogolabrus adspersus*) were common around rocky bottoms up to 25 m depth, sporting vibrant red and orange colors.

In summary, the benthic habitats in this region are patchy and highly variable, forming a mosaic of substrates and macrophyte beds. Compared to Sambro Ledges, which is an area of high

[1] The Sigma-T was used as the survey platform for each of these three trips. She steamed from BIO to Sheet Harbour for each trip, with Sheet Harbour as the base of operations. CWS bird observers were on board for each of the 13 survey days plus the 6 transit days between BIO and Sheet Harbour.

[2] Green algae (e.g. *Ulva*, *Chaetomorpha*) tend to occur shallower than the >10 m used for this survey design, although *Codium fragile* was sometimes observed in the shallows around 10 m.

rugosity and extensive kelp beds and *Boltenia* concentrations, the Eastern Shore Islands is more heterogeneous in substrate type and seaweed patches across its area (see Vandermeulen 2018a). These habitat patches within the AOI vary approximately every 400 m across all depths, which is unique relative to other surveyed areas, including Port Joli and Sambro. The patch scale at Sambro is approximately 5 km at depths greater than 30 m, while the Port Joli area is predominantly inshore sandy habitat surrounded by rocky patches. This suggests greater habitat complexity within the AOI relative to Sambro and Port Joli, which may coincide with higher species diversity (H. Vandermeulen, Pers. Comm.).

AQUATIC MACROPHYTES

A number of aquatic macrophytes, including plants (Eelgrass), seaweeds, algae, and kelps are commonly found in the Eastern Shore Islands, providing important habitat and providing ecosystem services. The depth ranges of common species are provided in Table 8.

Eelgrass

Eelgrass beds are found across a range of environments in Atlantic Canada, including protected and exposed sites with different thermal regimes (Wong 2017). Along the Atlantic coast of Nova Scotia, many soft-sediment habitats support beds of seagrass, specifically Eelgrass *Z. marina* (Schmidt et al. 2011). Eelgrass is found from Labrador to North Carolina and can form extensive beds from the intertidal to the subtidal at 12–20 m depending on light availability. Eelgrass has an optimal salinity range of 20–26 ppt for photosynthesis, but it is tolerant of salinity levels of 5 to 35 ppt. Optimal temperatures for Eelgrass growth are between 10 and 25°C, but it is tolerant of freezing temperatures and waters exceeding 35°C. Elevated water temperatures (>25 °C) are associated with weakened Eelgrass and increased susceptibility to disease (DFO 2009). Eelgrass is common throughout eastern Canada but is absent from rocky, high energy coastlines or in areas of high turbidity, which limits the amount of light Eelgrass requires for photosynthesis (DFO 2009). *Z. marina* is considered an Ecologically Significant Species in eastern Canada, providing important three-dimensional habitat for numerous fish and invertebrate species. There are no substitute structuring organisms with the same function as Eelgrass should it be perturbed or displaced, suggesting the loss of Eelgrass would lead to ecological consequences much greater than associated with the removal of most other species in the community (DFO 2009). This has been observed in the Gulf of St. Lawrence where the collapse of Eelgrass beds has been linked to the drastic decline in foraging marine birds, including Canada Geese (*Branta canadensis*) and Common Goldeneye (*Bucephala clangula*) (Seymour et al. 2002).

The Eastern Shore Islands AOI contains numerous Eelgrass beds (Figure 13), often associated with the leeward side of islands (e.g., Cable Island; M. Wong, Pers. Comm.) where sandy and muddy substrates accumulate. While numerous, these Eelgrass beds are not as extensive as those found in the Southern Gulf of St. Lawrence. Likely the exposure and geology of the Eastern Shore (i.e., primarily exposed bedrock on the windward side of the islands) is not conducive to the growth of large Eelgrass beds, which require a layer of fine sediment to anchor their roots. Eelgrass meadows are often associated with other macrophytes such as red seaweeds and epiphytic algae (Allard et al. 2014). Eelgrass bed structure varies on a site-by-site basis, but the macroinfaunal community is relatively consistent within a region when comparing New Brunswick, Nova Scotia, and Newfoundland (Cullain et al. 2018).

Marine vegetation provides a variety of functional services to coastal ecosystems including the provision of habitat, primary productivity, filtration of pollutants, sediment stabilization, sequestration of carbon, and nitrogen retention (Jones et al. 2013, Namba et al. 2018, Schmidt et al. 2011). Surveys of Eelgrass beds along the Eastern Shore have noted significantly enhanced abundance and diversity of associated flora and fauna, including several commercially important species (Schmidt et al. 2011, Wong and Dowd 2015, Wong et al. 2016). Juvenile Atlantic Cod and Haddock are known to use Eelgrass as nursery areas (Gotceitas et al. 1997, Laurel et al. 2003). Gorman et al. (2009) have shown that juvenile Cod use Eelgrass to hide from predators, and, correspondingly, predators are often associated with the edges of Eelgrass beds in search of prey. Indeed, the structural habitat provided by marine plants, like Eelgrass, provides refuge to a variety of fish species and most often during larval and early juvenile ontogenies. Marine vegetation, particularly Eelgrass, also provides feeding grounds to many marine birds and waterfowl, such as geese, ducks, and the Atlantic Brant (*Branta bernicla hrota*), which feeds almost exclusively on Eelgrass (Hastings et al. 2014). Eelgrass also acts as important nurseries for young fish and shellfish, including Tomcod (*Microgadus tomcod*), White Hake, Silversides (*Menidia menidia*), Winter Flounder (*Pseudopleuronectes americanus*), and Pollock (*Pollachius virens*) (Bundy et al. 2014, Joseph et al. 2006). Non-commercially important species, such as hermit crabs (Paguridae), Grass Shrimp (*Palaemonetes vulgaris*), Sand Shrimp (*Crangon septimspinosa*), Three-Spined Stickleback (*Gasterosteus aculeatus*), and Cunner are also frequently found in and among Eelgrass beds (Joseph et al. 2006, Namba et al. 2018, Wong and Dowd 2016). Combined studies by the labs of M. Wong (DFO) and H. Lotze (Dalhousie) have found 23 species of fish, 73 species of sessile, mobile, infaunal, and epiphytic invertebrates, and 21 species of seaweeds associated with Rockweed or Eelgrass beds (Table 9). Surveys of Cable Island Eelgrass beds show the highest fish abundance and benthic animal abundance, while benthic animal richness at Cable Island is comparable to that in St. Margarets Bay (Figure 14).

Contrasting to some parts of the Scotian Shelf where Eelgrass is in significant decline, such as Musquodoboit, Eelgrass beds of the Eastern Shore Islands in the vicinity of Jeddore Harbour, Clam Harbour, Cable Island, Taylor Head, Gerard Island (Hill et al. 2012), and Gegogan Harbour seem to be abundant and stable. Data collected by M. Wong and H. Lotze between 2007 and 2017 show healthy and stable Eelgrass beds with high biomass and shoot densities at False Passage/Cable Island and Taylor Head. These locations within the AOI are comparable to those in Port Joli on the South Shore, which has also low human impacts (Figure *15*). Declines in Eelgrass have been linked to increased nitrogen loading from anthropogenic sources in other parts of the Northwest Atlantic, primarily as a result of increased algal blooms that limit light availability (Hauxwell et al. 2003). The most significant threats to Eelgrass are climate change, wasting disease caused by fungus (*Labyrinthula* sp.), and anthropogenic stressors such as coastal development, recreation, and sewage or agricultural runoff leading to low light availability for photosynthesis (Bundy et al. 2014). Sedimentation, increased turbidity, anoxic conditions, high flow regime, and physical damage are also notable stressors on Eelgrass beds (Vandermeulen et al. 2012). Increasing anthropogenic pressures on coastal ecosystems such as the Eastern Shore AOI threaten the essential functions and services that macrophytes provide (Schmidt et al. 2011). Schmidt et al. (2011) determined that both Eelgrass and Rockweed have a very different canopy structure and complexity and utilize different bottom types that support unique species assemblages, meaning one habitat cannot replace another. Therefore, protecting these marine macrophyte beds should be a management priority (Schmidt et al. 2011).

Salt Marsh

Salt marshes are highly dynamic ecosystems, responding to the interactions between freshwater, saltwater and sediments, and they serve as a transition zone between the terrestrial and marine environments (Bowron et al. 1999). Salt marshes, estuaries, and Eelgrass beds are important habitat for many species of fishes and invertebrates, including several species of snail (Gastropoda), stickleback (Gasterosteidae), Silversides, Northern Pipefish (*Syngnathus fuscus*), and Mummichogs (*Fundulus heteroclitus*). In low marsh areas, the perennial cord grass *Spartina alterniflora* dominates, while high marsh areas are abundant in *Spartina patens*. Salt marshes are significant in Clam Bay, Clam Harbour, Tangier, Owls Head, Kirby River, Quoddy Harbour, and Marie Joseph Harbour, ranging in size from 0.4–100 Ha (Figure 16). These salt marshes function as a sanctuary, as well as breeding and nursery habitat for terrestrial, near-shore and migratory birds (Bowron et al. 1999) including dabbling ducks, geese, herons, shorebirds, and some passerine birds, such as Nelson's Sharp-tailed Sparrow (Allard et al. 2014, Hanson and Shriver 2006).

Salt marshes perform a number of important functions, including providing habitat for fish and migratory birds, filtering sediments and contaminants from water, buffering against storms and coastal erosion, reducing desiccation and thermal stress in associated organisms, and aiding in the function of global nitrogen and sulfur cycles. Salt marshes in Nova Scotia are primarily threatened by sea level rise under a changing climate (Watson et al. 2016) and shoreline development (Bundy et al. 2014) such as damming, ditching, draining, burying/filling, excavation, road construction, and improper culvert sizing and placement (Bowron et al. 1999).

Macroalgae (Seaweed and Kelp)

The Eastern Shore contains diverse and abundant algae, indicating high productivity (Gromack et al. 2010). Algae provide important food and habitat for invertebrates, fishes, and marine birds in the coastal zone. These range from single-celled diatoms, to filamentous algae, to large kelps. Kelp beds are known to be very important to the nearshore ecology of Nova Scotia, particularly in their links to commercial fish and invertebrates (DFO 2013a). Kelps are typically found from the low intertidal to depths of approximately 20 m, with variation in the depth range related to light attenuation and exposure. Filamentous red, green, and brown algae tend to be seasonal in abundance, but perennial kelp beds occur on rocky substrate such as bedrock and boulder fields within coastal Nova Scotia, including within the Eastern Shore. Seaweed diversity is generally the highest in the subtidal where red, green, and brown algae species coexist. Red calcareous (coralline) crusting algae is abundant in the Eastern Shore Islands (Vandermeulen 2018b) and is important in stabilizing the substrate allowing other species to flourish (Bundy et al. 2014). Coralline algae were the only algae detected at depths >50 m in the Eastern Shore drop camera survey, as they can survive at low light levels (Vandermeulen 2018b). In the intertidal zone of Nova Scotia, Rockweed (*Ascophyllum nodosum*) and other brown seaweeds (*Fucus* spp.) dominate, as they are both resistant to desiccation. *A. nodosum* is typically found in protected waters, while *Fucus* spp. is found in more exposed areas, though both species may exist in either protected and exposed areas. Similar to Eelgrass, both Rockweed and kelp beds provide carbon storage and essential habitat and food for a wide range of invertebrate, fish, and bird species (Schmidt et al. 2011, Schmidt and Scheibling 2007, Seeley and Schlesinger 2012, Vandermeulen 2013, Watt and Scrosati 2013a, b). Macroalgae and macrophytes have been shown to be an important component of Lobster and crab diets, potentially providing resistance against bacterial infection (Bushmann et al. 2018). Studies on the diet composition of the American Lobster found that individuals captured within macroalgal beds had a more diverse diet than those living in barren areas (Elner and Campbell 1987). This diverse diet was likely associated with the concomitantly diverse assemblage of organisms within the rockweed beds and the algal substrate itself, which comprised an important and targeted (i.e., non-coincidental consumption) diet component (Elner and Campbell 1987).

Kelp beds occur along the rocky semi-protected to exposed coastlines of the Eastern Shore, and they are amongst the most productive ecosystems worldwide (Krumhansl et al. 2016). Kelp forests concentrate secondary productivity in the coastal zone through the provisioning of food and biogenic habitat to coastal food webs (Krumhansl and Scheibling 2012, Miller et al. 2018).

Ecosystem services provided by kelps include nutrient cycling, carbon storage and flow, coastal protection, and the support of lucrative commercial fisheries through high primary productivity (Krumhansl et al. 2016, Smale et al. 2013). In Atlantic Canada, several important commercial fishes and crustaceans utilize kelp beds at some point throughout their lifetime, including Atlantic Cod, Tomcod, White Hake, American Lobster, Rock and Jonah crab (Bologna and Steneck 1993). Kelp forests have undergone cyclic fluctuations over the past century due to various environmental and biogenic drivers. Sea urchins play a key role in determining overall levels of ecosystem productivity and diversity through their grazing activity, which can result in complete losses of kelp over tens of kilometers of coastline (Scheibling et al. 1999). In recent years, urchin populations in Eastern Canada have been limited by increased mortality associated with recurrent outbreaks of an amoebic pathogen, which has decreased grazing rates on kelp beds (Scheibling et al. 2010). Because kelps thrive in cold, nutrient-rich water, ocean warming associated with climate change has had a measureable and negative impact on kelps worldwide and in Nova Scotia specifically (Filbee-Dexter et al. 2016, Krumhansl et al. 2016). Warming temperatures also drive high encrustation rates of the invasive bryozoan *M. membranacea* on kelps in Nova Scotia, which causes kelp tissue weakening (Krumhansl et al. 2011) and high rates of canopy loss (Krumhansl and Scheibling 2011a). This, combined with higher grazing rates by the mesograzer *Lacuna vincta* in warmer water temperatures (Simonson et al. 2015a) are leading to high canopy defoliation rates and losses of kelp coast-wide, particularly in semi-protected bays and inlets (Filbee-Dexter et al. 2016). Coastal headlands with higher exposure and nutrient flushing are likely refuges from these effects; however, as these areas tend to have cooler water temperatures and lower encrustation and grazing rates by *M. membranacea* and *L. vincta* (Krumhansl and Scheibling 2011b, O'Brien 2018). Few studies in Nova Scotia have focused specifically on kelp in the Eastern Shore AOI, but the available evidence suggests similar ecological dynamics between this area and other parts of the coastline that are more heavily studied (e.g., St. Margarets Bay and Sambro area). Recently, kelps including *Laminaria digitata*, *Saccharina* spp., and *Agarum clathratum* were frequently observed on the exposed sides of the islands and rocky outcroppings within the AOI (e.g. Long Island, Halibut Island, Tuffin Island) (Metaxas, Unpublished; Vandermeulen 2018b).

The two most important marine plant (seaweed) harvests in Nova Scotia are Irish Moss (*Chondrus crispus*) and Rockweed (DFO 2013a). Rockweed is a brown algae especially abundant in the intertidal zone, covering 80–90% of the intertidal zone in Atlantic Canada, and the nearshore subtidal at depths up to 10 m (Kay et al. 2016, Khan et al. 2018). Rockweed is also important in storing carbon and has roles in cycling nutrients. Numerous invertebrate, including American Lobster, and fish species use Rockweed as a shelter at high tide (Table 9) (Karnofsky et al. 1989, Schmidt et al. 2011). Floating canopy associated with mature rockweed beds offers protection and substrate for prey during the Common Eider (*Somateria mollissima dresseri*) brood rearing period, especially during the initial weeks of duckling development (Hamilton 2001, McAloney 1973). Research in the outer Bay of Fundy by Blinn et al. (2008) found low slope unharvested rockweed beds were used preferentially and longer during brood rearing than steep slope harvested sites. Kay et al. (2016) demonstrated that canopy height, density, and circumference were much better predictors of community structure than Rockweed biomass alone, and they recommend incorporating differences in canopy structure into ecosystem-based management of Rockweed harvest.

Surveys by Schmidt et al. (2011), Kay et al. (unpublished), and Vercaemer et al. (2018) showed that Rockweed biomass in the Eastern Shore Islands region is comparable to those on the South Shore and in Southwest (SW) Nova Scotia (Figure 17), which is the main area of the commercial Rockweed harvest, as it has more extensive Rockweed beds and canopy height (DFO 2013a, Ugarte and Sharp 2012, Vandermeulen 2013). Though similar in overall coverage and biomass, Rockweed plants on the Eastern Shore are much shorter than those on the South

Shore and in SW Nova Scotia (Figure 17). This morphological difference is likely associated with the overall colder water and lower productivity of the Eastern Shore (Cousens 1986, Ugarte and Sharp 2012, Vandermeulen 2013). Rockweed harvesting has generally been much lower and less expansive in the Eastern Shore in comparison to southern Nova Scotia and the Bay of Fundy (DFO 2013a, Vandermeulen 2013). This difference in harvest activity has left many Rockweed beds in the AOI relatively and uniquely undisturbed. Recent surveys report that fish and invertebrate species richness is up to six times higher within Rockweed than on surrounding bare sediments, and this diversity is even higher within Eastern Shore Rockweeds beds relative to those in harvested SW Nova Scotia (Schmidt et al. 2011, Vercaemer et al. 2018) (Figure 18). This is supported by Seeley and Schlesinger (2012) who describe more than 100 species of animals associated with Rockweed beds. Because Rockweed harvesting disturbs habitat through alteration of the canopy structure and has high levels of bycatch, unharvested Rockweed beds, which are likely more common on the Eastern Shore, have a substantially higher habitat value than those that are harvested (Rangeley 1994, Rangeley and Kramer 1995, Seeley and Schlesinger 2012).

The Province of Nova Scotia has issued 20 province wide leases for Rockweed, including *Ascophyllum nodosum* and *Fucus* spp., and four new proposals are under review for the Eastern Shore region as of late 2017. More than 24,000 t of Rockweed was harvested under provincial leases in 2016, the vast majority of which comes from southwest Nova Scotia (DFO 2013a). Halat et al. (2015) calculated that detrital biomass from epidermal shedding of Rockweed amounts to 2 t ha^{-1}. This loss of biomass is not considered when evaluating the potential the impact of annual harvests (20 t ha^{-1}). Of this detritus, 5% originates from shed biomass and frond removal, respectively, and 90% is reproductive tissue, (Halat et al. 2015). Detrital seaweeds are important as ephemeral protection and forage food for epifaunal invertebrates and fishes; for example, American Lobster were observed using loose detrital seaweeds as cover on open sandy areas during the 2017 drop camera surveys in the Eastern Shore Islands.

Irish Moss is a red intertidal to subtidal algae, found within the AOI. Irish Moss is susceptible to eutrophication (Vandermeulen 2009), an issue which could negatively impact this species in populated areas. In the early 1970s, when landings were highest in Nova Scotia (>10,000 t), harvests of Irish Moss in the Eastern Shore totaled between 200 and 400 t, while the highest harvests occurred along the South Shore (Sharp et al. 2008). From the 1980s through 2004, landings decreased to less than 2,500 t for the entire province. There are currently no documented large-scale impacts from harvesting Irish Moss in Nova Scotia due to the sporadic and near non-existent harvest at this time (DFO 2013a). DFO (2013a) provided science advice for ongoing management of Rockweed, Irish Moss, and kelp, as well as recommendations for protecting these seaweed populations in Nova Scotia. These recommendations include the establishment of permanently closed control sites for evaluating impacts of harvesting on standing stocks of Rockweed and Irish Moss, enforcing a minimum 5 mm rake tine spacing for Irish Moss, and replacing cutting heights of 127 mm with a height of 254 mm for Rockweed to ensure survival and regeneration (DFO 2013a).

The invasive green alga *Codium fragile* has been present in the Eastern Shore since 2000 but is cyclical in abundance. *C. fragile* is often found where the invasive bryozoan *M. membranacea* has defoliated native kelps, allowing its establishment (see *Invasive Invertebrates section* below). Fortunately, the presence of this species does not prevent re-colonization of native algae and kelps, but continued monitoring of its presence or absence is necessary (Watanabe et al. 2010). The invasive red alga, *Dasysiphonia (Heterosiphonia) japonica,* has been detected in the Mahone Bay area south of Halifax (Savoie and Saunders 2013), but, as of 2018, has not been recorded within the boundaries of the AOI, likely due in part to relatively colder ocean temperatures in the Eastern Shore.

Undisturbed seaweed populations tend to be stable over long periods of time. Standing stock levels respond most prevalently to short-term (years) events such as storms, ice scour in the intertidal (both affecting mainly *Ascophyllum* and *Chondrus*), or “outbreaks” of herbivores (i.e., sea urchins) in the subtidal. Anthropogenic activities cause the greatest fluctuations in algal populations through long-term alterations like climate change or short-term events like harvesting or deterioration in water quality. High water temperatures, specifically, have been shown to reduce growth and recruitment of seaweeds (Dayton 1985, Simonson et al. 2015a, Simonson et al. 2015b). Disturbance associated with hydrodynamics can also affect seaweed populations where, for example, increased wave exposure and surge can lead to dislodgment and thus increase mortality for kelps (Dayton 1985, Filbee-Dexter and Scheibling 2012, Krumhansl and Scheibling 2011b).

INVERTEBRATES

Diversity

The diversity of physical and biogenic habitats that characterize the coastal zone are associated with a similarly diverse invertebrate assemblage. Sandy and muddy areas are home to infaunal invertebrates including worms (polychaetes) and intertidal areas support marine plants, which provide refuge to a variety of species including crabs, lobsters and amphipods. Habitat forming invertebrates, such as sponges and stalked tunicates, find attachment on rocky bottom areas and themselves provide habitat to other heterospecifics. Crustaceans, echinoderms, polychaetes, tunicates, and molluscs are abundant and occupy a diversity of habitat types and are reviewed here. Other phyla, including cnidarians, nemerteans, bryozoans, and poriferans are found as well, but are not reviewed in detail. More than 70 species of invertebrates have been documented in association with Eelgrass and Rockweed in the Eastern Shore based on studies by H. Lotze and M. Wong (Table 9). This high diversity of invertebrates may contribute to ecosystem resilience, as predators could switch among more abundant prey types as species abundances fluctuate under natural and anthropogenic stressors. Invertebrate biodiversity assessments based on the Snow Crab Survey revealed relatively high diversity associated with the waters near the seaward boundary of the AOI in comparison to coastal waters south of Halifax and deeper waters of the Scotian Shelf—see Figure 3.4.1-1 in Ford and Serdynska (2013).

Invasive Species

There are a variety of invertebrate, AIS species present in the coastal Scotian Shelf, including tunicates, crustaceans, and bryozoans, which have negative impacts on ecosystem health. Specifically, the four tunicate species *Ciona intestinalis*, *Botryllus schlosseri*, *Botrylloides violaceus*, and *Styela clava*, the crustacean *C. mutica*, and the bryozoan *M. membranacea* are biofouling species, clogging pipes, aggregating on marine vessels, and disrupting aquaculture practices (Carver et al. 2003, Daigle and Herbinger 2009, Sephton et al. 2017). *M. membranacea* additionally defoliates kelps through tissue weakening (Krumhansl et al. 2011, Saunders and Metaxas 2008), but its range is limited by cold temperatures (Saunders et al. 2010). European Green Crab (*Carcinus maenas*) are another notorious invader abundant in the inshore and is present in the Eastern Shore. In general, the Eastern Shore has fewer and less abundant invasive species relative to southern Nova Scotia and the Canso region (Sephton et al. 2017), and, in fact, the invasion extent is much lower relative to sites south/west of the AOI boundaries (Table 3).

A three-year study by Sephton et al. (2017) monitored 32–57 coastal stations in the Maritimes Region from 2012–2015, collecting temperature, salinity, chlorophyll *a*, and oxygen data, and used monitoring plates to determine the presence or absence of aquatic invasive species. Less than 10% of stations were free of invasive tunicates, suggesting they are ubiquitous along the coast of Nova Scotia. *C. mutica* and *M. membranacea* were detected at 50% of stations during this timeframe. Three stations – Ship Harbour, Sheet Harbour, and Cooper's Point – are within the AOI boundaries and were monitored in at least one year. Ship Harbour is noted as a Sentinel Station, meaning it is monitored every year. In addition, the East Petpeswick Yacht Club and Port Bickerton sites are adjacent the western and eastern AOI boundaries, respectively. In Nova Scotia, *B. schlosseri* was the most common tunicate in all regions, ranging from 77–85% present in these records, while *C. intestinalis* was the second most common and also found at all stations except the inner Bras d'Or Lake. Data for Ship Harbour shows that two AIS species were detected, the Sea Vase (*C. intestinalis*) and Golden star Tunicate (*B. schlosseri*) during 2012–2014. Only *C. intestinalis* was present in 2015 (Sephton et al. 2017) and most recently during 2016–2017 (Silva, A. Pers. Comm.). The average coverage of *C. intestinalis* on monitoring plates was <25% for 2012–2014 and increased to <50% in 2015 (Sephton et al. 2017) where it has remained (Silva, A. Pers. Comm.). The average cover of the Golden Star Tunicate during 2012–2014 was <25% and it has not been detected since 2014. Port Bickerton, a sentinel station is located at the northeastern edge of the AOI's boundary, was also monitored from 2012–2015. In addition to Sea Vases and Golden Star Tunicates, the Violet Tunicate (*B. violaceous*) was also recorded. The average cover of Violet Tunicate on the monitoring plates did fluctuate from the highest of nearly 75% in 2012 to <25% in 2015 (Sephton et al. 2017). The most recent coverage estimates for this species was <50% at the Ship Harbour monitoring site. The average cover of *C. intestinalis* and *B. schlosseri* on Port Bickerton monitoring plates during 2012–2015 was <25%.

Other invasive invertebrates are observed less frequently. The crustacean *C. mutica* was only present in Ship Harbour in 2013 and *M. membranacea* was only present in 2012 (Sephton et al. 2017). Recent unpublished data from C. DiBacco and A. Silva shows that *C. mutica* was has been detected in both 2016 and 2017 in Ship Harbour, and *M. membranacea* was detected at Port Bickerton in 2017. *M. membranacea* was also abundant on kelps observed during the 2017 drop-camera surveys conducted by Vandermeulen (2018b) and has been previously recorded in 2007 (Watanabe et al. 2010).

C. maenas juveniles were occasionally observed on the monitoring collectors, likely using the collection plates as a refuge, and local ecological knowledge suggests that Green Crab are ubiquitous along the Eastern Shore, as they are along all of coastal Nova Scotia. Green Crab may be problematic in the Eastern Shore, as they are voracious omnivores that feed primarily on shellfish (Klassen and Locke 2007). Green Crab have been observed digging through and dislodging Eelgrass (Garbary et al. 2014) and disrupting fine sediments (Matheson et al. 2016) in some areas of eastern Canada. The presence of Green Crabs has also been linked to the decline in Eelgrass cover and an up to 10 fold decline in fish abundance and biomass (Matheson et al. 2016). Though these effects have not been observed in the Eastern Shore, these invasive invertebrates nonetheless may represent a threat to the Eelgrass beds found within the AOI.

Jeffery et al. (2017b) reveal that Green Crabs north of Halifax are genetically distinct from Green Crab in the Bay of Fundy and United States, likely due to the environmental tolerances of different ecotypes. Green Crab were originally introduced to the New York, USA region approximately 200 years ago, where they halt south of Halifax until a second, more-recent, invasion occurred in the 1980s. This invasion brought Green Crab propagules from northern Europe, which appeared better adapted to the colder temperatures in the Eastern Shore and north of Halifax. These cold-water adapted Green Crabs spread further north and began to hybridize with crabs from the southern invasion that had reached their northern limit (Audet et al. 2003, Jeffery et al. 2017a, Roman 2006). This genetic information is crucial, as it suggests that, had a second invasion not occurred, Green Crab would not likely have established stable populations on the Eastern Shore due to the colder temperatures relative to areas further south. The position of the Eastern Shore near the interface of the 'northern' and 'southern' crab populations (approximately 44 °N) suggests that population dynamics of this invasive species could be impacted by climate change, as anomalies projected for the Eastern Shore Islands (1.6 ± 0.2 and 1.3 ± 0.1, mean ± sd; surface and bottom temperature, respectively; See *Long-term changes, resiliency and recoverability* section for more detail) bridge the thermal threshold delimiting the two population groups (Jeffery et al. 2018, Tepolt and Somero 2014).

Sephton et al. (2017) noted that 2012 and 2015 were the two warmest years recorded as part of DFO's AIS Monitoring Program. Tunicate recruitment is highest and tunicate abundance was greatest in these particularly warm years (Lowen and DiBacco 2017). Overall, there are fewer invasive species (2 tunicates – *C intestinalis* and *B. schlosseri*) that have been detected within the AOI than further north, where there are 4 species of tunicates in addition to *B. violaceous* and *S. clava*. Further to the south, it has been documented that additional species *Ascidiella aspersa* (Southwest Nova Scotia) and *Didemnum vexillum* (Bay of Fundy) have been detected with increasing frequency (Sephton et al. 2017). Continued monitoring of invasive species within the AOI and surrounding areas will be necessary. Changing climate conditions for the Eastern Shore are expected to change the faunal composition of invasive tunicates, though anticipated changes based on suitable habitat for the Eastern Shore are less pronounced than other areas projected to be warmer in future climates, such as the Northumberland Strait and St. Margarets Bay (Lowen and DiBacco 2017).

Sponges and Cnidarians

Cnidarians – including soft corals (Alcyonacea), gorgonian corals (Gorgonacea), anemones (Anthozoa), and sea pens (Pennatulacea) – provide important biogenic habitat in Atlantic Canada. Several species of soft corals, such as *Paragorgia arborea*, grow quite large, but they are typically found in deeper offshore waters and rarely found inshore. Distributions maps in Cogswell et al. (2009) show no presence of Alcyonacea or Gorgonacea in inshore regions, which are instead abundant in the Gulf of St. Lawrence and in deep canyons such as the Gully and Fundian Channel. Anemones were commonly observed on hard surfaces within the AOI boundaries in the 2017 drop camera survey but less so than stalked tunicates (Vandermeulen 2018b). There is evidence of suitable habitat and records from the DFO summer ecosystem survey for sea pens (Pennatulacea) immediately adjacent to the seaward boundary of the AOI (Beazley et al. 2016); however, sea pens are generally more abundant in deeper waters such as within the Gully and Laurentian Channel and were not observed within the AOI during drop camera surveys in 2017.

Most species of sponge (phylum Porifera) that occur in the North Atlantic are isolated individuals but may form dense communities consisting of multiple species (ICES 2009). Sponges are filter-feeders that provide important biogenic habitat for numerous other species of invertebrates and fishes, some of which live within the sponge itself. The species which live within the AOI boundaries have not been identified, but isolated encrusting sponges have frequently been observed on hard surfaces by drop camera within the AOI (Vandermeulen 2018b).

Tunicates

As noted in the Invasive Species section, four species of solitary and colonial tunicates are invasive in the Maritimes Region, though only two have been detected within the Eastern Shore

Islands boundaries by DFO's AIS Monitoring Program. Native Stalked Sea Squirts (*B. ovifera*) are widespread but sparse within the AOI (Vandermeulen 2018b). *B. ovifera* is widely distributed across the North Atlantic between depths of 10 and 300 m, and it forms significant concentrations in the Bay of Fundy and off Halifax (Beazley et al. 2017). Depth, substrate type, and benthic algal type are suggested to be strong predictors of *B. ovifera* abundance. Predictions of presence probability (Beazley et al. 2017) exclude a 5 km buffer zone seaward of the mainland, but do show *B. ovifera* having suitable habitat in the Eastern Shore. *B. ovifera* also provides habitat for other invertebrates, such as bivalves and crustaceans, that attach to their stems and holdfasts (Murillo et al. 2011). *B. ovifera* have undergone declines in the Bay of Fundy, as they are at risk of irreversible damage from bottom-contact fishing. This species has a very long regeneration time (>20 years) and, as such, are known as a Vulnerable Marine Ecosystem (VME) indicator species (Murillo et al. 2011).

Lobster

The American Lobster (herein Lobster) is a decapod crustacean abundant in the inshore waters of Atlantic Canada. Lobsters are meroplanktonic with a brief pelagic dispersal phase ranging 3–6 weeks, followed by settlement to the benthic environment in generally near-shore, shallow areas with cobble bottom as juveniles. Lobster reach sexual maturity at 6 to 9 years of age and shortly thereafter recruit to the fishery as a 'legal sized' Lobster. At maturity, Lobsters move to deeper, warmer waters in the fall and winter, and return to the inshore in the spring (Campbell 1986). Lobsters breed in the late summer-early fall and carry their eggs under their abdomen for up to one year. They are found in a variety of habitats, including soft muddy substrates, cobbles or bedrock, and Rockweed and Eelgrass beds, and sandy substrates (Bundy et al. 2014, Cooper and Uzmann 1980, Karnofsky et al. 1989). Juvenile Lobsters prefer complex habitat that provides shelter, such as Rockweed beds or cobble fields (Karnofsky et al. 1989). Barshaw and Lavalli (1988) used experimental evidence to show that juvenile Lobsters create burrows for protection in rock substrates more often than muddy substrates, and more often in Eelgrass beds than mud substrates. Lobsters are omnivorous, preying on invertebrates such as sea urchins and mussels, but also Eelgrass and macroalgae (Bushmann et al. 2018, Elner and Campbell 1987, Elner and Jamieson 1979).

The American Lobster is a vital fished species in coastal Nova Scotia and specifically to the Eastern Shore. The fishery is trap only and is portioned among two Lobster Fishing Areas (LFAs) that overlap with the boundaries of the AOI (32 and 31B; Figure 19) (DFO 2004b). All LFAs east of Halifax are spring fisheries (April/May to June/July). Within the Eastern Shore, Lobster undergo slower growth compared to the Bay of Fundy as a result of generally colder waters. Lobster in this region also achieve a smaller size at maturity (75 mm carapace length; Port Bickerton) relative to Bay of Fundy Lobster (>100 mm carapace length; Grand Manan) (Watson et al. 2013). Between 1998 and 2001, minimum legal size (MLS) increased by 1.5 mm in both LFAs, and each licence holder was required to v-notch and return 50 kg of large, non-ovigerous females to the fishing ground annually (DFO 2004b). By 2011, the MLS was 82.5 mm in both LFAs. The majority of the fishery within LFA 32 occurs in waters shallower than 90 m (A. Cook, Pers. Comm.), suggesting that Lobster are fished in the majority of the AOI, which extends approximately to the 100 m isobath.

As observed over the past decade across much of the Canadian Lobster distribution, landings within LFAs 32 and 31B have shown increased to near record highs (Figure 20). In LFAs 32 and 31B, landings peaked in 2016 at 1289 t and 1187 t in 2017, respectively, while catch per unit effort was highest in LFA 32 in 2016 (DFO 2017b). A similar increasing trend over the last decade can be observed off Cape Breton (LFA 27) and along the South Shore (LFA 33), peaking in 2014 and 2016, respectively (DFO 2017b). Landings in LFAs 31B and 32 are an order of magnitude lower than in LFA 34 off Southwest Nova Scotia, which has the highest landings in Canada (>25,000 t in 2016).

Recruitment, measured as the number of sublegal-sized Lobster per standardized trap from the FSRS, show slight increases between 1999 to 2016 (see Figure 4 in DFO (2017b)). These increases in recruitment starting in 2010 in LFAs 31B and 32 correspond with increased landings during this time. The CPUE of sublegal lobster is similar between LFAs 30, 31B, 32, and 33E (DFO 2017b).

Crabs

A number of crab species inhabit the Eastern Shore AOI, including Rock Crabs (*Cancer irroratus*), Jonah Crab (*Cancer borealis*), hermit crabs (*Pagurus* spp.), spider crabs (*Hyas* spp.), and the invasive European Green Crab (*Carcinus maenas*). Many of these species are associated with Eelgrass and Rockweed beds (Table 9). While Snow Crab (*Chionectes opilio*) can be found inshore, they prefer depths >60 m (Bundy et al. 2014) and are often found deeper just outside the AOI boundary, and they are not discussed here. There are no active directed fisheries for Rock and Jonah crabs the Eastern Shore, though historically landings increased five-fold between 1994 and 1999 (Bundy et al. 2014). However, both species may be caught as bycatch in the Lobster fishery.

Green Crab, discussed in the *Invasive Species* section, are a highly invasive species and are well-established in Canadian waters (Therriault et al. 2008). This species is generally considered destructive and has been observed disturbing Eelgrass beds and preying on molluscs, including wild and farmed bivalves. This species is well established in Nova Scotia and monitoring continues as part of the DFO AIS program (Sephton et al. 2017).

Echinoderms

Sea stars (*Asterias* spp.), brittle stars (Ophiuroidea), Green Sea Urchins (*Strongylocentrotus droebachiensis*), Sea Cucumbers (*Cucumaria frondosa*), and Sand Dollars (*Echinarchius parma*) may all be found within the AOI boundaries. These species are common in nearshore subtidal areas, though Sand Dollars and some species of sea stars and brittle stars (*Ophiopholis aculeata* and *Amphiolis squamata*) are found offshore as well.

Green Sea Urchins range from the intertidal to approximately 140 m depths, and spawn in inshore waters in the spring. Following a two month planktonic larval period, juveniles settle on hard substrates, preferably cobble, and generally prefer ledges or crevices as adults. Kelp beds of *Saccharina* and *Laminaria* are the primary, preferred food source of Green Sea Urchins, in addition to bryozoans, coralline algae, or filamentous red and brown algae (Scheibling and Anthony 2001). Green Sea Urchins are a prey species for various invertebrates, groundfish, and marine birds like the Common Eider (Goudie and Ankney 1986, Himmelman and Steele 1971). Following a grazing front of adult urchins, which can consume several meters of kelp bed per month, it can take several years to a decade for the reestablishment of kelp in a grazed area (Lauzon-Guay et al. 2009). Outbreaks of an amoeba (*Paramoeba invaclens*), which are linked to hurricane frequency (Scheibling and Lauzon-Guay 2010), occasionally result in mass mortalities of Green Sea Urchins, and disease transmission and mortality are more common when the water is warm (Scheibling et al. 2010). These mass mortalities, either from disease or starvation, can allow the reestablishment of kelp beds (Miller and Nolan 2000). Green Sea Urchins are fished for their gonads, and they must have minimum test diameter of 50 mm to be harvested. The fishery is largest in the Bay of Fundy, with landings of 1240 t from 2005–2009, and only 22 t in the Eastern Shore (Bundy et al. 2014). Based on drop camera surveys conducted in fall 2017, sea urchins were rare within the AOI, and consisted primarily of small individuals hiding in crevices.

Sea stars are often cited as a “keystone species”, meaning they are crucial to maintaining the diversity of the communities they live in, and the loss of a keystone species would lead to drastic changes in an ecosystem (Menge et al. 1994). Though ecologically important, to date there has been no commercial market established for sea stars. At least four species of sea stars, including brittle stars, can be found in inshore regions of Nova Scotia. Sea stars prey upon barnacles, mussels, sea urchins, and various bivalves (Bundy et al. 2014). Most sea stars settle on rocky substrates following a pelagic larval phase, and they are often found in kelp beds and near subtidal mussel beds (Barbeau et al. 1996). Brittle stars were observed frequently but sparsely during the 2017 drop-camera surveys conducted within the AOI (Vandermeulen 2018b).

Sand Dollars are found as epifauna and shallow infauna in the subtidal zone in fine to medium sandy sediments, and they are found offshore on shallow banks (e.g., Sable Island Bank). Juveniles generally prefer the inshore area, specifically depths of 16–20 m, while adults are less constrained by depth. Sand Dollars feed on organic materials in the sediment, particularly diatoms, and, as such, generally prefer shallower waters where diatoms are more abundant. Sand Dollars are preyed upon by marine birds, groundfish, crabs, and sea stars (Cabanac and Himmelman 1996). While Sand Dollars are observed in the Eastern Shore area (Vandermeulen 2018b), there is little information on their overall abundance.

Little information on inshore stocks of Sea Cucumber exists for the Scotian Shelf. *C. frondosa* is a common species that is found from the intertidal zone up to 370 m deep, but it is most often found in depths shallower than 30 m. Sea Cucumbers have separate sexes and spawn gametes into the water column, and larvae are planktonic for 48 days. Settling juveniles and adults attach to hard substrates and filter-feed by extruding their oral tentacles into the water column (DFO 1996). While a Sea Cucumber fishery exists on the Scotian Shelf, there is no commercial fishery within the Eastern Shore Islands study area.

Polychaetes

Polychaetes (Annelid worms) are highly diverse and may be sedentary, burrowing, or free-swimming. Polychaetes prefer soft sediments and thus are most abundant in fine sediment areas such as mudflats or sandy bottoms. Bloodworms (*Glycera dibranchiata*) are abundant in muddy, soft substrates, while Sandworms (*Nereis virens*) prefer coarser substrates often associated with clam beds. Cullain et al. (2018) report that five species of polychaetes (*Clymenella torquata, Glycera* sp., *Nereis* sp., *Nephtys* sp., and *Pectinaria gouldii*) are often associated as infauna with Eelgrass beds, with greater abundance or biomass of these species on the Scotian Shelf and New Brunswick relative to Newfoundland. This study included two sites within the Eastern Shore Islands (False Passage and Taylor Head).

While no commercial polychaete fishery exists on the Eastern Shore, polychaete fisheries area active in the Minas Basin and western Nova Scotia (Miller and Smith 2012). Sandworms and Bloodworms are harvested recreationally as fish bait in the Eastern Shore, particularly in West Jeddore and Jeddore Harbour (Bundy et al. 2014).

Molluscs

Some bivalve molluscs of economic and recreational importance occur inshore, including Ocean Quahogs (*Arctic islandica*), Softshell Clam (*Mya arenaria*), Blue Mussel (*Mytilus edulis* and *M. trossulus*), and Sea Scallops (*Placopecten magellanicus*). Snails (*Littorina* spp.), Moon Snails (*Euspira heros*), and Whelks (*Buccinum undatum*) are also common in intertidal and subtidal habitats. The gastropod *L. vincta* is a snail species common on kelps and other algae, which plays an important role in the ecology of kelp beds (Krumhansl and Scheibling 2011b). Quahogs, particularly older-larger individuals, are less abundant inshore than offshore, while Softshell Clams and Sea Scallops are present throughout coastal Nova Scotia. Blue Mussels are ubiquitous along hard substrates in the intertidal and shallow subtidal. Recreational clamming previously occurred within the AOI boundaries, but has remained closed since 2015 because of a lack of environmental monitoring by the CSSP in this region.

Blue Mussels (*M. edulis*) and a sister species, *M. trossulus*, are prevalent in rocky subtidal habitats throughout Nova Scotia. They are typically found in the intertidal zone, and in subtidal depths of 3 m, but may be found in depths up to 60 m (Kenchington et al. 2002, Scrosati and Heaven 2007, Seed and Suchanek 1992). Both species settle and attach to hard substrates as juveniles where they remain as adults, filter feeding algae, diatoms, planktonic larvae and bacteria, and other detritus from the water. These species often coexist, but *M. trossulus* prefers depths of <1 m and is more tolerant of less salty water than *M. edulis* (Bundy et al. 2014, Kenchington et al. 2002). Blue Mussels spawn in May to June, and planktonic larvae are able to swim and choose specific substrates on which to settle. Adult mussels are preyed upon by sea stars, crabs, and occasionally Whelks, and are the preferred prey for Common Eider (Guillemette et al. 1992). Wild adult Blue Mussels are rarely harvested due to extensive shellfish aquaculture of these mussels, with the exception of some wild larvae or spat to supplement existing farms. *M. trossulus,* on the other hand, is not commercially exploited (Bundy et al. 2014).

Softshell Clams occur in muddy bays and estuaries, and significant beds are found in Clam Harbour within the AOI boundary (McCullough et al. 2005). Softshell Clams are preyed upon by diving marine birds (i.e., scoters and Common Eider), groundfish, and the invasive Green Crab, and they are filter-feeders that filter organic material out of the water column (Bundy et al. 2014). Gold mining tailings along the Eastern Shore have historically had adverse effects on clam beds in this region, leading to high levels of arsenic and mercury in Clam Harbour and Isaac’s Harbour, though these levels remain low compared to other parts of the Eastern and South Shores of Nova Scotia. Softshell Clam were last assessed by DFO in 1995.

There is little information on the abundance and distribution of inshore Sea Scallop in Nova Scotia. Sea Scallops are common at depths of 35–120 m, and they are found in a broad temperature range (0–18 ºC) (Brocken and Kenchington 1999). Scallops are abundant on substrates that contain a combination of mud, gravel, and/or plants, and in areas of high current. Adult scallops are prey for Atlantic Cod, wolffish, and sea stars, but may be preyed upon by other species like crabs and Lobster if they are damaged (Brocken and Kenchington 1999, Elner and Jamieson 1979). Sea Scallops are commercially fished in the Bay of Fundy using scallop drags. There is also a recreational fishery in the Bay of Fundy and Atlantic coast of Nova Scotia using SCUBA, dip nets, and rakes and tongs. Scallop Fishery Area (SFA) 29 encompasses the entire Eastern Shore, ranging from Yarmouth to Cape North including up to 22 km offshore. In SFA 29 East, shell height must be at least 95 mm to be harvested, but no formal stock assessment is conducted in this SFA. Annual landings within SFA 29 are highly variable but are primarily from Lunenburg and Queens counties rather than the Eastern Shore.

Two species of squid occur in Canadian waters – the Longfin Squid (*Loligo pealeii*) and the Shortfin Squid (*Illex illecebrosus*) (Dawe et al. 2007). Both species have short (annual) life cycles and form an important component of the coastal and offshore food webs, preying upon euphausiids and mysids, which are preyed upon by seals, marine birds, and pelagic fishes. Longfin Squid are found as far south as the Gulf of Venezuela, while Shortfin Squid occur as far south as central Florida (Dawe et al. 2007). Both species range up to Newfoundland, but the Longfin Squid rarely occurs north of Browns Bank on the Scotian Shelf. The Shortfin Squid is a migratory species and may transit through the Eastern Shore (Dawe et al. 2007) while migrating to northern feeding grounds or offshore spawning areas. Migratory Shortfin Squid are an important prey species for Great Shearwater (*Ardenna gravis*) along the Atlantic coast (Brown et al. 1981). Shortfin Squid spawn offshore below the surface of the Gulf Stream where their eggs are neutrally buoyant, while Longfin Squid spawn in nearshore coastal zones in the spring and summer. Recent data suggest that warming waters under climate change may favour northward expansion of Longfin Squid but lead to unfavourable oceanic conditions for Shortfin Squid. If the distribution of Longfin Squid does shift north, it is likely that the AOI could be an important area to monitor this change.

Other Invertebrates

Other invertebrates are common in coastal Nova Scotia, including cnidarians (hydrozoans, scyphozoans, and anthozoans), ctenophores, nemertean worms, bryozoans, brachiopods (*Terebratulina* sp.), other crustaceans such as isopods (*Idotea* spp.), barnacles, and Sand Shrimp (Crangonidae), and other less diverse phyla. While these invertebrates are certainly important components of the ecosystem, their abundance and economic/ecological importance in this area is not well-quantified, and, thus, they were not included in the overview.

FISH

Fish Diversity

The diversity of habitats in the Eastern Shore Islands provides shelter and food for dozens of species of pelagic and demersal or benthic fishes. A number of pelagic and diadromous fishes live in the Eastern Shore. Diadromous fishes include Atlantic Salmon (*Salmo salar*), Brown Trout (*Salmo trutta*), Brook Trout (*Salvelinus fontinalis*), River herring (*Alosa pseudoharengus* and *A. aestivalis*), Sea Lamprey (*Petromyzon marinus*), Smelt (*Osmerus mordax*), and American Eel (*Anguilla rostrata*). Trout, river herring, and Smelt are important recreational fisheries in the Eastern Shore. Sea Trout, the marine form of anadromous Brown Trout and Brook Trout, are known to use the coastal zone and are often found associated with seaweed beds (B. Rutherford, Pers. Comm.).The AOI overlaps with the Halifax/Eastern Shore Atlantic Herring spawning area, and Mackerel are known to migrate through this region to reach spawning grounds in the Gulf of St. Lawrence. Kelp and Eelgrass beds are used as nurseries for Juvenile Atlantic Cod, Haddock, Pollock, White Hake, and other less commercially important species, such as Cunner. Skates and sharks may also be present within the AOI, as well as occasional large pelagics such as Bluefin Tuna (*Thunnus thynnus*) and Swordfish (*Xiphias gladius*). Subtropical species are occasional visitors in warmer years, as individual Bandtail Puffers (*Sphoeroides spengleri*) have been observed in 2005 and 2006 (O'Connor 2008). O'Connor (2008) identified 12 juvenile fish species near Moosehead in the Eastern Shore, suggesting the area may be an important nursery. Furthermore, early juvenile fish species accumulation curves on the Eastern Shore show a greater number of species relative to the South Shore or St. Margarets Bay in Nova Scotia when controlling for shore length (O'Connor 2008). In contrast, standardized species accumulation curves generated using 4VsW Sentinel Survey data suggests that species richness is higher in locations sampled west of the Eastern Shore Islands and lower to the east (Figure 21). Community analysis of juvenile fish (O'Connor 2008) and those species captured in the sentinel survey (this review) show generally weak spatial structure in fish assemblages, with the Eastern Shore Islands showing significant overlap with coastal locations immediately to the east and west. Other species, such as Cusk, Three-Spined Stickleback, Longhorn Sculpin (*Myoxocephalus octodecemspinosus*), and Sea Raven (*Hemitripterus americanus*) are known to inhabit the coastal zone of Nova Scotia and have been observed within the AOI, but they are not discussed in detail here because of a lack of data or sparse records.

PELAGIC AND DIADROMOUS FISHES

Atlantic Salmon

The Atlantic Salmon is an anadromous fish species that shows high but not complete fidelity to their natal rivers. As a result, rivers in close geographic proximity are treated as uniform units for management and assessment purposes. COSEWIC identified four of these geographic groups or designatable units (DUs) for evaluation when evaluating the extinction risk of Atlantic Salmon in Canada. The Eastern Shore study area is located within the Southern Upland DU of Atlantic Salmon. Southern Upland Salmon were assessed as Endangered by COSEWIC in November 2010 (COSEWIC 2010b) as a result of population declines and persisting threats to recovery. Little is known about the at-sea behaviour, distribution, and marine survival of these populations, but extensive research has been conducted to assess their freshwater habitat and abundance (e.g. Amiro 2000, Gibson and Bowlby 2009, Gibson et al. 2010). The Eastern Shore Islands AOI includes seaward approaches to rivers that support or once supported Atlantic Salmon. Juvenile salmon are known to make use of coastal areas adjacent to these rivers in May and June, and these nearshore habitats are also of important for species such as Brook Trout and American Eel. Adults may wait in the estuaries for ideal spawning conditions. During these periods, some fish have been observed to leave the estuaries for several days to unknown locations seaward of the archipelago before returning again to attempt to spawn.

Many rivers in the Southern Upland region have undergone some degree of acidification, which has been caused by a combination of acid rain and leaching from the underlying bedrock (Amiro 2000, Watt et al. 1983). Declines in salmon production (approximately 50% from historical levels by 1986) have been attributed largely to acid toxicity in the spawning rivers. Rivers in the Southern Upland DU that are known to have salmon returns (as of 2008/09) are the Salmon River (near Port Dufferin), Quoddy, Moser, and Ecum Secum rivers (Bowlby et al. 2014), but up to 14 rivers and streams between Musquodoboit and the St. Mary's river once supported salmon (DFO 2013b). Of note, the Musquodoboit and St. Mary's watersheds, which contain among the largest returns of adult salmon at present in region, are immediately adjacent to the western and eastern boundaries of the AOI (DFO 2013b).

Rivers with a pH as low as 4.7 are inhospitable for juvenile salmon. While the listed rivers are of a pH suitable for the survival of juvenile salmon (i.e., pH >5.0), none have met their conservation targets and recovery may take 50–100 years (Hastings et al. 2014). The St. Mary's River, adjacent to the study area, has declined from about 1,000 salmon in the mid-1990s to less than 400 since 2005; the LaHave River, south of the study area had returns of 4,000 to 5,000 salmon during the 1980s and now has fewer than 1,000, half the estimated spawning requirement for the river (Gibson et al. 2010).

Bowlby et al. (2014) list potential threats to juvenile and adult Atlantic Salmon in the Recovery Potential Assessment for the Southern Upland DU. In the freshwater environment, threats with a high level of concern for the DU (importance not implied by order) include river acidification from acid rain, altered hydrology, invasive fish species, physical obstructions, and illegal fishing. Threats in the marine environment with a high level of concern include salmonid aquaculture, changes in oceanographic conditions, and changes in predator or prey abundance which impact at-sea mortality (Bowlby et al. 2014). The rationale for each threat are listed in Table 10 and Table 11.

River Herring

Alewives (*A. pseudoharengus*) and Blueback Herring (*A. aestivalis*) are sympatric in their range in Nova Scotia and are collectively fished as 'gaspereau' or colloquially referred to as river herring. River herring are important prey for larger fishes and birds, and they prey upon zooplankton in the marine and freshwater environments (Loesch 1987). River herring are fished commercially and recreationally in the Maritimes using a variety of gear types, including trap nets, dip nets, and set or drift gill nets in lakes, rivers, estuaries, and coastal waters. In the Eastern Shore of Nova Scotia, the Musquodoboit River to the west of the AOI reports the highest landings; however, the average annual catch and total number of participants in the river herring fishery are among the lowest in Nova Scotia and New Brunswick (Gibson et al. 2016).

Adult river herring migrate up coastal rivers in late March to late June to spawn, with the majority of spawning runs occurring in May in Nova Scotia (Gibson et al. 2016). Adults return to the ocean following spawning, while young-of-the-year river herring move downstream in late summer and early fall to winter at sea (Gibson et al. 2016). These species mature between two and seven years of age, at which time they return to their natal rivers to spawn. River herring may spawn up to four to six times throughout their lives. River herring have a high degree of fidelity to their native rivers, and populations of each species in individual rivers are generally considered to be discrete (Gibson et al. 2016, McBride et al. 2014). Alewives tend to spawn in slow-flowing portions of streams and rivers, or in lakes or ponds, while Blueback Herring prefer spawning in fast moving water. The habitat preferences of adults of both species in the marine environment are relatively unknown. As with other diadromous fish species that spawn within the AOI, the use of the coastal zone by river herring remains largely unknown.

American Eel

American Eels are a facultatively catadromous fish that spawn in a large panmictic population within the Sargasso Sea. Following spawning, larvae known as leptocephali are carried northward by the Florida Current and then the Gulf Stream to the continental shelf of northern North America where they metamorphose into juveniles (Jessop 2010). Juveniles spend 3–25 years in either freshwater or brackish habitats, the majority migrating into freshwater rivers and estuaries (Jessop 2010, Oliveira 1999), before returning to the Sargasso to spawn (Pavey et al. 2015). Both adult and juvenile eels feed on many aquatic animals, including insects, crustaceans, polychaetes, and small fish (Smith and Tighe 2002). Threats to American Eel include directed and illegal fisheries, bycatch in other fisheries, pollution, loss of habitat, ecosystem changes such as the introduction of non-indigenous predators, and altered hydrology through damming that impedes upstream migration of juvenile eels (Chaput et al. 2014). American Eel are more or less tolerant of acidic river conditions at different life stages; yellow eels are more tolerant of acidic rivers than elvers, which may experience high mortality in these conditions (Jessop 2003). The Southern Uplands of Nova Scotia are heavily affected by declines in river pH, and improving the water quality in this region as part of the juvenile Salmon Habitat restoration efforts may be beneficial to a number of diadromous species in this region.

American Eel have been historically fished in eastern Canada in aboriginal, commercial, and recreational fisheries (Chaput et al. 2014). Commercial North American harvests began to decline in the early 1990s most drastically in Ontario and Quebec. In 2012, American Eel were assessed as Threatened (COSEWIC 2012a). American Eels are still important in the Maritimes Region to indigenous, commercial and recreational fishers. Large (adult) eels are managed through effort control, so there is no total allowable catch (TAC) for adult eels in the Maritimes Region. The TAC for elvers in the Maritimes is 9,960 kg (wet weight), and licence holders are each allotted 1,200 kg of quota, with no more than 400 kg taken from each river. Landings and catch per unit effort (CPUE) for the elver fishery are generally the highest along the Nova Scotian south shore-lower Bay of Fundy area. Within the Eastern Shore, the Musquodoboit River, Moser River, and rivers near Sheet Harbour, Ecum Secum, Ship Harbour, and Mushaboom are important Eel habitat (Eales 1966).

Tunas and Mackerel

Atlantic Mackerel (*Scomber scombrus*; herein mackerel) are a migratory species that spawn in the Gulf of St. Lawrence in Canada (DFO 2017a). Mackerel overwinter offshore in depths of 70–200 m and migrate to the Gulf in May and June, traveling along the Nova Scotia coastline during this time (Grégoire 1999, Scott and Scott 1988). Mackerel are found inshore in the spring and summer (DFO 2017a). Mackerel are an important forage species for a variety of top predators in the coastal ecosystem, including Harbour Seal (*Phoca vitulina concolor*) (Bowen and Harrison 1996), Blue Shark (*Prionace glauca*) (McCord and Campana 2003), Great Shearwater (Brown et al. 1981), and Northern Gannet (*Morus bassanus*) (Garthe et al. 2014, Montevecchi and Myers 1997). Mackerel is primarily used as bait in Lobster, Bluefin Tuna, Snow Crab, and Atlantic Halibut fisheries (Van Beveren et al. 2017). A gillnet fishery for Atlantic Mackerel exists primarily in the western portion of the Eastern Shore AOI.

Mackerel are managed within NAFO subareas 3 and 4, with the Eastern Shore Islands falling within subarea 4. Commercial landings for both subareas reached a historic high in 2005 (54,621 t) but fell to a historic low a decade later (4,134 t); recreational and baitfish landings are not recorded, and, as such, landings are likely underestimated across Canada (DFO 2017a, Van Beveren et al. 2017). Results from an informal survey conducted by DFO estimate that true landings of this fishery are 150% of the declared catch (Van Beveren et al. 2017). The biomass of Mackerel is estimated using data from an egg survey that takes place at the primary spawning site in the southern Gulf of St. Lawrence. Biomass estimates reached a historic low in 2012 (14,568 t), then rose to 52,667 t in 2016; however, these biomass indices are well below the high levels of 750,000 t in the 1980s (DFO 2017a). As such, the stock is considered in the Critical Zone under the precautionary approach, and, as such, requires a rebuilding plan (DFO 2018b). DFO (2018b) states that in order for the stock to move out of the Critical Zone by 2022, the TAC cannot exceed 4,000 t (a total catch of up to 10,000 t including undeclared catches); under the current total catch of 16,000 t, the stock has a 75% probability of growing out of the Critical Zone by 2025.

Bluefin Tuna (*Thunnus thynnus*) are a species of economic importance in Canadian and North Atlantic waters that were designated Endangered in 2011 due a decline in the abundance of spawning individuals by 69% (COSEWIC 2011). This species lives in the pelagic ecosystem of the North Atlantic, from Newfoundland to the Mediterranean, and is able to live in cold and warm waters. While primarily surface/subsurface occupants, Bluefin Tuna have been noted to dive to depths exceeding 500 m, likely to feed (Maguire and Lester 2012). Their preferred prey includes Atlantic Herring, Mackerel, Capelin (*Mallotus villosus*), and squid. The preferred (pelagic) habitat for tuna is not well understood, but hotspots for the distribution of Bluefin Tuna in Canada include the “Hell Hole” between Browns and Georges Banks, the southern Gulf of St. Lawrence, St. Margarets Bay, and coastal fishing areas in the Eastern and South Shores. Bluefin Tuna have been observed within the AOI boundaries near the shore, presumably feeding on Atlantic Herring that were aggregating in the area at the time (N. Jeffery, Pers. Obs. August 2017). Tagging studies have revealed that the Halifax/Eastern Shore region is one of the most heavily used inshore areas by Bluefin Tuna in Atlantic Canada (DFO 2011). Other species of tuna, including Bigeye, Skipjack, Yellowfin, and Albacore Tuna also occur in Atlantic Canada, but little or no data exist on these species for the Eastern Shore.

Atlantic Herring

Atlantic Herring (*Clupea harengus*) are an important pelagic forage species in the North Atlantic. Atlantic Herring have a high energy content and are a preferred prey item for many marine birds, fish, and marine mammals (Bowen and Harrison 1996, Hastings et al. 2014). Atlantic Herring eggs are high in lipid content and are a common source of energy for Common Eiders in the Gulf of St. Lawrence (Cantin et al. 1974). Atlantic Herring are identified as a Type 1 Ecologically Significant Species and Community Property (ESSCP), meaning they are a forage species with a crucial trophodynamic role (DFO 2006, Hastings et al. 2014). Atlantic Herring were one of the most abundant species collected in the Eastern Shore area by O'Connor (2008).

Atlantic Herring spawn in late summer and early fall (August and September) in the Eastern Shore and most of coastal Nova Scotia, though a spring spawning ecotype does exist, and this species has a strong homing fidelity to its spawning grounds (DFO 2015a). Atlantic Herring mature and spawn at three or four years of age (or 23–28 cm in length) (DFO 2004a, 2015b). Atlantic Herring eggs adhere to cobble, gravel, sand, or submerged macrophytes, and as such areas with these substrates are important for Herring spawning (Franke and Clemmesen 2011, Kotterba et al. 2017). Adult Atlantic Herring migrate large distances to offshore feeding grounds, where they form a mixed stock of genetically distinct Herring from various populations in the North Atlantic (Bekkevold et al. 2011).

4VWX Atlantic Herring fisheries are divided into four components for evaluation and management, with Atlantic Herring in the AOI managed as part of the Coastal (South Shore, Eastern Shore and Cape Breton) Nova Scotia spawning component. Each component has several spawning areas and there is a mixing of fish among spawning components (DFO 2017f). Collapsed Atlantic Herring subpopulations, such as those in the Bras d'Or Lakes, appear to recover very slowly, making current spawning grounds all the more important to the future of this forage species. The AOI overlaps with the Halifax/Eastern Shore spawning area within NAFO division 4W, and it is considered an important Atlantic Herring spawning area (Figure 22). Estimates of acoustic spawning stock biomass (SSB) in the Halifax/Eastern Shore spawning area reached a historic low of 3,668 t in 2012 but underwent a dramatic increase from 9,586 to 68,562 t between 2014 and 2015. As of 2016, the estimated SSB decreased to 54,094 t (DFO 2017f). The estimated SSB for 2015 and 2016 are well above the average for the last five years (28,556 t) (DFO 2017f). Estimates of error are not available around these acoustic SSB estimates, and, as such, caution is warranted when interpreting the absolute tonnage of Herring.

In addition to coastal fixed gear fisheries for bait and subsistence in the Eastern Shore (as well as the South Shore and Cape Breton), there are active gillnet licenses to catch spawning Herring for roe, primarily near the western boundary of the AOI (DFO 2004a). As of 2004, the fishery for spawning Atlantic Herring had existed for eight years (DFO 2004a). The gillnet fishery is size selective, with 89% of Herring being age 5 and older, and 39% being age 6 (DFO 2017f). Individual spawning groups of Atlantic Herring within the coastal component are considered vulnerable to overfishing because of their relatively small size (biomass) and proximity to shore (DFO 2015a). Herring may also be negatively affected by climate change, as it has been demonstrated that the metabolism of larval Herring is negatively affected by ocean acidification linked to warming ocean temperatures and increasing atmospheric carbon dioxide (Franke and Clemmesen 2011).

Sharks

There are few data on sharks that have been collected for the inshore region of Nova Scotia. Shallow coastal waters are not thought to be the preferred habitat for most species of sharks;

however, Blue Sharks, Shortfin Mako (*Isurus oxyrinchus*), and Porbeagle (*Lamna nasus*) may follow schools of fish in close to shore to feed. Blue Sharks and Porbeagle are often encountered off Halifax, Jeddore, and Ship Harbour, though usually in waters deeper than those encompassed by the boundaries of the AOI (H. Bowlby and W. Joyce, Pers. Comm.). Great White Sharks (*Carcharodon carcharias*) and Shortfin Makos sometimes stray close to shore; in August 2017, the non-profit shark conservation and research group OCEARCH tagged a Great White Shark (named Savannah) that was later detected near Liscomb Mills, as was the Great White Shark Hilton in October 2017. Hilton migrated through the Eastern Shore Islands area towards Cape Breton again in August 2018. A Mako Shark (named Carl) was detected near Taylor Head in August 2015. Basking Sharks (*Cetorhinus maximus*) are also occasionally observed inshore in coastal Nova Scotia.

Spiny Dogfish (*Squalus acanthias*) live at a wide range of depths and are found inshore along the coast of Nova Scotia. The 4VsW Sentinel Survey has recorded 27 individual Spiny Dogfish from within the AOI, but there are no data on trends in abundance or stock status for inshore Spiny Dogfish. While the Eastern Shore Islands appear to be important habitat for some key prey species (e.g., Atlantic Herring and Atlantic Mackerel) for sharks, this location does not appear to be critical habitat for sharks in general (H. Bowlby and W. Joyce, Pers. Comm.).

BENTHIC AND DEMERSAL FISHES

A diversity of benthic and demersal fishes inhabit inshore Nova Scotia, with Atlantic Cod, Winter and Smooth Skates, Pollock, Sea Raven, Cunner, Yellowtail, and Winter Flounder most frequently observed. Atlantic Halibut are caught inshore as well, though the 4VsW Sentinel Survey did not catch any Halibut in depths <100 m in 2010 or 2011. Greenland Halibut (*Reinhardtius hippoglossoides*) have also been recorded from the Eastern Shore Islands, but they are not common to this area and are primarily found further offshore along the continental slope. Similarly Hagfish (*Myxine glutinosa*) are found within the AOI and comprise a small fishery, but this species is more common in offshore areas with a soft bottom, and no information is available on their biology specific to the coastal zone. Not all benthic fishes are discussed here, primarily due to a lack of information specific to the Eastern Shore.

Atlantic Cod

Atlantic Cod (herein Cod) are a historically exploited demersal fish. In 2010, COSEWIC designated the Southern population, Newfoundland and Labrador population, Laurentian North and the Laurentian South populations (including the Eastern Scotian Shelf) as Endangered (COSEWIC 2010a). Three populations exist within the Laurentian South DU: southern Gulf of St. Lawrence Cod (4TVn), 4Vn resident Cod, and eastern Scotian Shelf Cod (4VsW). In the Eastern Shore, NAFO division 4VsW Cod have been under a moratorium since 1993, but they are occasionally caught as bycatch in other fisheries (Bundy et al. 2014). 4VsW Cod are composed of several spawning components, including summer and fall components (Mohn and Rowe 2012). This stock does not undertake long migrations as seen in other Cod populations, but it does undergo seasonal movements to deeper, warmer waters in the winter (Mohn and Rowe 2012). In recent surveys, Cod are widespread and it is possible that inshore spawning occurs in certain areas, though inshore spawning populations are largely nonexistent in Nova Scotia. Compared to studies conducted prior to the collapse of 4VsW Cod (e.g., Suthers and Frank 1989), a more recent Individual Transferable Quota (ITQ) survey found that Cod of age 0 and 1 were more abundant inshore relative to offshore, and catches were highest off Cape Sable (Clark 2006).

Tupper and Boutilier (1995) showed that survival of post-settled Cod was higher in structurally complex habitats in St. Margarets Bay, and habitat type also may influence juvenile behaviour;

specifically, Cod in rocky reefs will defend their territories, whereas Cod in sandy areas will school for protection. Juvenile Cod can also be abundant in Eelgrass beds, where they are able to avoid predation and enhance their chances of reaching maturity; this has been demonstrated on both a local (Gotceitas et al. 1997, Laurel et al. 2003, Warren et al. 2010) and global scale (Lilley and Unsworth 2014). These studies suggest that a range of habitats of varying complexity are incredibly beneficial for juvenile Cod.

Whereas there are no directed landings in the 4VsW area due to the moratorium, the Sentinel Survey in this region indicates there are Cod inhabiting the Eastern Shore Islands and they are in fact more abundant inshore than offshore (Figure 23); however, CPUE has decreased continuously over the past 20 years (Figure 24). Further research will be required to determine the habitat usage and overall abundance of juvenile and mature Cod in the Eastern Shore Islands.

Haddock

The stock of Haddock in Atlantic Canada can be separated into the Gulf of St. Lawrence/Eastern Scotian Shelf and the Bay of Fundy/Browns Bank as two discrete populations (Bundy et al. 2014). Haddock prefer rocky or hard bottoms, ranging from the inshore to the continental shelf. Historically, landings of fished Haddock have been roughly equal between the offshore and inshore, but populations declined rapidly (Fowler 2011). Within the AOI boundaries, juvenile Haddock were common off Jeddore Harbour, East Head, and Taylor Head (Bundy et al. 2014). Few Haddock are caught in the Eastern Shore due to groundfish moratorium in 4VW, and there are very few mature Haddock in this inshore region detected by the 4VsW Sentinel Survey (Figure 25); however, inshore areas from Musquodoboit Harbour to Sheet Harbour have historically been considered important for juvenile Haddock (McCullough et al. 2005). Inshore waters have historically been noted as spawning habitat for Haddock and in the vicinity of the AOI, Jeddore Harbour, and the area between East Head and Taylor Head were identified as important juvenile Haddock areas (Bundy et al. 2014, Gromack et al. 2010, McCullough et al. 2005). These areas within the AOI, and inshore waters in general, were previously more extensive and contained more fish. It remains unclear what life stages of Haddock are most abundant in this inshore region. There is currently not sufficient evidence to suggest the Eastern Shore Islands is an important area for Haddock.

Pollock

In the Western Atlantic, Pollock range from southwestern Greenland to North Carolina. In the Maritimes Region, Pollock are managed as western (4X5) and eastern (4VW) areas, but are represented by two population components that differ geographically from the management areas. Eastern Component Pollock, which includes NAFO divisions 4VWXmn, are slower growing than those in the Western Component, which includes NAFO 4Xopqrs5 (Stone 2012). Like Haddock and Atlantic Cod, there are minimal catches of Pollock in the Eastern Shore due to the groundfish fisheries moratorium.

Pollock are semi-pelagic fish that prefer depths ranging from 35–380 m but may be found inshore in <10 m depths. Pollock spawn offshore on the Scotian Shelf in the winter, but inshore bays and estuaries are known nurseries for this species (Clay et al. 1989, Scott and Scott 1988). Age 0+ (juvenile) Pollock move into shallow intertidal and subtidal zones and remain inshore until the age of 2 (Rangeley and Kramer 1995). St. Margarets Bay is an important spawning area for Pollock, as well as offshore of Cole Harbour and Necum Teuch, near the edge of the AOI boundary at 100 m (McCullough et al. 2005). When found inshore, Vercaemer et al. (2018) report that Pollock appear to be highly associated with Rockweed beds, including in East Jeddore and Mushaboom within the Eastern Shore. Rockweed beds in general are known to be nurseries and refuges for Pollock within Atlantic Canada (McCain et al. 2016, Rangeley and Kramer 1995). Overall, the numbers of inshore juvenile and adult Pollock have experienced significant decline (Stone 2012).

Wolffish

Three species of wolffish – the Atlantic Wolffish (*Anarhichas lupus*), Spotted Wolffish (*A. minor*), and Northern Wolffish (*A. denticulatus*) – are found within the coastal zone of Nova Scotia; of these, the Atlantic Wolffish was listed as a species of Special Concern under SARA in 2003 and was confirmed in 2012 (COSEWIC 2012b), while the other two species are listed as Threatened (COSEWIC 2012d, e, Novaczek et al. 2017).

While typically found at depths >50 m, Atlantic Wolffish in particular exhibit a wide depth range, and they can be seen as shallow as 5 m (Novaczek et al. 2017). Wolffish prefer cold bottom temperatures and high oxygen saturation, and, in coastal areas, are associated with high-slope and high-rugosity boulder and bedrock, which can be used for nearshore dens (Novaczek et al. 2017). All three species are found in tows from the Summer RV Survey on the Eastern Scotian Shelf, though Spotted and Northern wolffish appear to be rare west and south of Halifax (Ward-Paige and Bundy 2016).

During the 2010 and 2011 4VsW Sentinel Surveys, there were no reports of Northern Wolffish, and only one Spotted Wolffish was recorded along the Eastern Shore. In the Eastern Scotian Shelf, Atlantic Wolffish are thought to be concentrated north of Banquereau and Middle Bank, and, in the inshore, at less than 90 m. In 2010 and 2011, four Atlantic Wolffish were caught inshore during this survey (Simpson et al. 2013).

This AOI may provide denning and nursery habitat for wolffish, but additional surveys are needed to estimate the abundance of wolffish within and adjacent to the AOI boundaries.

Hake

White Hake (*U. tenuis*) are a demersal species found on the continental shelf and upper continental slope in the Atlantic (Fahay and Able 1989, Hurlbut and Clay 1998), from Labrador south to North Carolina. White Hake have a generation time of nine years. Fish older than two years tend to be found in depths between 50–200 m on fine substrates such as mud and silt, and spawn in the offshore pelagic zone along shelf breaks in the spring or summer (Kulka et al. 2005, Markle et al. 1982). Juvenile White Hake are known to utilize warmer, less saline, inshore areas, including estuaries (Hare et al. 2001), Eelgrass beds (Joseph et al. 2006), Rockweed, and various substrates such as sand, gravel, mud, and/or clay (Vercaemer et al. 2018). These habitats are important for feeding and protection of juveniles, similar to other groundfish (Joseph et al. 2006). While in these inshore areas, juvenile White Hake prey upon invertebrates such as polychaetes and crustaceans, and they are themselves a common prey source for breeding Terns (*Sterna* spp.) (Rock et al. 2007a, Rock et al. 2007b), Harbour Seal (Bowen and Harrison 1996), and other large predators. White Hake are primarily caught as bycatch in fisheries targeting Halibut, Redfish, Atlantic Cod, or Pollock using longlines or gillnets, usually at least 22 km offshore where adults are found.

White Hake are divided into two main stocks in Canada. White Hake in the Eastern Shore are part of the Atlantic and Northern Gulf of St. Lawrence population, which was assessed as Threatened in 2013 (COSEWIC 2013). Adults in this population are estimated to have declined by up to 70% over the past three generations, though the population has remained relatively stable since the mid-1990s. The other stock, known as the Southern Gulf of St. Lawrence population, is considered Endangered (COSEWIC 2013). A combination of genetic analysis (Roy et al. 2012), demographic information, and spawning behaviour were used to divide White

Hake into these stocks (COSEWIC 2013, Roy et al. 2012). While the AOI is not considered an important area for spawning White Hake, the diverse habitat types are important for juveniles and, as such, may be important for rebuilding this stock.

Silver Hake (*Merluccius bilinearis*) are not considered abundant inshore, as they prefer deep continental slope and basin waters, and they aggregate to spawn in shallow waters near the Sable Island and Emerald banks (DFO 2017d). It is possible that coastal spawning areas for Silver Hake do exist, but this has not been documented to date. A commercial fishery exists for this species, but it appears unlikely that the Eastern Shore is significantly important for Silver Hake stocks.

Flatfish

In the Maritimes Region, commercially harvested flatfish species include Atlantic Halibut, American Plaice (*Hippoglossoides platessoides*), Yellowtail Flounder (*Limanda ferruginea*), Witch Flounder (*Glyptocephalus cynoglossus*), and Winter Flounder. Of these species, the Winter Flounder is most common inshore. Winter Flounder are right-eyed flounders that live at depths of 1.8–37 m, on substrates ranging from muddy to hard bottoms, as well as in Eelgrass beds (Joseph et al. 2006). The species has a broad temperature tolerance, having been found in St. Margarets Bay at water temperatures of -1.2 ºC. This species spawns in estuaries in the winter in the northeast United States, and in spring in Newfoundland. Juveniles remain inshore in shallow water for at least 2 years. Winter Flounder prey upon benthic invertebrates, and they are themselves an important food sources for Monkfish (*Lophius americanus*), Spiny Dogfish, seals, and numerous marine birds (Bundy et al. 2014). Winter Flounder make small migrations between the inshore and offshore in summer and winter, which may be due to either temperature fluctuations or food availability (Bundy et al. 2014). Winter Flounder are sexually mature at 3–4 years, or 20–25 cm in length.

American Plaice occur in both the eastern and western North Atlantic, ranging from roughly 50–72º latitude (Busby et al. 2007). Scotian Shelf American Plaice in Divisions 4VW spawn on Banquereau but may be reinforced by spawners in the Gulf of St. Lawrence or Grand Banks. Plaice inhabit a range of depths, including inshore waters, and are more abundant on the Eastern Scotian Shelf than the western Shelf (Horsman and Shackell 2009, Ward-Paige and Bundy 2016). Female Plaice are generally found in warmer, deeper waters than males (Busby et al. 2007, Swain and Morgan 2001, Swain 1997). Juveniles and adults may be found in depths of 20–700 m, but they appear to prefer depths between 100 and 300 m (Bowering and Brodie 1991). This species prefers sediments of fine sand or gravel, consistent with their major spawning banks and with the preferred substrate of Green Sea Urchin, an important prey species (Scott and Scott 1988). Adults may migrate to the inshore region in the summer to feed, then overwinter in deep, offshore areas (Powles 1965, Swain et al. 1998). American Plaice in the Maritime population were assessed as Threatened as a result of a decline in mature individuals on the Scotian Shelf by 67% over the past 36 years (COSEWIC 2009a). Like other groundfish, there is little information for American Plaice specific to the Eastern Shore, but this area may provide an important summer feeding ground.

Flounders are fished as part of a mixed flatfish fishery in NAFO Divisions. 4VW. Flounders are a quota species for fixed gear fisheries in 4VWX5Y, but catch is limited to bycatch only as a result of low available quota. In 4VW, a 1000 t TAC is maintained for flounders, of which no more than 500 t may be American Plaice. Witch Flounder are the primary target species in 4VW in the mixed fishery, while Yellowtail Flounder are also a target. RV survey data for this species fluctuates, but the biomass index for this species is currently well above the limit reference point proxy of 40% of the long-term mean calculated from the Summer RV Survey.

Cunner

Cunner are a species of wrasse that are common in inshore, shallow waters. Cunner spawn in the late summer on the Scotian Shelf and mature at lengths of 8–11 cm. They live near the bottom of the water column and are often found congregating around complex habitat, such as wharves, shipwrecks, and kelp beds. Cunner may be found in the intertidal or very shallow water, and they are able to survive a broad temperature range. In the winter, Cunner enter a torpid state and burrow into the sand or hide in crevices (Scott and Scott 1988). Cunner feed upon molluscs and crustaceans, other invertebrates, fish eggs, and macrophytes, and Cunner are preyed upon by birds such as cormorants, and larger benthic fishes (Scott and Scott 1988). Cunner are ecologically significant, as they have been found to prey upon juvenile Lobster (Barshaw and Lavalli 1988), as well as the larvae of non-native crab species (Savaria and O'Connor 2013). Vandermeulen (2018b) found that Cunner were common on rocky bottoms in the Eastern Shore to depths of 25 m. Although Cunner are abundant and widespread in the Eastern Shore, little information on their life history specific to this region exists.

Skates

Winter Skate (*Leucoraja ocellata*), Smooth Skate (*Malacoraja senta*), Little Skate (*Leucoraja erinacea*), Barndoor Skate, and Thorny Skate (*Amblyraja radiata*) all occur in inshore areas of Nova Scotia (Bundy et al. 2014). Little Skate are the most likely to be found in shallow, coastal waters. Rarely are Little Skate found deeper than 400 m and they are most abundant in shallow, offshore banks such as Georges Bank and parts of the Eastern Scotian Shelf (Simon et al. 2003). Winter Skate generally prefer depths of <100 m, with some observations in less than <1 m of water.

In the NAFO Divisions 4VsW, landings of Winter Skate decreased from 2152 t in 1994 to 200 t in 2002, which corresponds to reductions in TAC over that period of time (DFO 2002). Since 2015, Winter Skate on the Eastern Scotian Shelf are considered Endangered due to a decline in abundance of 98% since the 1970s (DFO 2017c). This region is the only area where Winter Skate overlap with Thorny Skate, with Winter Skate being near their northern limit and Thorny Skate near their southern limit.

Sand Lance

Sand lance (*Ammodytes* spp.) are key non-commercial species associated with soft bottom, sandy sediments and are commonly found inshore (Wong et al. 2016). Sand lance do not undergo winter migrations, and, instead, different species are abundant either inshore or offshore; American Sand Lance (*A. americanus*) are more typical inshore (between 6 and 20 m), while Northern Sand Lance *(A. dubius*) are more common offshore, in depths between 70 and 90 m (Scott and Scott 1988a). Sand lance exhibit cryptic behaviours, burrowing into sandy bottoms to avoid predators and while overwintering and schooling, forming dense aggregations while feeding. Little information exists on sand lance in coastal Nova Scotia, but they are an important forage species for larger fish, such as Atlantic Cod, Haddock, White Hake, and marine birds, including Endangered Roseate Tern (Auster and Stewart 1986, Rock et al. 2007a, Rock et al. 2007b). Sand lance are highly abundant on the Eastern Scotian Shelf based on the DFO Summer RV Survey, but their abundance inshore is not well quantified (Ward-Paige and Bundy 2016). Wong et al. (2016) did not detect any sand lance at the one site (Cable Island) located within the Eastern Shore area in their study; however, this habitat may be unsuitable for sand lance (i.e., rocky/hard substrate), and field observations will be required in soft bottom habitat to determine the abundance of sand lance in the Eastern Shore. Moreover, given their cryptic nature, a lack of observations is not unexpected. Nonetheless, systematic beach seining of areas with a sandy substrate is required to evaluate the distribution and abundance of sand lance in the AOI. Unlike other forage species (e.g., Herring), sand lance do not possess a swimbladder, making hydroacoustic surveying of their biomass difficult.

MARINE MAMMALS

Two species of pinnipeds (seals) inhabit inshore waters of Nova Scotia – the Harbour Seal and Grey Seal (*Halichoerus grypus*). Harp Seal (*Pagophilus groenlandica*) and Hooded Seal (*Cystophora cristata*) sightings are rare in this area. Grey Seals typically prey on forage and groundfish, including sand lance, White Hake, Atlantic Cod, and flatfish (Hammill et al. 2014). The world's largest colony of Grey Seals exists offshore on Sable Island, approximately 200 km from the Eastern Shore Islands, where the breeding colony has rapidly increased since the 1970s (Bowen et al. 2007, Bowen et al. 2003, den Heyer et al. 2017). There are two Grey Seal breeding colonies on islands along the Eastern Shore, Bowen's Ledge and White Island in the AOI (den Heyer et al. 2017). However, there were no Grey Seals pupping on Bowen's Ledge in 2016 (den Heyer et al. 2017).

Harbour Seals are common in Nova Scotian inshore waters and feed on Atlantic Herring, Cod, Pollock, squid, and Mackerel (McCullough et al. 2005). Surveys of Traditional Ecological Knowledge (TEK) noted equal numbers of haulout sites – where seals temporarily leave the water to mate or rest – in the inshore ranging from St. Margarets Bay to Liscomb Harbour. In recent years, few studies have been conducted on the abundance of Harbour Seals in Nova Scotia. The large number of islands and islets associated with the archipelago may provide ample haulout sites for both Harbour and Grey seals. A comprehensive Harbour Seal survey tentatively planned for 2019 or 2020 would provide revised information on the distribution and pupping status of seals in the AOI.

There is a small commercial harvest for Grey Seal in the Gulf of St. Lawrence and along the Eastern Shore of Nova Scotia. They may also be taken under scientific permits, under the nuisance seal permit provision and as incidental catch in commercial fisheries (DFO 2017e). Fishermen are required to report the number of seals removed under the nuisance license, but many do not report this information (DFO 2017e). Grey Seals also transmit a parasite known as seal- or codworm (*Pseudoterranova decipiens*), which accumulates in the flesh of Atlantic Cod and other groundfish (DFO 2010). This infection increases processing costs and reduces marketability of the groundfish, but it seems to have little impact on the condition of Cod (DFO 2010). This parasite is more abundant in Cod found in NAFO division 4T relative to those in 4VsW and 4X.

Cetaceans of a variety of species commonly occur on the Scotian Shelf (Gomez-Salazar and Moors-Murphy 2014), but their occurrence and use of inshore regions is largely unknown. In general, the distribution range of Blue, Fin, Sei, Minke, Humpback, North Atlantic Right, Sperm and Pilot whales, as well as Short Beaked Common, Atlantic White-Sided and White-Beaked dolphins, and Harbor Porpoise all overlap the boundaries of the AOI (Breeze et al. 2002).

The MarWhales Sightings Database (MacDonald et al. 2017) contains opportunistically collected cetacean sightings (i.e., sightings reported without associated search effort) from various platforms including dedicated cetacean research platforms, the Environment and Climate Change Canada Eastern Canada Seabirds At Sea (ECSAS) program, whale watch vessels, marine mammal observers onboard oil and gas platforms, fisheries observers, fisheries officers, and others (including sightings submitted from the general public). There are biases and caveats associated with these opportunistic sightings data that must be considered when interpreting cetacean occurrence. Areas where cetacean sightings were reported most frequently may be areas of importance for the species, or they may be areas with greater presence of opportunistic platforms and, therefore, represent more effort and not necessarily more whales. Conversely, areas with little or no effort will yield fewer sightings, regardless of the true underlying cetacean occurrence. For example, many sightings were reported opportunistically by people aboard non-scientific vessels such as whale-,watching boats and oil and gas platforms, and research vessels conducting summer field studies, which are more likely to be operating during summer months. Thus, there are generally a higher number of sightings submitted from summer months due to increased search effort during this period. The quality of these sightings varies, from high quality sightings (e.g., sightings submitted from experienced researchers, trained marine mammal observers, or associated with photos/video so that species identification can be confirmed) to sightings associated with a lower level of quality (e.g., sightings submitted by individuals or organizations of unknown background in marine mammal identification). It is thus possible that some of the sightings shown may have been classified incorrectly (such as misidentified Sei Whales, *Balaenoptera borealis*). Caution therefore, needs to be taken when interpreting these data.

Data from the MarWhales Sightings Database (MacDonald et al. 2017) include 111 sightings along the Eastern Scotian Shelf from 2007 to 2016 (see Appendix). This database includes sightings of Humpback Whales (*Magaptera novaeangliae*), Atlantic Pilot Whales (*Globicephala melas*), Common (*Delphinus delphis*) and Atlantic White-sided Dolphin (*Lagenorhynchus acutus*), Harbour Porpoise (*Phocoena phocoena*), Fin (*Balaenoptera physalus*), Minke (*B. acutorostrata*), North Atlantic Right Whales (*Eubalaena glacialis*), and a number of unconfirmed species/species of unknown identification. To date there have been no sightings recorded in the MarWhales database within the AOI boundaries, but the closest records to the offshore portion of the boundary include sightings of Atlantic Pilot Whales, pods of White-Sided and Common Dolphin (up to 50 individuals each), and sightings of Humpback, Minke, and Sperm whales (*Physeter macrocephalus*) in various years (Figure 26, Table 12). It is important to distinguish that a lack of sightings within the AOI boundaries does not mean that cetaceans are not present in the area, but it is more likely that there has been relatively little dedicated cetacean research in the area and that sightings that have occurred in the area have not been reported. Additional work on the inshore habitat use of cetaceans in the coastal zone would be valuable to address this knowledge gap.

MARINE BIRDS

The Eastern Shore Islands is identified as both a coastal EBSA and an Important Bird Area due to the habitat the area provides for many species of marine birds (IBA Canada 2018). McCullough et al. (2005) reported that over 85 marine bird colonies exist in this area, based on Local Ecological Knowledge (LEK) and bird surveys (Figure 27). The Canadian Wildlife Service Colonial Waterbird database shows records of at least 101 distinct colony locations within the AOI (Figure 28). These include colonies of Common Eider, Common Tern (*S. hirundo*), Arctic Tern (*S. paradisaea*), Roseate Tern (Endangered - SARA), Leach's Storm-Petrel (*Oceanodroma leucorhoa*), Herring Gull (*Larus smithsonianus*), Great Black-Backed Gull (*L. marinus*), Great Cormorant (*Phalacrocorax carbo*), Double-Crested Cormorant (*P. auritus*), Black Guillemot (*Cepphus grylle*), and Great Blue Heron (*Ardea herodias*). Other species known to congregate in this area include Great Shearwaters, Sooty Shearwater (*Ardenna grisea*), Cory's Shearwater (*Calonectris borealis*), and Wilson's Storm-Petrel (*Oceanites oceanicus*). Northern Gannet are known to migrate through this area on spring and fall migrations. Great Cormorant and Double-Crested Cormorant, both pursuit-diving coastal piscivores, breed and forage within the AOI.

This broad representation of species includes surface-seizing plank-piscivores (e.g., storm petrels), pursuit diving coastal piscivores (e.g., Common Loon (*Gavia immer*), Great Cormorant), benthic molluscivores (e.g., Common Eider, Harlequin Duck, scoters), shallow diving pursuit generalists (e.g., shearwaters), and surface shallow diving piscivores/generalists (e.g., gulls, terns), indicative of a diverse and productive marine prey base. For example, significant numbers of Common Eider breed in the AOI area (Figure 29). Adults of this species rely predominantly on Blue Mussel prey, while young ducklings depend almost entirely on invertebrate prey associated with floating Rockweed canopy (Hamilton 2000, 2001).

Colonies of Great Blue Heron host individuals that forage for small fish and crustaceans in nearshore estuaries and intertidal flats, for example within the archipelago off Quoddy Head. Hedd et al. (2018) highlight the use of two islands – Bird Island, within the AOI, and Country Island, adjacent to the AOI – by Leach's Storm-Petrel, which forms nesting colonies on these islands. Individuals from these islands undergo multi-day foraging trips up to 830 km from the colonies. The colony on Country Island is currently declining, while the status of the colony on Bird Island is unknown. It is possible declines of these island-nesting colonies are linked to offshore oil and gas platforms that intersect with their foraging grounds, but further investigation of the impacts of these platforms on storm-petrels is needed (Hedd et al. 2018).

Endangered Roseate Terns (COSEWIC 2009b) occupy several colony locations on nearshore islands between Liscomb Point at the north end of the AOI and Beaver Harbour, though the shifting nature of small tern colonies in particular has led to some uncertainty regarding their current status (Hastings et al. 2014). Roseate Tern adults generally forage within a 20 km radius of their breeding colonies, in less than 5 m of water, and close to land (< 1.3 km from shore) (Rock et al. 2007a, Thaxter et al. 2012), suggesting that an MPA would afford protection to foraging habitat. Martinique Beach and Clam Harbour Beach have been identified as critical habitat for the Piping Plover (SARA; EN). The Eastern Shore also supports significant numbers of migrating waterfowl species, specifically large numbers of sea ducks, including Common Eider and scoters (Figure 30). It also provides important wintering habitat for the Harlequin Duck (SARA; Special Concern; Figure 31) (Boyne 2008). The Purple Sandpiper, a generalist carnivorous intertidal gleaner associated with exposed rocky coastlines, also winters in significant numbers within the AOI (Figure 32).

The following habitats in the Eastern Shore Islands AOI and its vicinity are important for a wide variety of bird species (modified from Allard et al. (2014)):

1. Colony-coastal island habitats, including inshore and offshore barrier islands, especially those hosting no or few terrestrial predators. Such islands are important habitat for nesting or roosting by colonial bird species, such as the Common Eider, Great Blue Heron, gulls, terns, and cormorants.
2. Salt marshes are ecologically rich and productive coastal wetlands that are important for several duck species, as well as Great Blue Heron and multiple shorebird species.
3. Beach habitat, including sandy and small cobble beaches, provides important habitat for multiple shorebird species, including the Piping Plover, and, when located on islands, terns. Beaches offer several key prey for these bird species, such as beach fleas and other small crustaceans, small molluscs, and polychaete worms.
4. Mud flats, which may include some Eelgrass, are important for many migratory bird species, including waterfowl and shorebirds including scoters, which prefer certain mudflat prey, such as marine worms, bivalves, and amphipods.
5. Rocky habitat, characterized by large cobbles >30 cm in diameter and a spray zone that transitions into the marine habitat, can host Common Eider, Harlequin Duck, Purple Sandpiper, and Black Guillemot. Of note, Purple Sandpiper and Harlequin Duck (SARA; Special Concern) occur in the largest concentrations provincially, within the AOI area.

6. Eelgrass habitat, characterized by the presence of *Z. marina*, as well as other plants such as Sea Lettuce and red seaweeds, provide important feeding grounds for Atlantic Brant, Canada Goose, and American Black Duck (*Anas rubripes*).
7. Inshore habitat, including waters <30 m in depth and excluding the above-mentioned habitat types, is used by water column and benthic foraging birds, such as cormorants, loons, and ducks.
8. Offshore habitat, with waters >30 m in depth, as well as offshore banks and shoals, is used by species that forage on the surface or within the water column, such as shearwaters, storm petrels, auks, jaegers, and phalaropes. These species typically feed on phytoplankton, zooplankton, squid, and small forage fish.

The Eastern Shore Islands AOI is characterized by all eight of these habitat types and, as such, may be particularly beneficial habitat for seabird diversity. A recent study by Mallory et al. (2015) revealed that marine birds within the Eastern Shore Islands play a significant role in moving both pollutant and nutrient trace elements, including potassium, calcium, selenium, and zinc, from the ocean onto islands, which differed significantly in chemical composition relative to islands without bird colonies. The results of Mallory et al. (2015) suggest these birds may potentially influence habitat quality for certain coastal terrestrial plants and animals in this region.

MIGRATIONS

Groundfish

The Eastern Shore Islands AOI may be a critical location for groundfish that make seasonal or developmentally/ontogenetic associated migrations. The Eastern Shore Islands provide important nursery for some groundfish, and summer feeding grounds for flatfish. Most groundfish found in the AOI, including Atlantic Cod, Pollock, Haddock, and Hake, are pelagic offshore spawners, with the exception of Winter Flounder. Juveniles of these species inhabit the complex inshore habitat of the Eastern Shore, preferring diverse substrate types, Eelgrass, and estuaries.

White Hake typically spawn at least 20 km offshore, and juveniles actively move to inshore estuaries and macrophyte beds where they remain for at least one year (Hare et al. 2001). Adult and large juvenile White Hake undergo inshore movements in warmer months and disperse to warmer, deep offshore waters in the winter. As with other groundfish, the highest dispersal potential for White Hake occurs during the egg and larval phases that travel with the prevailing currents (COSEWIC 2013).

Atlantic Cod in 4VsW are composed of several spawning components, including summer and fall spawners. This stock does not undergo the long migrations observed in southern Gulf of St. Lawrence Cod or Cod found on Browns and Georges banks, but it does undergo movements into deeper, warmer waters in the winter (Mohn and Rowe 2012). Seasonal movements are attributed to geographic differences in water temperature, food supply, and fidelity to homing grounds (COSEWIC 2010a). Evidence suggestions that tagged individuals rarely move more than 500 km, and spawning and overwintering sites show high annual fidelity (COSEWIC 2010a). Dispersal potential of Atlantic Cod is highest during the egg and larval phases that undergo passive dispersal associated with surface currents.

Winter Flounder and other flatfish species make short migrations between the inshore and offshore on a seasonal basis, which may be due to avoidance of very cold or hot temperatures, or following food availability, avoiding pack ice, or a combination of these (McCracken 1963, Van Guelpen and Davis 1979). American Plaice similarly undergo seasonal migrations to inshore summer feeding grounds and offshore overwintering grounds (Powles 1965, Swain et al. 1998), though no information specific to the Eastern Shore exists.

Pelagic Fishes and Turtles

Atlantic Herring spawn in the inshore in the fall, and migrate offshore the following summer. After spawning, adult Atlantic Herring migrate to feeding or overwintering areas to form large mixed stocks. Chebucto Head south of Halifax is an important overwintering area for coastal spawning Herring (McCullough et al. 2005).

Atlantic Mackerel migrate from the coast of New England in the spring along the Scotian Shelf and coastal areas of Nova Scotia to the Gulf of St. Lawrence where they spawn (Grégoire 1999). While the Eastern Shore Islands are unlikely to be important spawning habitat for Atlantic Mackerel, they do migrate through this region on their way to the southern Gulf and are captured in a gillnet fishery.

Large pelagic fishes, including Bluefin Tuna, sharks, and Swordfish, are likely to occasionally visit the Eastern Shore to feed on Atlantic Herring or Atlantic Mackerel, and transit through the area. Bluefin Tuna spawn in warm waters in the Gulf of Mexico and Mediterranean Sea, but they forage in the Northwest Atlantic in summer months (Block et al. 2001, Lutcavage et al. 1999). Sharks especially are transient visitors, including Basking Sharks, Mako, Porbeagle, Blue, and Great White sharks. Some whales, including Humpbacks and Minkes, may use this inshore region as a travel corridor to move to the Gulf of St. Lawrence to feed in the summer.

A number of diadromous species, including Atlantic Salmon, Brown Trout, Brook Trout, Sea Lamprey, river herring, and American Eel, migrate to and from rivers in the Eastern Shore to marine feeding or spawning grounds. Atlantic Salmon spawn and develop in rivers within the Eastern Shore as part of the Southern Uplands COSWEIC DU, which is considered endangered by COSEWIC and is currently being considered for listing under SARA. Adults migrate to offshore feeding grounds in the Gulf of Maine or near St. Pierre and Miquelon and West Greenland before returning to freshwater to spawn. American Eels spawn in the Sargasso Sea, where the majority migrate into freshwater and rivers that feed into the AOI to feed and develop. As such, this coastal AOI is important for maintaining a natural habitat for these migratory species.

Leatherback Sea Turtle (*Dermochelys coriacea*) is a species that is considered Endangered by COSEWIC (2012c). This species undergoes annual migrations from nesting grounds in the tropics to northern feeding grounds. The Eastern Shore Islands are part of a coastal migration route for Leatherback Sea Turtles moving northeast towards the Gulf of St. Lawrence. These migrations typically occur in July, but in warmer years may occur earlier. Entanglements in Lobster gear are not uncommon during this time. Sea turtles in general are also commonly caught as bycatch by longlines; while longlining activity within the AOI is likely limited, the impacts of potential coastal longliners should be considered in corridors for turtle migration such as this (Lewison and Crowder 2007, Lewison et al. 2004). Though this area is used by migrating Leatherback Sea Turtles, it is nonetheless an ephemeral habitat, as Leatherbacks tend to forage further north in the summer (M. James, Pers. Comm.).

Commercially Harvested Invertebrates

Shortfin Squid spawn offshore within the Gulf Stream and are often found in coastal and offshore zones of Atlantic Canada and the USA. An inshore fishery exists in Newfoundland for this species, which has been shown to migrate more than 2000 km from Newfoundland to Maryland, USA (Dawe et al. 1981). Dawe et al. (2007) provides evidence that climate change may make Atlantic Canadian waters uninhabitable for Shortfin Squid, while Longfin Squid may become more common north of Browns Bank.

There is no information on the specific movement of commercially important crustaceans such as Lobster, Snow Crab, and Northern Shrimp (*Pandalus borealis*) in the vicinity of the Eastern Shore Islands. Inshore-offshore movements do occur in some crustaceans, such as Lobster. Mature offshore Lobsters may move inshore during the summer and into deeper waters in winter (Campbell and Robinson 1983). Lobster can move significant distances (>90–200 km) during these migrations (Campbell and Stasko 1985, Wilder 1974). Local ecological knowledge suggests lobster in the Eastern Shore move inshore as the Lobster season progresses and waters warm. Specific tagging studies of Lobster would be required to evaluate migratory behaviour in relation to the AOI boundaries.

Birds

The Eastern Shore Islands are a known migration stop, breeding area, and overwintering destination for migratory marine birds. The islands, coastal cliffs, macrophytes including Eelgrass, salt marsh, and seaweeds, as well as mud flats, estuaries, and offshore waters provide a wide variety of breeding and foraging habitats for migratory birds. Northern Gannets migrate through the area in the spring (northward) and fall (southward) (Huettmann and Diamond 2000). Other non-breeding species that occur within the AOI include shearwaters, terns, and gulls. Species such as Purple Sandpiper and Harlequin Duck use the AOI as a migratory destination, finding sufficient foraging resources to overwinter in significant concentrations within the area (Boyne 2008).

SPECIES AT RISK

A number of species, including fishes, turtles, mammals, and birds that are assessed or listed by COSEWIC, SARA, or both may be found within the AOI (Table 13).

For diadromous fishes, Atlantic Salmon in the Southern Upland Designatable Unit are considered Endangered by COSEWIC due to a decline of 61% over time (COSEWIC 2010b). Adult salmon spawn in multiple rivers within the AOI, and they feed beyond the islands while waiting for ideal spawning conditions. American Eel are considered Threatened by COSEWIC, largely because of dramatic declines in Lake Ontario, the Ottawa River, and St. Lawrence populations (COSEWIC 2012a). This species is treated as a single stock across their range, so their status is highly variable. In Atlantic Canada, American Eel populations are generally considered stable. Other Endangered fish species include Winter Skate, Bluefin Tuna, and Atlantic Cod, which have undergone large declines as a result of overfishing and have not recovered substantially. Fish species that are Threatened or Special Concern include American Plaice, Atlantic, Northern, and Spotted Wolffish, and White Hake. These species likely use the inshore for spawning or denning, and juveniles are often found inshore, using the habitat heterogeneity to avoid predators.

Leatherback Turtles are considered Endangered by COSEWIC and SARA, as populations have declined by 70% worldwide. These declines are attributed to bycatch, pollution, and entanglement in longline and fixed fishing gear. The Eastern Shore Islands AOI is not considered important foraging habitat for Leatherbacks, but it is likely used as a migration corridor for turtles moving to the Gulf of St. Lawrence to feed. As such, entanglements in fishing gear along this corridor are a potential threat for this species.

Finally, several bird species that are at risk are found within the AOI in significant numbers. Barrow’s Goldeneye (*Bucephala islandica*; Special Concern), Harlequin Ducks (Special

Concern), Piping Plover (Endangered), and Roseate Tern (Endangered) either nest or roost or overwinter and forage within the AOI. Piping Plover are known to nest at Martinique Beach (immediately east of the AOI boundary) and at Clam Harbour Beach (within the AOI). Colonies of Roseate Terns are found on islands within the AOI, and Harlequin Ducks overwinter in the AOI in significant concentrations, where they forage on molluscs inshore.

LONG-TERM CHANGES, RESILIENCIES, AND RECOVERABILITY

Long-term changes in biological and physical characteristics of the Scotian Shelf and the Northwest Atlantic over the past several decades are evident. These include changes in Eelgrass, kelp, and Rockweed distributions, groundfish abundances, and marine climate. Changes in the marine climate, in particular, have been linked to shifts in some species' distributions and the possibility of extirpation or extinction of others. This section summarises observed and potential changes in the Northwest Atlantic and, where possible, the coastal Scotian Shelf specifically.

Climate change is an important consideration for the long-term perspective of the system and will play a critical role in its resiliency and any recoverability. Annual forecasts of temperature and salinity for the year 2075 are available through numerical models of projected anomalies in the Northwest Atlantic (Nucleus for European Modeling of the Ocean Representative Concentration Pathway 8.5 at a nominal 5 km by 5 km resolution) (Brickman et al. 2016). Projections for the Eastern Shore Islands AOI show a general warming and decreasing salinity at the surface and bottom (Table 14). Relative to other coastal areas (see details for coastal planning region in (King et al. In prep.)), warming in the Eastern Shore is projected to be greater at the surface and lesser at the bottom, suggesting a future temperature change refuge for benthic coastal fishes (Figure 33). Overall, changes in salinity at the surface and bottom are projected to be minimal and are about average compared to the coastal planning area.

Stanley et al. (2018) describe the area near Halifax and the Eastern Shore as an abrupt transition point in genetic population structure in five marine species (Atlantic Cod, American Lobster, Green Crab, Sea Scallop, and Northern Shrimp). At this point, oceanic bottom and surface temperatures transition from warm to cold water, and a genetic break coincides with this change in average temperatures. Southern, warm water-adapted populations are not found north of this transition point, where instead genetically differentiated cold water-adapted populations are found. This suggests this transition point provides an important break in cryptic population structure, and it will be an area of particularly dynamic change that is important for future monitoring under climate change.

Yeats et al. (2010) describe a general decline in nutrient and oxygen content on the Scotian and Labrador Shelves. In particular, phosphates and silicates appear to have declined more rapidly than nitrates since the 1970s. This decrease appears constant across the Cabot Strait, Eastern Scotian Shelf, and Central Scotian Shelf. Yeats et al. (2010) attribute this nutrient and oxygen decline to a general slowing of oceanic circulation, which allows more time for biological oxygen consumption. The decrease in nutrients may also be the result of melting Arctic sea-ice, which contains low concentrations of nitrates and phosphates, thus diluting concentrations in the open ocean (Yeats et al. 2010).

Due to the relatively low human impact on the Eastern Shore in terms of coastal development, pollution, and aquaculture, climate change is anticipated to be the biggest current threat to this area. Climate change has the potential to raise sea levels through thermal expansion of oceanic waters and melting ice, potentially inundating islands and coastal zones within the Eastern Shore. Shaw et al. (1998) conducted a study to discern the sensitivities of all of Canada's coasts to sea level rise and identified the Eastern Shore, as well as Nova Scotia's South Shore, as an area of moderate to high sensitivity to sea level rise. This change in sea level is likely to increase coastal erosion, and beach and bluff retreat, and salt marshes are expected to move landward as they become flooded (Shaw et al. 1998). More recently, James et al. (2014) examined sea-level rise projections across Canada and the United States and showed that the Halifax region would experience a sea level rise of >60 cm by 2100, similar to the Gulf of St. Lawrence, Newfoundland, and the northeastern United States. Climate change would likely impact the community composition of fishes and invertebrates within the AOI through warming temperatures and ocean acidification. For example, increases in oceanic carbon dioxide have been shown to negatively affect the metabolism of embryonic Atlantic Herring, suggesting climate change could lead to declines in Herring populations (Franke and Clemmesen 2011).

Changes in Eelgrass, Rockweed, and kelp distribution and abundance have occurred over the past several decades and are expected to change further under climate change and warming ocean temperatures (Filbee-Dexter et al. 2016, Ugarte et al. 2010). Eelgrass is prone to die-offs from high turbidity and pollution that limits the amount of light and oxygen that these meadows require (Vandermeulen et al. 2012). Increased turbidity, shading, and oxygen depletion can lead to increased canopy patchiness or, in extreme conditions, could result incomplete canopy loss (Coll et al. 2011). Coastal development and high population densities in the vicinity, as well as developed riparian grounds, can all lead to declines in Eelgrass, as recently observed in Musquodoboit Harbour (Figure *15*). The presence of herbivorous snails in Eelgrass beds can help reduce algal mats and epiphytes, which themselves reduce the amount of light and oxygen for Eelgrass, so snail abundance could be a useful indicator of Eelgrass bed health or resiliency (Vandermeulen et al. 2012). A study by Coll et al. (2011) examined food webs and resiliencies to loss of species in Eelgrass beds across Prince Edward Island (PEI), New Brunswick, and Nova Scotia. Four Eelgrass beds – two of which are in the Eastern Shore (Taylor Head and False Passage) – were less impacted relative to the Gulf of St. Lawrence. Additionally, food webs in Nova Scotia were more robust to simulated loss of species compared to New Brunswick and PEI, suggesting they are the most resilient to change. This was correlated with their low-impact status relative to beds of medium and high impact in New Brunswick and PEI (Coll et al. 2011). If maintained, current low levels of impact along the Eastern Shore should reduce the likelihood of declines in Eelgrass meadows associated with human activities.

Rockweed beds are mainly impacted by direct commercial harvesting, nutrient loading and climate change (Blinn et al. 2008, Khan et al. 2018, Seeley and Schlesinger 2012, Worm and Lotze 2006). A recent study by Khan et al. (2018) found that the latitudinal ranges of seven species of commercially harvested kelps and seaweeds will undergo significant range contractions by 2100 under different climate change models. As more than 100 species of macrophytes and animals have been found associated with Rockweed (Seeley and Schlesinger 2012), range contractions will likely have significant consequences for these associated species as well.

Climate change poses a significant threat to the health and resilience of kelp species in the Northwest Atlantic. Warming waters have been shown to reduce recruitment and growth rates of kelps (Krumhansl et al. 2014, Simonson et al. 2015a, Simonson et al. 2015b). Warming waters also drive higher rates of kelp blade encrustation by *M. membranacea* and higher grazing rates by *L. vincta* (Krumhansl and Scheibling 2011b, Saunders et al. 2010), both increasing kelp bed defoliation and loss, which may facilitate further invasions by other marine nonindigenous species (Saunders et al. 2010). In the Bay of Fundy, decreases in kelp abundance are correlated with warming water temperatures (Longtin and Saunders 2016). Losses of large kelps have been observed to lead to a transition in turf-forming algae, which may alter the entire community composition (Filbee-Dexter et al. 2016). Other major threats to kelps are outbreaks of sea urchins, which feed on their stipes, and the invasive species green algae *C. fragile*

(Scheibling et al. 1999, Steneck et al. 2002). *C. fragile* is often found where the invasive bryozoan *M. membranacea* has defoliated kelps, and, unfortunately, this species was frequently observed on kelps within the AOI (Vandermeulen 2018b). However, cyclical abundances in sea urchins can allow the reestablishment of kelps over time, though recurrent disease outbreaks have maintained low sea urchin population densities in Nova Scotia over the past decade (Scheibling et al. 2010). Similarly, *C. fragile* may replace kelps once they are removed but does not necessarily prevent reestablishment of kelp species, so kelp abundance may be cyclical (Watanabe et al. 2010). However, Filbee-Dexter et al. (2016) note persistent declines in kelps associated with warming waters, and replacement by turfs, suggesting losses may not be cyclical as once thought. Kelps appear to be quite resilient to cropping of their distal fronds during harvests, but this is dependent on the extent of tissue harvested; if the whole blade is removed, the kelp will not survive (Krumhansl and Scheibling 2011a). Monitoring of kelp abundances and patchiness will be warranted though to protect the ecosystem services provided by kelps, including habitat and food for fishes and invertebrates, energy capture and flow, and nutrient cycling.

Since 1993, moratoria for various groundfish, including Atlantic Cod and Haddock, in inshore regions including NAFO Division 4W have been in place. These moratoria limit directed fishing effort. Landings for groundfish in 4W are comprised of bycatch only. Cod have not increased significantly following the moratoria, and hypotheses as to why are numerous but include reduced recruitment of juvenile Atlantic Cod or loss of key prey species, such as shrimp, or an increase in larger predators such as seals. Frank et al. (2005) suggest that removal of top predators, including Atlantic Cod, has resulted in a restructuring of the food web in the Eastern Scotian Shelf. The collapse of the benthic fish community, including Atlantic Cod, Haddock, Pollock, White and Silver Hake, skates, and flounders, resulted in increases of small pelagic fishes and benthic macroinvertebrates, which are known prey of large benthic fishes. Large-bodied zooplankton decreased from the 1960s to 1990s as a result of size-selective predation by pelagic fishes, while phytoplankton increased at this time due to this trophic cascade (Frank et al. 2005). Frank et al. (2005) also attribute the lack of recovery of groundfish species to changes in the physical environment, including changes in bottom temperature and reduced energy flux to the benthic community as a result of increased vertical stratification on the Scotian Shelf after the 1990s.

SOURCES OF UNCERTAINTY AND DATA GAPS

Overall systematic and comprehensive data describing coastal (<100 m depth) ecosystems and ecosystem processes is lacking in the Maritimes Region. Access to the Eastern Shore for data collection, in particular, has been limited by the availability of suitable boat launches. It was a general trend when consulting various sources that, for most taxa, data characterizing short and/or long-term trends in abundance were nonexistent for the Eastern Shore. Key existing data gaps and mechanisms to address them are summarized in this section and Table 15.

High resolution mapping of the seafloor using multibeam sonar within the AOI boundary is limited to an approximately 300 km^2 sized area 15 km south of Taylors Head (Figure 4a). Expanded multibeam coverage would provide higher-resolution information on sediment characteristics that would permit more accurate predictions of habitat and corresponding species distributions. The Canadian Hydrographic Service has recently completed (as of Fall 2017) comprehensive LiDAR surveys of the Eastern Shore of Nova Scotia, though the data were unavailable at the time of writing. This updated bathymetry data will not only improve navigational charts of the area but will provide high-resolution data on bathymetry and potentially substrate type for use in future research.

Though broad-scale circulation patterns for the region are known, the local bathymetric features associated with the complex coastline and archipelago limit the ability of circulation models (e.g., Finite Volume Community Ocean Model developed for the Gulf of Maine and Scotian Shelf - GOM-FVCOM) to accurately resolve local conditions. Detailed descriptions of local oceanographic conditions are important for understanding transport of physical (e.g., nutrients and sediments) and biological (e.g., egg and larval dispersal) components of the ecosystem. In particular, understanding how pelagic dispersive stages immigrate into and emigrate from the AOI requires accurate descriptions of local oceanographic conditions. Collecting *in situ* circulation information (i.e., through deployment of ADCPs) would benefit existing nearshore circulation models (i.e., GOM-FVCOM) to resolve how the complex bathymetry associated with the archipelago influences local oceanography. Continued sampling of fish communities in the coastal zone (i.e., through additions to the FSRS Sentinel survey and/or the addition of shallower inshore strata to the Research Vessel surveys) would be beneficial to further characterize the spatial and temporal patterns fish diversity in the Eastern Shore Islands. The inshore use of this area by large migratory pelagic fishes, sharks, and cetaceans should be better characterized as well. While the use of nearshore habitats may be ephemeral, foraging for prey such as Atlantic Herring nonetheless make this an important habitat for large marine organisms. The use of the Eastern Shore as a migration corridor for turtles, cetaceans, and sharks should be further investigated to understand how the use of this habitat by large marine animals interact, with existing human uses within and around the AOI.

The Lobster fishery is an essential industry for the Eastern Shore. Like many other areas in Eastern Canada, landings have steadily increased since the early 2000s. Collecting information on the relationship between Lobster abundance and habitat type would support the development of population baselines and improve understanding of the distribution of the resource relative to conservation features identified for the AOI. Local knowledge from Lobster fishermen suggests that optimal fishing generally is associated with rocky bottom, though some effort does occur in sandy/soft bottom areas and in Eelgrass beds. Fully protected areas in Newfoundland suggest that closures to extractive activities, even when applied at small (<10 km^2) spatial scales, could over time (10–20 years) yield measurable benefits (*sensu* Eastport MPA - Lewis et al. [2017]). Given the demonstrated link between larval recruitment and commercial landings, continued support and an expansion of cobble bio-collectors (*sensu* Hunt et al. 2017, Wahle et al. 2013) in the Eastern Shore Islands could provide valuable information for monitoring and a mechanism to evaluate current, and project future, population states for Lobster and other coastal invertebrates. Moreover, these collectors provide a unique and important snapshot of biodiversity in the rocky subtidal zone where few data exist (but see Scrosati and Ellrich 2017).

The use of inshore areas by depleted species, or those considered threatened or endangered, needs to be better characterized. For example, it remains unclear if the Eastern Shore Islands, or any inshore areas, are critical habitat for mature wolffish, Atlantic Cod, or White Hake. The complex habitat provided by the geological and bathymetric features of the AOI likely provides important nursery for juvenile demersal fish; however there remains no systematic baseline for larval or juvenile groundfish in the Eastern Shore. Before assigning conservation priorities or objectives for focal or threatened species, a more comprehensive understanding of their presence and usage of the area is required.

Aerial or remote sensing surveys of Eelgrass and salt marshes have provided good coverage of the coastline and large Eelgrass beds (Allard et al. 2014), but the true extent of Eelgrass in the Eastern Shore remains unknown. Because biogenic habitat and Eelgrass in particular provide a diversity of important ecosystem functions, including refuge from predators, substrate for planktonic larvae, and feeding grounds for many marine birds, the lack of comprehensive distributional information warrants further attention. Observational evidence suggests that Eelgrass in this area is abundant but patchy. How this abundance and distribution is linked to the physical characteristics of the area will require field studies and additional surveys. Furthermore, Eelgrass should be monitored regularly to examine any changes as a result of climate change and potential pollution point sources in areas of higher populations, such as off Sheet Harbour and Ship Harbour.

Rockweed is known to be important habitat for some juvenile fishes and Lobsters. Rockweed is extensive in the AOI, both in the intertidal zone of the mainland and also around many of the islands. Relative to southern Nova Scotia, Rockweed is relatively unexploited in the Eastern Shore Islands and shows a higher faunal richness compared to harvested areas to the south. An in-depth study of the organisms that live within Rockweed in the intertidal and subtidal zones along the coast and on islands in the area would help articulate the functional role and importance of Rockweed for fish and invertebrates, in particular Lobster, along the Eastern Shore.

Declines in macrophyte beds, especially kelp and Eelgrass, have been observed in Atlantic Canada, including southern Nova Scotia (Filbee-Dexter et al. 2016) and the Gulf of St. Lawrence (Garbary et al. 2014, Seymour et al. 2002). Stressors such as human impacts, sea level rise, and ocean warming have all been attributed to these declines. The mechanisms by, and the extent to which these stressors influence the distribution of Eelgrass, Rockweed, and kelp remains unknown for the Eastern Shore. A recent study by Coll et al. (2011) found that Nova Scotian Eelgrass beds are more resilient to the loss of individual species within the food web they support in contrast with in New Brunswick and PEI that have experienced higher human impacts. Ongoing Eelgrass monitoring projects in the Eastern Shore and South Shore are examining the densities and patchiness of Eelgrass beds over time to examine their resiliency and monitor any declines. Understanding how the physical attributes of the AOI relate to the apparent resiliency in the Eastern Shore in some areas is important when monitoring of these important habitats.

Remediation of these knowledge gaps will require field observations and monitoring by DFO Science and partners, as well as obtaining Local and Traditional Ecological Knowledge to determine important habitat areas and ecosystem changes over time.

ECOSYSTEM SYNTHESIS

From the available geological, human impact, and aquatic plant and animal data, it is clear that the Eastern Shore Islands AOI represents a unique, natural, and diverse coastal habitat. The area is both representative of the coastal Maritimes, with its diversity of substrate types and habitats, and unique due to its high concentration of nearshore islands and mosaic of heterogeneous patches of macrophytes and substrates. These habitats include mudflats, salt marshes, rocky and sandy intertidal, rocky cliffs, numerous nearshore and offshore islands, Eelgrass, Rockweed, and kelp beds, and a mosaic of subtidal substrates including mud, clay, sand, gravel, and boulder fields. The rocky subtidal substrates are often covered with coralline encrusting red algae and other types of seaweed. Rockweed and Eelgrass provide habitat for numerous species of marine birds, fish, and invertebrates, and species richness has been shown to be up to six times higher within Rockweed beds compared to bare sediment. The diversity in habitats is of particular importance to the more than 80 species of marine birds that live or migrate through this region, including significant numbers of Harlequin Ducks, terns, cormorants, and herons. The Eastern Shore is relatively highly natural, having lower levels of contaminants such as mercury and arsenic in the water and sediment from historical gold mining than further east of the AOI boundary, lower human impacts, and fewer invasive species than areas to the south. Due to the low population density in area, contaminants such as sewage and agriculture runoff are relatively low, except in Ship Harbour and Sheet Harbour, which are long, deep inlets that may retain contaminants and become prone to eutrophication.

Eelgrass, Rockweed, and kelp beds and estuarine salt marshes provide important nursery grounds for benthic fish species; including White Hake, Cod, and flounders, as well as complex habitat for invertebrates and spawning grounds for Atlantic Herring. Several species of marine birds, including waterfowl, shorebirds, and coastal waterbirds, depend entirely on salt marshes, Rockweed, and Eelgrass for foraging. Floating subtidal Rockweed canopy provides critical foraging habitat for Common Eider ducklings. Extensive kelp beds provide shelter for fishes and invertebrates, and contribute to the high primary productivity of this region.

The food web in this region appears typical of the coastal zone but is not well characterized. Seasonal upwelling from offshore regions leads to increases in nutrients that may become trapped in bays along the coastline. Eutrophication from human inputs, such as sewage, may be an issue that requires remediation, particularly in bays that retain nutrients and have lower oxygen content such as Ship Harbour. These nutrients however, particularly nitrogen and phosphorus, are critical for plankton blooms, which form the base level of the food chain. These algae are consumed by zooplankton, such as copepods and euphausiids, which are an important food source for pelagic fish and marine birds.

Notable fisheries in the Eastern Shore Islands include American Lobster (in LFAs 32 and 31B), Sea Scallop (SFA 29), Atlantic Mackerel, and Atlantic Herring – both as a fixed-gear inshore fishery and Atlantic Herring roe fishery – and a small number of licences for adult and juvenile American Eel. Most species of groundfish in the area are not directly fished given the groundfish moratorium established in 1992, but they are occasionally caught as bycatch. The importance of this ecosystem is not well understood for large pelagic fishes, such as sharks and tunas, or marine mammals, though there are two inshore breeding colonies of Grey Seal within the AOI boundaries. The area may be a migration corridor for Leatherback Turtles and various shark and cetacean species moving to the Gulf of St. Lawrence to feed. Conservation objectives should emphasize the protection and maintenance of the highly natural system and diverse mosaic of habitats, which have largely avoided high-impact human activities. The AOI contains a wide range of physical features, diverse macrophytes, invertebrates, and fishes, as well as foraging grounds for significant concentrations of marine birds, and potential feeding grounds and links to spawning areas for endangered Southern Upland Atlantic Salmon.

SUMMARY

The significance of the Eastern Shore Islands can be linked to the unique habitat attributes, including relatively low human impact in terms of pollution and coastal development, and the unique geology and associated diversity of marine plants and macroalgae supporting a diversity of fishes, invertebrates, and marine birds. Based on the best available data, the recommended conservation priorities for the area include

1. the relatively high naturalness;
2. the unique and complex geomorphology in terms of the dense archipelago and diverse mosaic of substrates and marine biogenic habitat, including subtidal macrophytes (specifically, Eelgrass and kelp);
3. an area of importance for Atlantic Salmon;
4. an Atlantic Herring spawning area;

5. an important area for juvenile groundfish including Atlantic Cod, White Hake, and Pollock; and
6. an important area for nesting, foraging, and migratory marine birds.

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TABLES

Table 1. Conservation Priorities based on the key ecological features identified during the process of selecting the Eastern Shore Islands as an Area of Interest and subsequently revised based on the available information. The rationale for each of these priorities is also provided.

Conservation Priority	Rationale
Relatively natural ecosystem	Relatively low human impact, low levels of pollution, and fewer/less abundant invasive species compared to other coastal regions within the Maritimes warrant protection of this area to remain viable for plants, invertebrates, fishes, and birds.
Complex/unique mosaic of substrates and habitat types	The coastline, including the bays, inlets, and islands of this area are highly complex. The geology of the area is unique due to the high proportion of exposed bedrock, with drowned valleys and various types of overlying sediments. Drop camera surveys revealed a heterogeneous mosaic of substrates and subtidal kelps/seaweeds with a patch size of approximately 400 m. This diversity of intertidal and subtidal habitats is relatively higher than other regions, including Sambro Ledges and Port Joli.
Biogenic habitat including macrophytes, especially Eelgrass and kelps	Macrophytes, including Eelgrass, Rockweed, kelps, and other seaweeds are primary producers, providing dissolved oxygen and sequestering carbon. Additionally, these macrophytes provide biogenic habitat and food for marine fishes, invertebrates, and marine birds. The full extent and distribution of macrophytes within the AOI has not been quantified, but they are thought to be extensive and diverse (Gromack et al. 2010, Hill et al. 2012). These habitats also provide attachment substrate for Atlantic Herring eggs. A significant fishery for American Lobster exists in the Eastern Shore, and macrophytes provide habitat for juvenile and adult lobsters. Furthermore, the subtidal Rockweed canopy provides a necessary resource for Common Eider ducklings, who feed almost exclusively on invertebrates found in the canopy.
Atlantic Salmon (*Salmo salar*) habitat	Rivers in the Eastern Shore are used for spawning by the Southern Upland Designatable Unit (COSEWIC – Endangered). While the marine coastal usage of smolts and adult Salmon is unknown, it is critical to protect the migration corridors of these fish, and the estuaries in which they live as juveniles.

Conservation Priority	Rationale
Atlantic Herring (*Clupea harengus*) spawning area	A known Herring spawning area occurs in the western portion of the AOI. Herring in this region belong to the Coastal Nova Scotia spawning component, which show a strong homing fidelity to their spawning grounds. Herring use inshore areas to spawn, and their eggs attach to gravel, cobble, boulders, and submerged seaweeds. The diversity of substrates and seaweeds in this area may be of benefit to spawning Herring.
Important habitat for juvenile groundfish including Atlantic Cod (*Gadus morhua*), White Hake (*Urophycis tenuis*), and Pollock (*Pollachius virens)*, provided by estuaries, subtidal Rockweed, Eelgrass, kelp, and rocky substrates	Macrophytes and complex substrates in the Eastern Shore provide protective habitat for juvenile groundfish, including Atlantic Cod, White Hake, and Pollock. Stocks of groundfish have not recovered since the groundfish moratorium, and protection of juvenile habitat may help stocks rebuild.
Important bird area for nesting, foraging, and migratory marine birds	The Eastern Shore Islands has been identified as an “Important Bird Area” (Hastings et al. 2014, IBA Canada 2018) and provides nesting, roosting, and foraging habitat for resident and migratory sea- and shorebirds. The isolated islands in this region provide nesting grounds and migratory stopovers for a variety of species. The Roseate Tern (Endangered – SARA) has known colonies on inshore islands in this area, and tends to forage within 20 km of its nesting grounds. Harlequin Ducks (Special Concern – SARA) are known to migrate through and forage in the Eastern Shore in significant numbers. Protection of marine foraging grounds will be critical for these bird species.

Table 2. A list of sites in the Eastern Shore, arranged from West to East, with their eutrophication indices (EI) from Strain and Yeats (1999). Sites with high values for the EI index are more prone to eutrophication.

Site	Eutrophication Index (EI)
Petpeswick Inlet[1]	8.74
Jeddore Harbour	4.30
Ship Harbour	5.87
Popes Harbour	2.23
Sheet Harbour	2.25
Beaver Harbour	-3.45
Moser River[2]	-5.30
Liscomb Harbour	-1.14
Wine Harbour[3]	9.03

[1]This location is immediately west of the AOI boundary.
[2]This site has the lowest EI of all 34 coastal sites in the study by Strain and Yeats (1999)
[3]This location is immediately east of the AOI boundary.

Table 3. Location, coastal land protection surrounding entire bay, urban cover in watershed, agriculture cover in watershed, human population density in watershed, nitrogen loading per area of estuary, total nitrogen loading, riparian land alteration, overwater structure, fecal coliform most probably number (MPN), and invasion extent measured by percent cover, which is a 10 year average of aquatic invasive species.

Bay	Coastal Protection (%)	Urban Cover (%)	Agriculture Cover (%)	Human Population (people/km^2)	N (kg N/ha)	Total N (kg N)	Riparian Alteration (%)	Overwater Structure (%)	Fecal Coliform (MPN/100 mL)	Invasion (%)
Taylor Head (44.82351° N, 62.57635° W)	55.25	2.58	0.00	4.266	31.32	86,655	3.875	0.00005	1.910	0.417
Cable Island (44.74134° N, 62.78970° W)	19.71	1.73	0.01	5.625	39.56	134,977	0.000	0.00000	2.467	0.334
False Passage (44.74441° N, 62.79645° W)	19.71	2.78	0.01	5.625	39.56	134,977	0.986	0.00002	3.440	0.334
Musquodoboit (44.70500° N, 63.09220° W)	9.60	7.20	2.20	7.242	108.56	258,222	0.284	0.00060	2.501	2.508
Sambro (44.45500° N, 63.58900° W)	2.74	8.94	0.04	51.824	57.76	56,252	1.552	0.00000	2.580	1.464
St. Margarets Bay (44.59246° N, 63.94378° W)	0.55	7.56	0.00	29.515	43.66	598,365	17.324	0.00042	11.262	2.361
Second Peninsula (44.39673° N, 64.28059° W)	0.00	10.90	10.96	28.884	46.63	20,971	13.450	0.00072	14.424	3.850
Port Joli (43.84175° N, 64.88012° W)	24.63	2.84	0.00	5.001	34.05	58,374	0.508	0.00000	1.900	2.941

Table 4. Data from the 4VsW Sentinel Survey. The numbers represent the number of sets that detected the species listed in the Species column. Atlantic Cod were the most commonly detected in the Eastern Shore Islands AOI, which nests within the Coastal column of the data, which in turn nests within the Sentinel column (which includes offshore collections).

Species	**Common**	**AOI**	**Coastal**	**Sentinel**
GADUS MORHUA	ATLANTIC COD	158	475	1571
SEBASTES SP.	ROCKFISH/REDFISH	52	120	183
MYOXOCEPHALUS OCTODECEMSPINOSUS	LONGHORN SCULPIN	47	162	527
BROSME BROSME	CUSK	44	84	428
ANARHICHAS LUPUS	ATLANTIC WOLFFISH	42	147	265
AMBLYRAJA RADIATA	THORNY SKATE	29	87	1133
SQUALUS ACANTHIAS	SPINY DOGFISH	27	85	806
MYOXOCEPHALUS SCORPIUS	SHORTHORN SCULPIN	23	76	80
HIPPOGLOSSOIDES PLATESSOIDES	AMERICAN PLAICE	18	96	457
HEMITRIPTERUS AMERICANUS	SEA RAVEN	17	42	75
HIPPOGLOSSUS HIPPOGLOSSUS	ATLANTIC HALIBUT	11	30	383
MELANOGRAMMUS AEGLEFINUS	HADDOCK	10	38	1111
UROPHYCIS TENUIS	WHITE HAKE	8	18	825
MERLUCCIUS BILINEARIS	SILVER HAKE	7	15	248
POLLACHIUS VIRENS	POLLOCK	7	41	134
ANARHICHAS MINOR	SPOTTED WOLFFISH	3	10	37

Species	Common	AOI	Coastal	Sentinel
PSEUDOPLEURONECTES AMERICANUS	WINTER FLOUNDER	2	6	13
UROPHYCIS CHUSS	RED HAKE	2	5	801
CRYPTACANTHODES MACULATUS	WRYMOUTH	1	11	55
LEUCORAJA OCELLATA	WINTER SKATE	1	1	260
LOPHIUS AMERICANUS	AMERICAN ANGLERFISH	1	3	576
MACROZOARCES AMERICANUS	OCEAN POUT	1	5	24
PRIONACE GLAUCA	BLUE SHARK	1	5	85
SCOMBER SCOMBRUS	ATLANTIC MACKEREL	1	2	2
ALOPIAS VULPINUS	COMMON THRESHER	0	0	1
ANARHICHAS DENTICULATUS	NORTHERN WOLFFISH	0	7	9
CENTROSCYLLIUM FABRICII	BLACK DOGFISH	0	0	1
CLUPEA HARENGUS	ATLANTIC HERRING	0	0	1
CONGER OCEANICUS	AMERICAN CONGER	0	2	5
COTTUNCULUS THOMPSONI	PALLID SCULPIN	0	0	1
DIPTURUS LAEVIS	BARNDOOR SKATE	0	0	305
GADUS OGAC	GREENLAND COD	0	21	22
GLYPTOCEPHALUS CYNOGLOSSUS	WITCH FLOUNDER	0	1	1
HARRIOTTA RALEIGHANA	NARROWNOSE CHIMAERA	0	0	1

Species	Common	AOI	Coastal	Sentinel
ISURUS OXYRINCHUS	SHORTFIN MAKO SHARK	0	0	6
LAMNA NASUS	PORBEAGLE	0	0	24
LEUCORAJA ERINACEA	LITTLE SKATE	0	2	79
LIMANDA FERRUGINEA	YELLOWTAIL FLOUNDER	0	1	1
LOPHOLATILUS CHAMAELEONTICEPS	GREAT NORTHERN TILEFISH	0	1	9
LYCODES RETICULATUS	ARCTIC EELPOUT	0	1	11
LYCODES SP.	EELPOUT	0	12	87
MALACORAJA SENTA	SMOOTH SKATE	0	0	23
MICROGADUS TOMCOD	ATLANTIC TOMCOD	0	1	1
MYOXOCEPHALUS QUADRICORNIS	FOURHORN SCULPIN	0	0	1
MYXINE GLUTINOSA	ATLANTIC HAGFISH	0	0	29
RAJELLA FYLLAE	ROUND SKATE	0	0	1
REINHARDTIUS HIPPOGLOSSOIDES	GREENLAND HALIBUT	0	21	83
UROPHYCIS CHESTERI	LONGFINNED HAKE	0	0	3
XIPHIAS GLADIUS	SWORDFISH	0	0	1
ZOARCIDAE F.		0	0	2

Table 5. Species detected by Hunt et al. (2017) in different portions of the Northwest Atlantic. Presence (1=Present, 0=Absent) of these fishes and invertebrates shows different faunal assemblages in each region.

Species	Bay of Fundy/ Gulf of Maine (Group 1PA)	Magdalen Shallows (Group 2)	Scotian Neritic (Group 3)	Eastern Shore Islands (Group 4)
Pandalus spp.	1	0	1	1
Lebbeus spp.	1	0	1	0
Homarus americanus	1	1	1	1
Pagurus arcuatus	1	0	1	1
Hyas sp.	1	1	1	1
Carcinus maenas	0	0	1	1
Cancer irroratus	1	1	1	1
Cancer borealis	1	0	1	1
Zoarces americanus	1	0	0	0
Urophycis spp.	1	0	0	0
Ulvaria subbifurcata	1	1	1	1
Tautogolabrus adspersus	0	1	1	1
Stichaeus punctatus	1	0	0	0
Pseudopleuronectes americanus	1	0	1	1
Pholis gunnellus	1	1	1	1

Species	Bay of Fundy/ Gulf of Maine (Group 1PA)	Magdalen Shallows (Group 2)	Scotian Neritic (Group 3)	Eastern Shore Islands (Group 4)
Myoxocephalus spp.	1	1	1	1
Liparis spp.	1	1	1	1
Eumesogrammus praecisus	0	0	0	1
Enchelyopus cimbrius	0	0	1	0
Cyclopterus lumpus	1	0	0	0
Ammodytes spp.	0	0	1	1

Table 6. Biotic and abiotic classification categories for image analysis of video transects at 9 sites in the Eastern Shore Islands Ecologically and Biologically Significant Area (EBSA) used in 2007 video survey.

Classification Categories For Biotic And Abiotic Features	**Taxonomic Level, Description of Category (Biotic) or Size Class (Abiotic)**
Saccharina latissima	Species
Laminaria digitata	Species
Agarum clathratum	Species
Unidentified kelp	Attached stipe, blade or holdfast of kelp that cannot be classified to species
Zostera marina	Species
Red turf	Functional classification
Green turf	Functional classification
Codium fragile	Species
Ascophyllum spp. and *Fucus spp.*	Genus
Coralline algae	Functional classification
Unidentified algae	Stipe, blade or holdfast of any algal species that could not be further classified
Boulder	Any sediments/rocks with a grain size >25 cm
Cobble	Any sediments/rocks with a grain size between 6.4–25 cm
Pebble	Any sediments/rocks with a grain size between 2–64 mm
Sand	Any sediments/rocks with a grain size <2 mm
Homarus americanus	Species
Desmarestia	Genus
Asteroidea	Class
Palmaria palmata	Species

Table 7. Benthic classification used in 2017 video survey (Vandermeulen 2018b).

Category	Details
Substrate	
mud/sand	flat bottom of small grain size, shell hash often present, ripples
gravel	
cobble/boulder	≥10 cm
ledge	larger blocks of rock, often deeply fissured
Macrophytes[3]	
coralline[4]	*Corallina officinalis* L.; *Lithothamnion glaciale* Kjellman; *Clathromorphum circumscriptum* (Strömfelt) Foslie; *Phymatolithon* spp.
red turf[5]	10–20 m: dominated by *Phyllophora pseudoceranoides* (S.G. Gmelin) Newroth and A.R.A. Taylor with a canopy mixture of *Chondrus crispus* Stackhouse, *Palmaria palmata* (L.) F. Weber and D. Mohr, *Phycodrys rubens* (L.) Batters and others; filamentous forms including *Bonnemaisonia hamifera* Hariot, *Ceramium* spp., *Antithamnion* spp., *Polysiphonia* spp. and similar >20 m: dominated by *Ptilota serrata* Kützing >40 m: red crusts (possibly *Hildenbrandia* or *Peyssonnelia*); small blades (possibly *Turnerella*)
Alaria	*Alaria esculenta* (L.) Greville

[3] Drift material on mud/sand or in deep crevasses was not counted in the classification, although this material may be important to local detrital food webs (Filbee-Dexter et al. 2016).

[4] Grab samples required to confirm species listed in ‘details’.

Category	Details
Saccharina[5]	the 'frilled morph' of *Saccharina latissima* (L.) C.E. Lane, C. Mayes, Druehl and G.W. Saunders – possibly including *S. nigripes* (J. Agardh) Lontin and G.W. Saunders
Laminaria	*Laminaria digitata* (Hudson) J.V. Lamouroux
Agarum	*Agarum clathratum* Dumortier
Desmarestia[5]	mainly *Desmarestia aculeata* (L.) J.V. Lamouroux; some *D. viridis* (O.F. Müller) J.V. Lamouroux
Invertebrates	
Boltenia	*Boltenia ovifera* (L.)
sponge[5]	a variety of species
anemone[5]	a variety of species[5]
sand dollar[5]	*Echinarachnius parma* Lamarck
brittle star[5]	*Ophiura* sp.
sea star	a variety of species
Lobster	*Homarus americanus* H. Milne Edwards

[5] There may be some soft corals in this mix. The video quality was too poor to discern differences and future grab samples will be required to confirm taxonomy.

Table 8. Depth ranges for common plants and seaweeds found within the Eastern Shore Islands Area of Interest (modified from Khan et al. 2018).

Species	**Depth range (m)**
Kelp (*Saccharina longicruris*)	2–60
Sugar Kelp (*Saccharina latissima*)	2.5–30
Oarweed (*Laminaria digitata*)	0–40
Bladder Wrack (*Fucus vesiculosus*)	0–10
Toothed/Serrated Wrack (*Fucus serratus*)	0–10
Irish/Carrageen Moss (*Chondrus crispus*)	0–20
Rockweed (*Ascophyllum nodosum*)	0–10
Eelgrass (*Zostera marina*)	0–20

Table 9. A list of animal and macrophyte species found to be associated with Rockweed (Ascophyllum nodosum) and Eelgrass (Zostera marina) beds in the Eastern Shore Islands region.

Taxonomic group	**Species**	**Schmidt et al. 2011** **2006** **Rockweed**	**Kay et al., unpublished** **2012** **Rockweed**	**Wong 2018*, Vercaemer et al. 2018**** **2016** **Rockweed**	**Schmidt et al. 2011** **2006** **Eelgrass**	**Namba et al. 2017** **2007** **Eelgrass**	**McIver et al., unpublished** **2013** **Eelgrass**
Mammals	Grey seal (*Halichoreus grypus*)				x		
Fish	Alewife (*Alosa pseudoharengus)*		x				x
	Sand Lance (*Ammodytes americanus*)			x		x	
	American Eel (*Anguilla rostrate*)	x	x	x		x	
	Fourspine Stickleback (*Apeltes quadracus*)			x			
	Atlantic Herring (*Clupea harengus*)			x			
	Mummichog (*Fundulus heteroclitus*)			x			
	Atlantic Cod (*Gadus morhua*)	x		x	x	x	
	Threespine Stickleback (*Gasterosteus aculeatus*)	x	x		x	x	x
	Sea Raven (*Hemitripterus americanus*)					x	
	Atlantic Silverside (*Menidia menidia*)			x			x
	Tomcod (*Microgadus tomcod)*	x		x	x	x	

Taxonomic group	Species	**Schmidt et al. 2011** **2006** **Rockweed**	**Kay et al., unpublished** **2012** **Rockweed**	**Wong 2018*, Vercaemer et al. 2018**** **2016** **Rockweed**	**Schmidt et al. 2011** **2006** **Eelgrass**	**Namba et al. 2017** **2007** **Eelgrass**	**McIver et al., unpublished** **2013** **Eelgrass**
Fish	Longhorn Sculpin (*Myoxocephalus octodecemspinosus*)	x					
	Shorthorn Sculpin (*Myoxocephalus Scorpius*)				x	x	
	Grubby Sculpin (*Myoxocephalus aenaeus*)			x			
	Smelt (*Osmerus mordax*)			x			
	Rock Gunnel (*Pholis gunnellus*)	x		x		x	
	Pollock (*Pollachius virens*)			x		x	x
	Winter Flounder (*Pseudopleuronectes americanus*)	x		x	x	x	x
	Ninespine Stickleback (*Pungitius pungitius*)			x			
	Atlantic Mackerel (*Scomber scombrus*)	x		x	x		
	Northern Pipefish (*Syngnathus fuscus*)	x		x			
	Cunner (*Tautogolabrus adspersus)*	x		x			
	White Hake (*Urophysis tenuis*)			x			
Arthropods*	American Lobster (*Homarus americanus*)	x				x	x
	Jonah Crab (*Cancer borealis*)	x					x

Taxonomic group	Species	Schmidt et al. 2011 2006 Rockweed	Kay et al., unpublished 2012 Rockweed	Wong 2018*, Vercaemer et al. 2018** 2016 Rockweed	Schmidt et al. 2011 2006 Eelgrass	Namba et al. 2017 2007 Eelgrass	McIver et al., unpublished 2013 Eelgrass
	Rock Crab (*Cancer irroratus*)	x		x	x	x	x
	European Green Crab (*Carcinus maenas*)	x	x	x	x	x	x
	Mud Crab (*Dyspanopeus (Neopanopeus)* say*i*)					x	
	Hermit Crab (*Pagurus acadiensis*)					x	x
	Hermit Crab (*Pagurus* sp.)	x			x		
	Mysid Shrimp (Mysidae)		x				
	Mysid Shrimp (*Mysis stenolepis)*	x	x		x	x	x
	Sand Shrimp (*Crangon septemspinosa*)			x	x	x	x
	Grass Shrimp (*Palaemon* sp.)			x			
	Isopod (*Idotea* sp.)				x	x	
	Isopod (*Idotea baltica*)						
	Isopod (*Idotea phosphorea*)						
	Isopod (*Jaera albifrons*)						
	Isopod (*Munna fabricii*)						
	Amphipoda sp.		x				x

Taxonomic group	Species	Schmidt et al. 2011 2006 Rockweed	Kay et al., unpublished 2012 Rockweed	Wong 2018*, Vercaemer et al. 2018** 2016 Rockweed	Schmidt et al. 2011 2006 Eelgrass	Namba et al. 2017 2007 Eelgrass	McIver et al., unpublished 2013 Eelgrass
	Skeleton Shrimp (Caprellidae)					x	
	Amphipod (*Corophium volutator)*						x
	Amphipod (Corophiidae)						
	Leptocheirus pinguis						
	Dexamine thea						
	Pontogeneia inermis						
	Gammarus lawrencianus						
	Photis sp.						
	Ischyrocerus anguipes						
	Orchomenella minuta						
	Phoxocephalus holbolli						
	Hardametopa carinata						
	Cucumacea						
	Chironomidae larvae						
	Barnacle (*Semibalanus balanoides*)	x	x				

Taxonomic group	Species	Schmidt et al. 2011 2006 Rockweed	Kay et al., unpublished 2012 Rockweed	Wong 2018*, Vercaemer et al. 2018** 2016 Rockweed	Schmidt et al. 2011 2006 Eelgrass	Namba et al. 2017 2007 Eelgrass	McIver et al., unpublished 2013 Eelgrass
Ctenophores	Sea Gooseberry (*Pleurobrachia pileus*)		x				
Jellyfish	Moon Jelly (*Aurelia aurita*)					x	
	Lion's Mane Jellyfish (*Cyanea capillata*)					x	x
Echinoderms*	Forbes Sea Star (*Asterias forbesii*)	x	x		x	x	
	Common Sea Star (*Asterias vulgaris/rubens*)		x		x	x	
	Dwarf Brittle Star (*Amphipholis squamata*)						
Molluscs*	*Anomia* sp.		x				
	Heteranomia squamula						
	Crepidula fornicata	x				x	
	Ilyanassa obsoleta						x
	Lacuna vincta				x	x	x
	Littorina spp.	x	x		x		

Taxonomic group	Species	Schmidt et al. 2011 2006 Rockweed	Kay et al., unpublished 2012 Rockweed	Wong 2018*, Vercaemer et al. 2018** 2016 Rockweed	Schmidt et al. 2011 2006 Eelgrass	Namba et al. 2017 2007 Eelgrass	McIver et al., unpublished 2013 Eelgrass
	Littorina littorea		x			x	x
	Littorina saxatilis		x			x	
	Littorina obtusata		x				
	Macoma						x
	Margarites helicinus					x	x
	Mytilus sp.	x	x			x	
	Nassarius trivittatus				x	x	x
	Naticidae sp.						x
	Notoacmaea testudinalis	x			x	x	
	Rissoidae						
	Skeneopsis planorbis						
	Solemya borealis						x
	Tellina agilis						x
	Testudinalia testudinalis						
	Tritia trivittata			x			

Taxonomic group	Species	Schmidt et al. 2011 2006 Rockweed	Kay et al., unpublished 2012 Rockweed	Wong 2018*, Vercaemer et al. 2018** 2016 Rockweed	Schmidt et al. 2011 2006 Eelgrass	Namba et al. 2017 2007 Eelgrass	McIver et al., unpublished 2013 Eelgrass
	Turbonilla sp.					x	
Sponges	Breadscrumb Sponge (*Halichondria panacea*)	x	x				
Worms*	Flatworm (*Convoluta convolute*)					x	x
	Spirorbis sp.	x			x	x	x
	Polychaeta						
	Oligochaeta						
	Nemertea						
Bryozoans	*Electra pilosa*		x				
	Flustrella hispida		x				
	Membranipora membranacea	x	x		x	x	x
	Lichenopora sp.					x	
Hydroids	*Hydroids*					x	x

Taxonomic group	Species	Schmidt et al. 2011 2006 Rockweed	Kay et al., unpublished 2012 Rockweed	Wong 2018*, Vercaemer et al. 2018** 2016 Rockweed	Schmidt et al. 2011 2006 Eelgrass	Namba et al. 2017 2007 Eelgrass	McIver et al., unpublished 2013 Eelgrass
	Obelia geniculata		x				
Tunicates	*Botryllus schlosseri*	x				x	
Plants	*Zostera marina*				x	x	x
Seaweeds**	*Agarum clathratum*					x	
	Ahnfeltia plicata		x		x		
	Ascophyllum nodosum	x	x			x	
	Bonnemaisonia hamifera						x
	Ceramium sp.					x	x
	Chaetomorpha melagonium					x	
	Chondrus crispus	x	x			x	
	Chorda filum					x	
	Chordaria flagelliformis					x	
	Cladophora rupestris	x					x

Taxonomic group	Species	Schmidt et al. 2011 2006 Rockweed	Kay et al., unpublished 2012 Rockweed	Wong 2018*, Vercaemer et al. 2018** 2016 Rockweed	Schmidt et al. 2011 2006 Eelgrass	Namba et al. 2017 2007 Eelgrass	McIver et al., unpublished 2013 Eelgrass
	Cladosiphon zosterae						x
	Corallina officinalis	x			x	x	
	Cystoclonium purpureum						x
	Ectocarpus siliculosus	x					x
	Erythrotrichia carnea	x					
	Fucus vesiculosus	x	x		x	x	
	Pilayella littoralis	x					x
	Polysiphonia fucoides	x			x		
	Saccharina latissima					x	
	Sphacelaria arctica	x					
	Sphaerotrichia divaricata					x	

**Wong et al. 2016 and Vercaemer et al. 2018 did not record seaweed species

Table 10. Potential threats of a high level of concern for Southern Upland (SU) Atlantic Salmon (Salmo salar) in the freshwater environment. Modified from Bowlby et al. (2014).

Threat	Evidence for Changes to Viability of SU Salmon Populations	Severity of Population Level Impacts	Rationale
Freshwater Environment			
Acidification	Very High	Extreme	Acid rain and bedrock leaching have led to acidification of SU rivers, which have a reduced buffering capacity. Low pH has negative effects on juvenile physiology and survival.
Altered Hydrology	Medium	High	Development and forestry along some rivers may increase or decrease flow, which decreases juvenile survival. Altered hydrology also affects adult returns to rivers, and extreme flow events have been observed.
Invasive Fish Species	Medium	High	Chain Pickerel and Smallmouth Bass are significant invasives that prey directly on salmon. These species are widespread across Nova Scotia.
Physical Obstructions	Very High	Medium to Extreme (depending on watershed structure)	Seasonal, partial, or complete barriers to movement of adult, smolt, and juvenile salmon. Structures alter habitat by affecting flow rate and sediment deposition. Obstructions fragment habitat, leading to reduced available habitat.
Illegal Fishing	High	Low to High (depending on number of salmon removed and size of population)	Direct adult mortality. Anecdotal evidence suggests poaching is widespread, and given the small population sizes, could have sever impacts on wild populations.

Table 11. Potential threats of a high level of concern for Southern Upland (SU) Atlantic Salmon (Salmo salar) in the marine environment. Modified from Bowlby et al. (2014).

Threat	Evidence for Changes to Viability of SU Salmon Populations	Severity of Population Level Impacts	Rationale
Marine and Estuarine Environments			
Salmonid Aquaculture	Low	Medium to High (depending on location of aquaculture sites and operating practices)	Impacts can include near-shore habitat loss, possible disease transfer, predator attraction, and interbreeding with aquaculture escapees. Introduction of deleterious alleles or reduced genetic diversity. May contribute to lower reproductive success, and increase immature and adult mortality rates.
Changes in Oceanographic Conditions	Low	Low to Extreme (depending on magnitude of change)	Climate change, ecosystem shifts, and human-induced changes affect mortality rates at sea.

Table 12. Whale, seal, and sea turtle sightings data from the Whale Sightings Database (OESD 2018) for the Scotian Shelf from 2007 to 2017. Note that numbers have not been verified and sightings are based on an opportunistic basis. Sightings may be reported by individuals with varying expertise in marine mammal identification.

Date	Latitude	Longitude	Number of individuals in group	Species Common Name
17-Jul-07	43.66	-63.53	8	DOLPHINS-COMMON
01-Aug-07	44.83283	-61.8055	1	SEATURTLE-GREEN
06-Aug-07	44.07333	-61.4867	3	WHALE- LONG-FINNED PILOT
07-Aug-07	44.44833	-61.6367	1	WHALES (NS)
26-Sep-07	43.91667	-63.7333	1	WHALE-MINKE
26-Sep-07	44.06667	-63.3167	7	DOLPHINS-COMMON
03-Oct-07	44.28333	-62.6167	50	DOLPHINS-ATLANTIC WHITE-SIDED
03-Oct-07	44.31667	-62.5333	50	DOLPHINS-COMMON
20-Apr-08	44.347	-62.0968	3	WHALE-HUMPBACK
11-Jun-08	45.388	-59.4197	2	PORPOISE-HARBOUR
14-Jun-08	45.44683	-59.305	7	DOLPHINS/PORPOISE (NS)
14-Jun-08	45.44683	-59.305	1	WHALE-HUMPBACK
14-Jun-08	45.27967	-59.0718	6	WHALE-ATLANTIC PILOT
14-Sep-08	43.83617	-65.6428	1	WHALES (NS)

Date	Latitude	Longitude	Number of individuals in group	Species Common Name
14-Sep-08	43.54167	-65.1808	1	WHALE-FIN
14-Sep-08	44.0965	-65.1777	1	WHALE-FIN
15-Oct-08	44.91283	-61.563	1	WHALE-FIN
15-Oct-08	45.23333	-60.6793	2	WHALE-HUMPBACK
17-Oct-08	45.25433	-59.277	15	DOLPHINS-COMMON
17-Oct-08	45.235	-59.2572	1	WHALE-FIN
17-Oct-08	45.185	-59.2057	2	DOLPHINS-COMMON
26-Apr-09	45.1885	-59.202	1	WHALE-FIN
28-Apr-09	44.49417	-61.5218	3	WHALE-FIN
03-Jun-09	44.46667	-63.64	2	WHALE-HUMPBACK
08-Aug-09	43.502	-66.4542	7	WHALE-HUMPBACK
08-Aug-09	43.56	-66.4497	2	WHALE-HUMPBACK
12-Aug-09	44.666	-63.5885	1	WHALE-FIN
12-Aug-09	44.64267	-63.564	1	WHALES (NS)
12-Aug-09	44.63417	-63.5583	1	WHALE-FIN
27-Aug-09	43.96567	-64.11	8	DOLPHINS-ATLANTIC WHITE-SIDED

Date	Latitude	Longitude	Number of individuals in group	Species Common Name
07-Jun-10	44.55783	-62.5317	1	WHALE-MINKE
29-Jul-10	44.021	-64.0848	1	CETACEAN (NS)
23-Jun-11	45.0915	-61.538	2	WHALE-NORTH ATLANTIC RIGHT
16-Jul-11	44.66667	-62.2333	1	SEATURTLE-LEATHERBACK
11-Jul-12	43.8004	-63.2224	1	WHALE-FIN
29-Jul-12	45.48333	-60.7	1	SEATURTLE-LEATHERBACK
01-Jun-13	44.6614	-63.9241	1	PORPOISE-HARBOUR
07-Jul-13	43.98067	-63.1353	1	CETACEAN (NS)
13-Jul-13	45.41683	-60.3367	1	SEATURTLE-LOGGERHEAD
23-Jul-13	43.58333	-65.0333	1	SEATURTLE-LEATHERBACK
30-Jul-13	44.39417	-63.3972	1	WHALE-HUMPBACK
15-Aug-13	44.61233	-62.544	2	WHALE-FIN
15-Aug-13	44.64567	-62.4373	1	WHALE-SPERM
06-Oct-13	44.48463	-63.7761	1	WHALE-NORTHERN BOTTLENOSE
10-Nov-13	43.7109	-66.0269	1	SEATURTLE-LEATHERBACK
30-Nov-13	44.08333	-62.6833	16	WHALE-ATLANTIC PILOT

Date	Latitude	Longitude	Number of individuals in group	Species Common Name
05-Dec-13	44.06667	-62.9667	4	WHALE-ATLANTIC PILOT
05-Dec-13	44.21667	-62.8	4	WHALE-ATLANTIC PILOT
06-Dec-13	44.6449	-63.3769	1	PORPOISE-HARBOUR
13-Apr-14	43.98583	-62.0728	1	WHALES (NS)
30-May-14	44.67417	-63.0485	1	WHALES (NS)
11-Jun-14	45.1155	-61.5832	2	WHALE-NORTH ATLANTIC RIGHT
16-Jul-14	43.77667	-62.1667	4	WHALE-HUMPBACK
22-Jul-14	43.79074	-64.4336	2	WHALE-FIN
22-Jul-14	43.75944	-64.4132	3	WHALE-FIN
22-Jul-14	43.75859	-64.4127	1	WHALE-HUMPBACK
22-Jul-14	43.73409	-64.3532	2	CETACEAN (NS)
22-Jul-14	43.61216	-64.1824	1	CETACEAN (NS)
22-Jul-14	43.57646	-63.7054	10	DOLPHINS-ATLANTIC WHITE-SIDED
22-Jul-14	43.80987	-63.6964	1	WHALE-FIN
22-Jul-14	43.79505	-63.6867	1	CETACEAN (NS)
22-Jul-14	43.59492	-63.4432	1	CETACEAN (NS)

Date	Latitude	Longitude	Number of individuals in group	Species Common Name
22-Jul-14	43.67754	-63.3898	1	WHALE-MINKE
22-Jul-14	43.62965	-63.3453	5	WHALE-NORTH ATLANTIC RIGHT
22-Jul-14	43.63962	-63.3356	1	CETACEAN (NS)
22-Jul-14	43.63011	-63.3338	5	WHALE-NORTH ATLANTIC RIGHT
22-Jul-14	43.74623	-63.0953	1	CETACEAN (NS)
25-Jul-14	43.79018	-64.0674	15	DOLPHINS/PORPOISE (NS)
25-Jul-14	43.534	-63.7669	1	WHALE-FIN
25-Jul-14	43.54696	-63.7246	2	DOLPHINS/PORPOISE (NS)
25-Jul-14	43.59249	-63.3046	1	CETACEAN (NS)
25-Jul-14	43.58792	-63.2841	1	WHALE-FIN
25-Jul-14	43.51928	-63.2439	30	CETACEAN (NS)
25-Jul-14	43.52246	-63.2401	50	CETACEAN (NS)
25-Jul-14	43.54731	-63.2247	20	DOLPHINS/PORPOISE (NS)
25-Jul-14	44.23143	-63.2183	1	CETACEAN (NS)
25-Jul-14	43.71144	-63.1183	1	WHALE-FIN
25-Jul-14	43.71956	-63.113	1	CETACEAN (NS)

Date	Latitude	Longitude	Number of individuals in group	Species Common Name
25-Jul-14	43.99135	-63.0669	1	WHALE-FIN
25-Jul-14	43.98265	-63.0578	50	DOLPHINS-COMMON
25-Jul-14	43.97056	-63.0571	1	CETACEAN (NS)
25-Jul-14	43.96076	-63.0408	1	WHALE-FIN
25-Jul-14	43.92781	-63.0364	1	CETACEAN (NS)
25-Jul-14	43.84332	-63.0325	2	WHALE-HUMPBACK
25-Jul-14	43.96103	-63.0304	2	DOLPHINS/PORPOISE (NS)
25-Jul-14	43.9621	-63.0282	1	WHALE-FIN
26-Jul-14	43.50901	-63.9891	1	CETACEAN (NS)
26-Jul-14	43.6343	-63.9379	1	SEATURTLE-LEATHERBACK
26-Jul-14	44.22063	-63.7347	1	WHALE-HUMPBACK
26-Jul-14	44.23008	-63.7314	1	WHALE-MINKE
26-Jul-14	44.25252	-63.7236	1	CETACEAN (NS)
27-Jul-14	45.03181	-61.3053	1	WHALE-HUMPBACK
27-Jul-14	44.77843	-61.2069	3	DOLPHINS/PORPOISE (NS)
27-Jul-14	44.77558	-61.2034	2	DOLPHINS/PORPOISE (NS)

Date	Latitude	Longitude	Number of individuals in group	Species Common Name
27-Jul-14	44.76986	-61.1963	10	DOLPHINS/PORPOISE (NS)
27-Jul-14	44.7695	-61.1959	10	WHALE-MINKE
27-Jul-14	44.76878	-61.195	50	DOLPHINS/PORPOISE (NS)
27-Jul-14	44.77262	-61.1948	30	DOLPHINS/PORPOISE (NS)
27-Jul-14	44.76161	-61.1863	30	DOLPHINS-COMMON
27-Jul-14	44.77515	-61.183	1	WHALE-MINKE
27-Jul-14	44.75626	-61.1781	50	DOLPHINS-COMMON
27-Jul-14	45.19058	-60.898	1	SEATURTLE-LEATHERBACK
27-Jul-14	44.79959	-60.6487	1	FALSE KILLER WHALE
27-Jul-14	45.16188	-60.5112	15	WHALE-ATLANTIC PILOT
27-Jul-14	45.07596	-60.4057	1	SEATURTLE-LEATHERBACK
27-Jul-14	45.28629	-60.3691	1	SEATURTLE-LEATHERBACK
27-Jul-14	45.14762	-60.1925	1	WHALE-MINKE
27-Jul-14	45.03703	-60.0541	1	SEATURTLE-LEATHERBACK
27-Jul-14	45.00863	-60.0201	1	FALSE KILLER WHALE
31-Jul-14	44.2	-63.87	7	WHALE-FIN

Date	Latitude	Longitude	Number of individuals in group	Species Common Name
01-Aug-14	43.53	-65.29	1	WHALE-FIN
07-Aug-14	44.7993	-60.0747	12	DOLPHINS-ATLANTIC WHITE-SIDED
24-Oct-14	43.95733	-63.5002	1	BALEEN WHALE (NS)
12-Feb-15	44.36667	-63.7	1	SEALS (NS)
16-Mar-15	43.6304	-65.2799	1	SEAL-GREY
05-May-15	45.2618	-59.0275	1	CETACEAN (NS)
25-May-15	44.69466	-63.6378	1	WHALE-BELUGA
17-Jul-15	43.6667	-66.05	3	CETACEAN (NS)
20-Aug-15	45.0961	-59.4318	1	WHALE-MINKE
04-Oct-15	43.6906	-64.5632	1	CETACEAN (NS)
11-Oct-15	44.1501	-63.176	1	WHALE-BLUE
21-Jul-16	44.64667	-63.5539	1	WHALE-MINKE

Table 13. Species occurring within or near the Area of Interest (AOI) arranged in alphabetical order with the population or designatable unit (DU); their conservation status including year of last assessment by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC); reason for designation; and risk status for the Species at Risk Act (SARA) and year of designation if listed on schedule 1; and notes on species presence within or near the AOI.

Species	Conservation Status in Canada			
	Population/DU	**COSEWIC (year designated)**	**Reason for Designation**	**SARA (year listed on schedule 1)**
American Eel (*Anguilla rostrata*)	Nova Scotia populations	Threatened (2012)	Dramatic declines in Lake Ontario and St. Lawrence populations, but variable trends in other areas	No status
American Plaice (*Hippoglossoides platessoides*)	Maritime population	Threatened (2009)	Mature individuals have declined by 67% on the Scotian Shelf	No status
Atlantic Cod (*Gadus morhua*)	Laurentian South population	Endangered (2010)	Populations have declined by 90% and have not improved	No status
Atlantic Salmon (*Salmo salar*)	Southern Upland DU	Endangered (2010)	Mature individuals have declined by 61% in the Southern Upland	Pending
Atlantic Wolffish (*Anarhichas lupus*)	Atlantic and Arctic population	Special Concern (2000, confirmed 2012)	Steep declines until the mid-1990s, continued declines on Scotian Shelf	Schedule 1, Special Concern
Barrow's Goldeneye (*Bucephala islandica*)	Eastern Canada	Special Concern (2000, confirmed 2011)	Small population found only in eastern Canada	Schedule 1, Special Concern
Bluefin Tuna (*Thunnus thynnus*)	Atlantic population	Endangered (2011)	Decline in spawning individuals by 69%	No status
Harlequin Ducks (*Histrionicus histrionicus*)	Eastern population	Special Concern (2013)	Small population size susceptible to oil spills and other events	Schedule 1, Special Concern
Leatherback Sea Turtle (*Dermochelys coriacea*)	Atlantic population	Endangered (2012)	Global populations have declined by 70% due to bycatch, marine pollution, entanglement in longline and fixed fishing gear.	Schedule 1, Endangered

Species	Conservation Status in Canada			
	Population/DU	**COSEWIC (year designated)**	**Reason for Designation**	**SARA (year listed on schedule 1)**
Northern Wolffish (*Anarhichas denticulatus*)	Atlantic and Arctic population	Threatened (2001, confirmed 2012)	Strong declines in abundance and range in the 1980s	Schedule 1, Threatened
Piping Plover (*Charadrius melodus*)	Subspecies *melodus*	Endangered (2001, updated 2013)	Numbers remain extremely low and population continues to decline	Schedule 1, Endangered
Roseate Tern (*Sterna dougallii*)	Northeastern population	Endangered (1999, confirmed 2009)	Only 200 mature individuals occur in Canada	Schedule 1, Endangered
Spotted Wolffish (*Anarhichas minor*)	Atlantic and Arctic population	Threatened (2001, confirmed 2012)	Strong declines in 1970s and 1980s with some evidence of recovery.	Schedule 1, Threatened
White Hake (*Urophycis tenuis*)	Atlantic and Northern Gulf of St. Lawrence population	Threatened (2013)	Adults have declined by 70% over the past three generations	No status
Winter Skate (*Leucoraja ocellata*)		Endangered (2015)	Abundance of mature individuals has declined by 98% since the 1970s	

Table 14. Summary of 2075 climate forecasts for the Eastern Shore Islands AOI and the Coastal Planning area (Coastal) binned by season: Winter (January–March), Spring (April–June), Summer (July–September), and Fall (October–December). Forecasts are made for the upper surface layer or at depth. The mean change in salinity and temperature with standard deviations is shown. Refer to Brickman et al. (2016) for details on the climate projection (Nucleus for European Modelling of the Ocean Representative Concentration Pathway 8.5).

Location	Depth	Variable	Season	Mean	S.D.	Lower	Upper
AOI	Surface	Salinity	Winter	-0.33	0.05	-0.34	-0.33
			Spring	-0.40	0.06	-0.41	-0.39
			Summer	-0.29	0.04	-0.30	-0.28
			Fall	-0.22	0.03	-0.22	-0.22
		Temperature	Winter	1.75	0.15	1.73	1.77
			Spring	1.82	0.07	1.81	1.83
			Summer	1.41	0.12	1.40	1.43
			Fall	1.51	0.10	1.50	1.53
	Bottom	Salinity	Winter	-0.17	0.11	-0.19	-0.16
			Spring	-0.21	0.15	-0.24	-0.19
			Summer	-0.09	0.15	-0.11	-0.07
			Fall	-0.05	0.12	-0.07	-0.04
		Temperature	Winter	1.35	0.34	1.31	1.40
			Spring	1.32	0.28	1.28	1.36
			Summer	1.23	0.33	1.18	1.27
			Fall	1.21	0.32	1.17	1.25
Coastal	Surface	Salinity	Winter	-0.17	0.24	-0.18	-0.16
			Spring	-0.20	0.21	-0.21	-0.19
			Summer	-0.13	0.18	-0.13	-0.12
			Fall	-0.05	0.16	-0.05	-0.04
		Temperature	Winter	1.47	0.34	1.46	1.48

Location	Depth	Variable	Season	Mean	S.D.	Lower	Upper
			Spring	1.47	0.32	1.46	1.49
			Summer	1.28	0.36	1.27	1.29
			Fall	1.25	0.39	1.24	1.27
	Bottom	Salinity	Winter	-0.34	0.18	-0.34	-0.33
			Spring	-0.43	0.12	-0.43	-0.43
			Summer	-0.36	0.09	-0.36	-0.35
			Fall	-0.24	0.11	-0.24	-0.23
		Temperature	Winter	1.67	0.26	1.66	1.68
			Spring	1.76	0.21	1.76	1.77
			Summer	1.36	0.13	1.35	1.36
			Fall	1.41	0.13	1.41	1.42

Table 15. Identified knowledge gaps, reasons why a gap exists, and potential remedies.

Knowledge Gap	Reasoning	Potential Solution(s)
Local coastal oceanography	Few data exist for the coastal zone on fine-scale patterns of upwelling and currents in the archipelago.	Deploy ADCPs at several locations for at least one year in the Eastern Shore. Develop models based on ADCP to understand fine-scale oceanography in the region.
Eelgrass, kelp, and Rockweed extent and resiliency	Few access points allow fieldwork to be conducted across entire Eastern Shore, meaning the full extent of macrophyte beds remains unknown. The resiliency of Eelgrass to stressors is also unknown in the AOI.	Aerial surveys to image Eelgrass beds. Potential construction of boat launch to facilitate access to nearshore areas. Long-term monitoring of Eelgrass, Rockweed, and kelp beds will determine resiliency to stressors and climate change.
Temporal usage of Eelgrass, Rockweed, and kelp by fish, invertebrates, and marine birds	While biodiversity of animals associated with macrophytes is well-studied, there are few studies specific to the Eastern Shore. Additional factors such as the seasons (phenology) and little is known about the usage of this habitat by different juvenile fish species .	Conduct beach seines in macrophyte beds at different times of year to study usage of this habitat by juvenile fish and invertebrates.
Macrophytes as biogenic habitat in the subtidal zone	Macrophytes such as Rockweed are used as protective habitat by invertebrates and fishes, but how many species and in what frequency remains unknown. Furthermore, most studies refer to intertidal Rockweed, whereas the associated fauna of subtidal Rockweed and other macrophytes is less well-studied.	Conduct comparative studies on intertidal/subtidal macrophytes to assess which species use this as habitat.
American Lobster movements	Local ecological knowledge suggests Lobster move inshore as the fishing season progresses. Movements outside of the fishing season are unknown.	Lobster tagging study to evaluate movement patterns would be beneficial to study where Lobster migrate to and why they go there.
Invertebrate biodiversity	Few studies have assessed invertebrate biodiversity in coastal Nova Scotia. Inshore Ecosystem Project was run adjacent to, but outside, AOI boundaries.	Conduct collections using plankton tows, SCUBA surveys, benthic dredges, to assess biodiversity of understudied phyla. Additional stations on Sentinel Survey, Halibut Survey, and/or Snow Crab Surveys shallower than 100 m would provide data.
Coastal zone usage by large pelagic fishes	Bluefin Tuna are fished and have been observed within the AOI and other coastal areas. It is assumed that large pelagics such as tunas and	Work with local fishers to better report sightings of large pelagic fish and their behaviours.

Knowledge Gap	Reasoning	Potential Solution(s)
	sharks are feeding in the coastal zone, but the degree to which the AOI contributes to this and other behaviours is unknown.	
Coastal zone usage by cetaceans and sea turtles	The AOI may be a coastal migration route for cetaceans and sea turtles moving to the Gulf of St. Lawrence to feed. There has been no systematic survey for these animals, and recorded, verified observations are lacking.	Work with local fishers to better report sightings of cetaceans and sea turtles within the AOI.
Zooplankton and Ichthyoplankton	Krill and copepods reported from the area, but unknown if any species are unique to the area and in what densities they occur. Juvenile fish are known from the area, but ichthyoplankton are not quantified.	Plankton tows in multiple seasons to better describe the zooplankton and ichthyoplankton of the area.
Atlantic salmon coastal usage	Atlantic Salmon spawn in a number of rivers in the Eastern Shore and move to sea as adults. However, whether they remain near the coast or undergo migrations to offshore feeding grounds remains unknown. Genetic evidence suggests few Southern Upland Salmon visit the West Greenland feeding grounds.	Tagging of smolts as they prepare to leave the rivers could provide data on Salmon movements in the coastal zone.
Influence of islands on Eelgrass, Rockweed, kelp, and animal distributions	Hundreds of islands lie within the AOI boundaries. It is hypothesized that the depth contours created by these islands increase habitat complexity, providing habitat for fishes and invertebrates, and providing wind and surge protection for Eelgrass beds and kelps.	Conduct systematic studies on island size, Eelgrass bed and kelp presence, and animal biodiversity associated with islands and non-island-associated habitat.

FIGURES

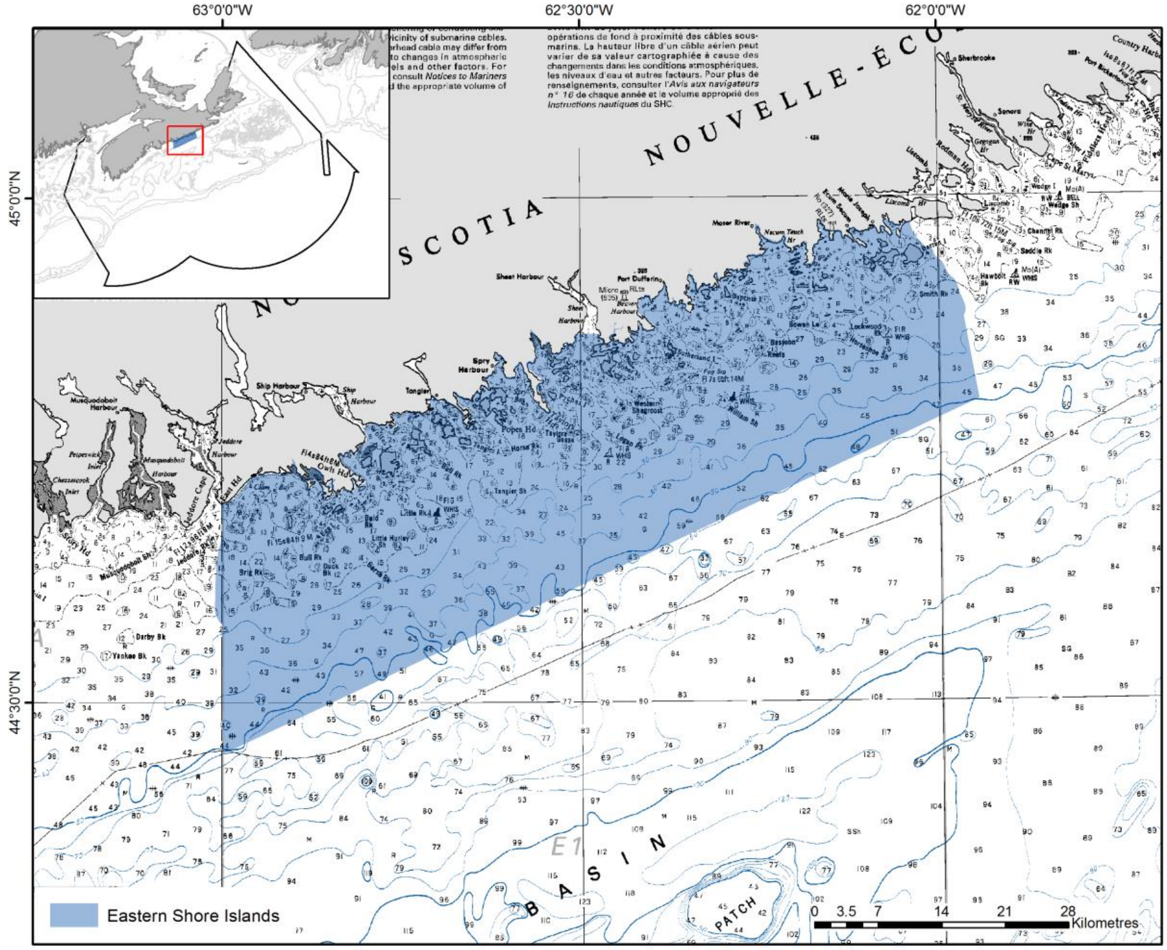

Figure 1. Eastern Shore Islands Area of Interest (AOI; shaded blue area) in Nova Scotia. AOI boundary is not final, is subject to change, and does not necessarily reflect a proposed MPA boundary. Basemap: Canadian Hydrographic Service nautical chart 4013 (not to be used for navigation).

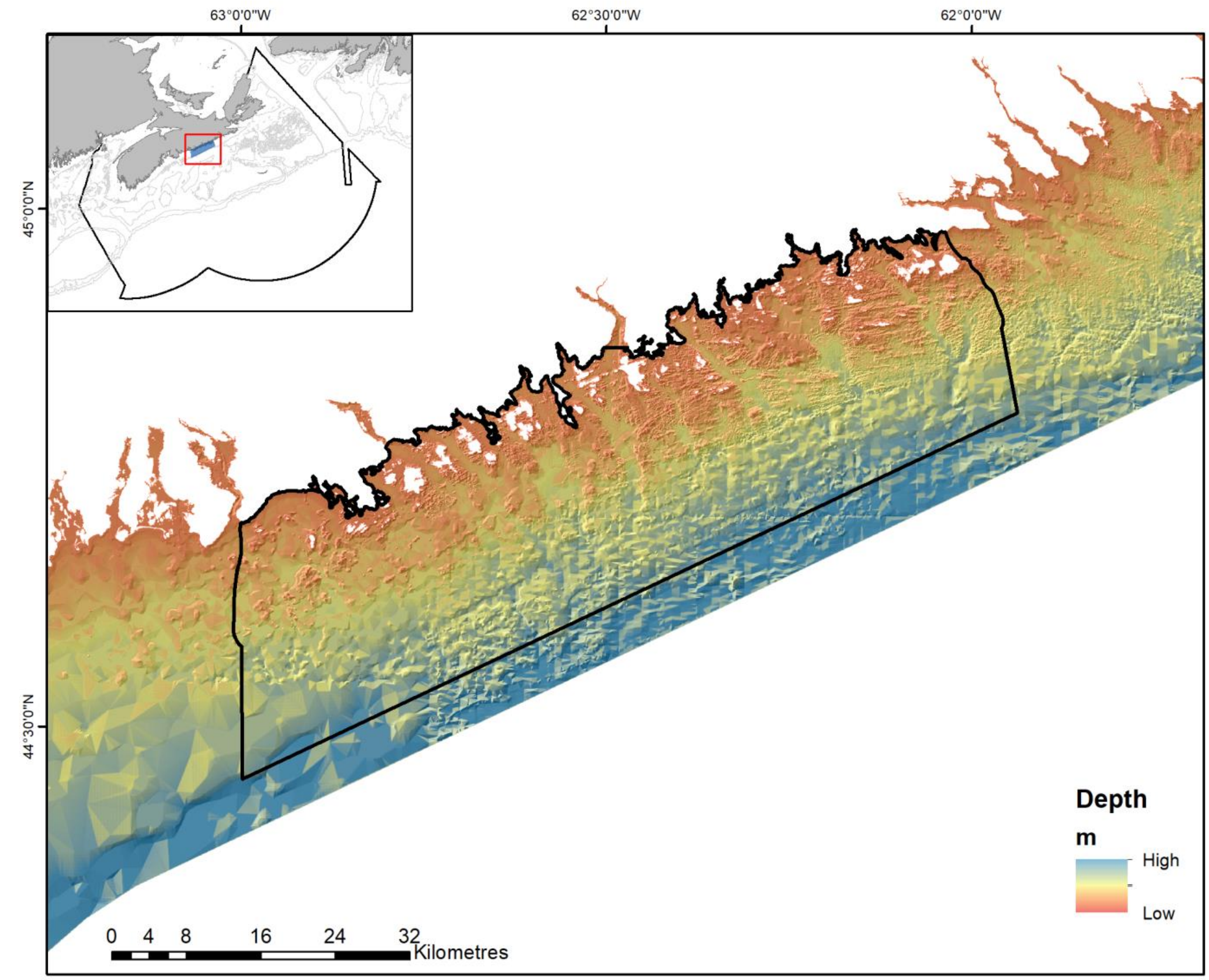

Figure 2. Digital elevation map with hillshading showing bathymetry of the Eastern Shore Islands area at 35 m resolution.

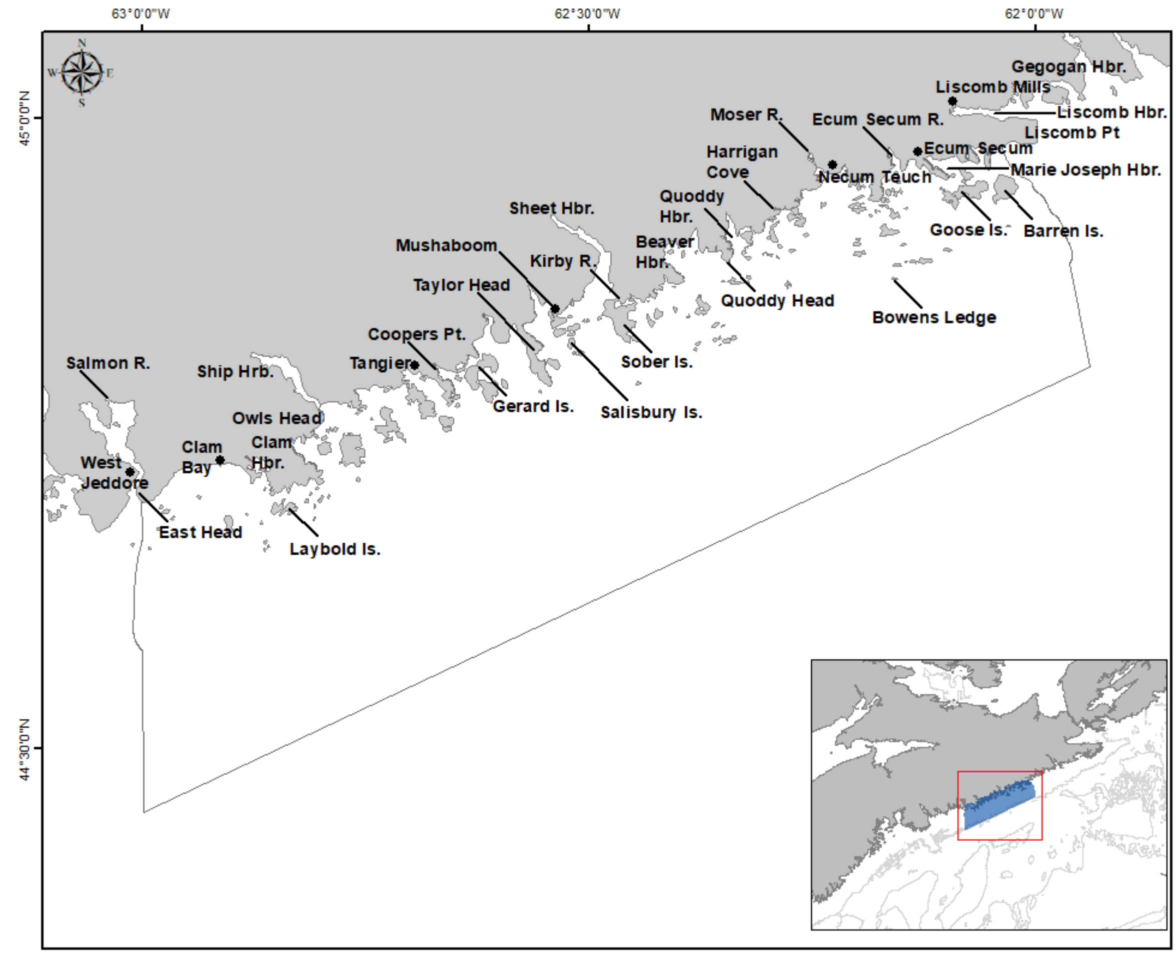

Figure 3. Eastern Shore Islands study area (blue shaded and outlined area) with locations referenced within this document.

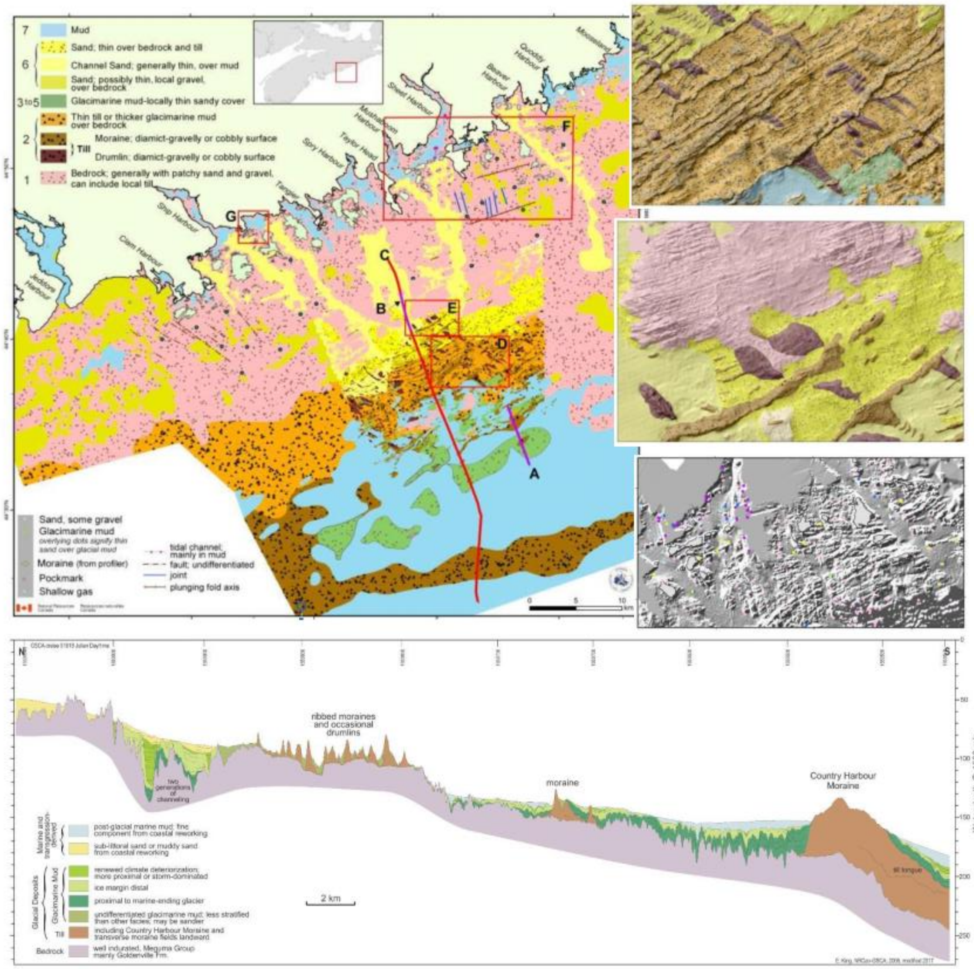

Figure 4. Geology of the Eastern Shore of Nova Scotia. The inshore region is predominantly bedrock with patchy or thin sand, gravel, and glacial till. Muddy areas are prevalent in inlets and farther offshore. Panels showing detailed geological features refer to boxes or transects in the map panel.

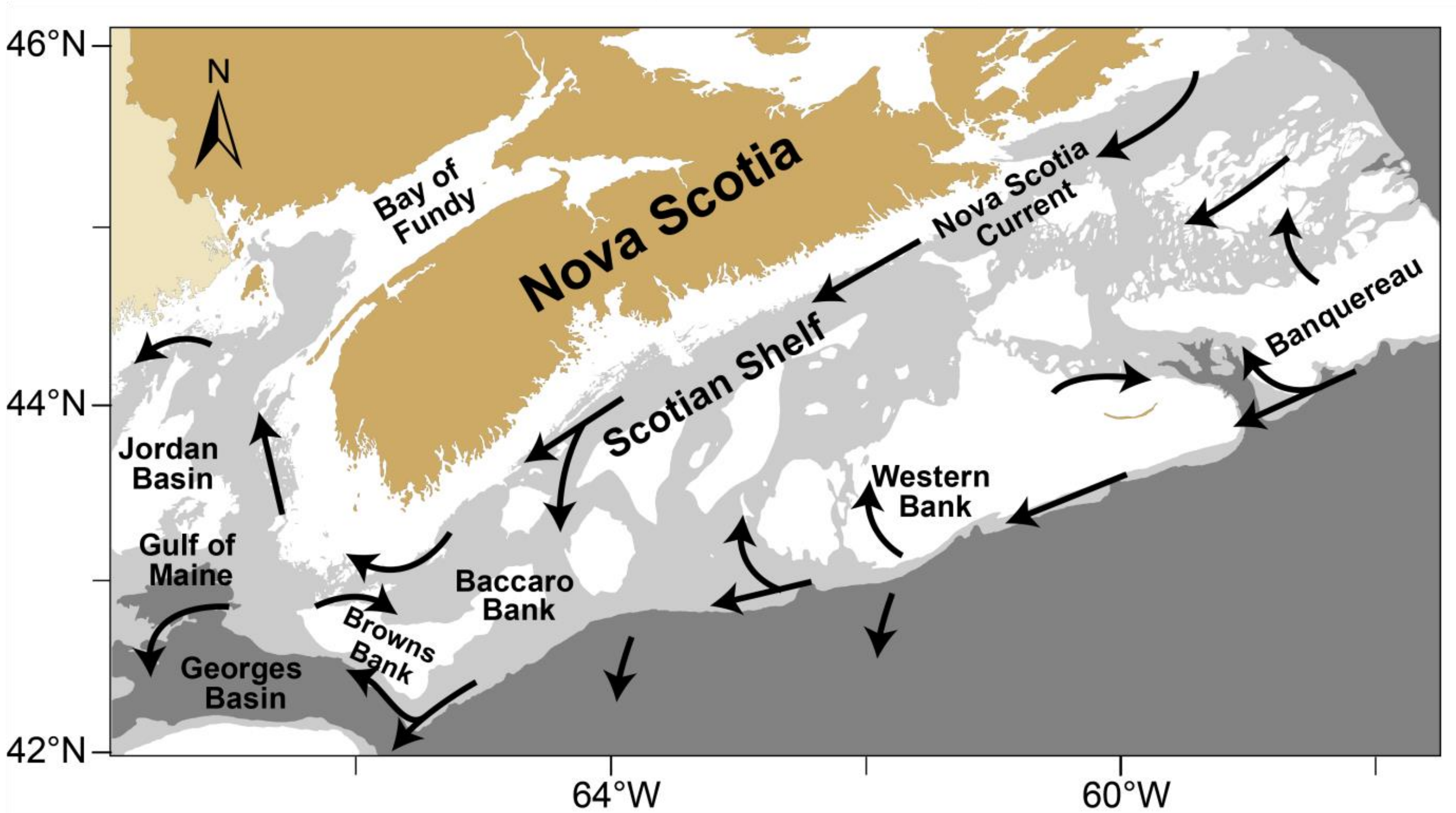

Figure 5. Nearshore currents and banks of Nova Scotia. Recreated from Bundy et al. (2014).

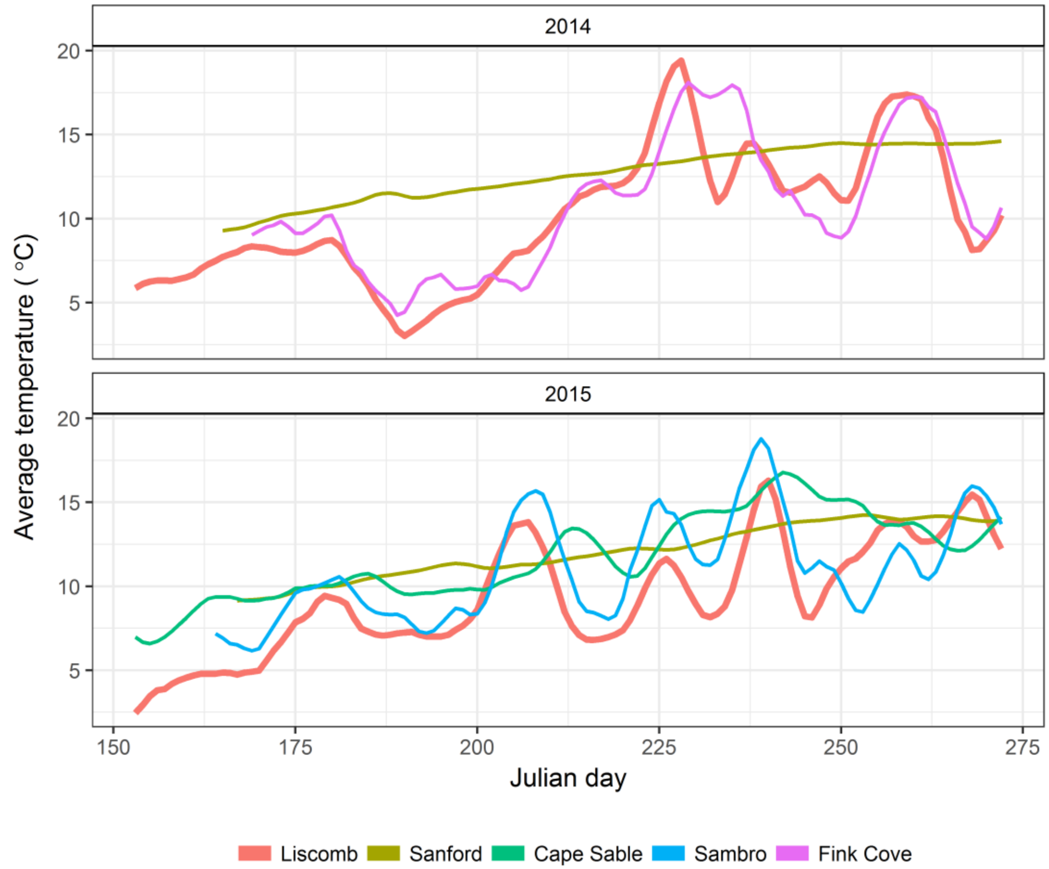

Figure 6. Temperature logger information collected at a variety of coastal sites in Nova Scotia. Deployments were 5–15 m in depth and were sampled June–September and are presented as daily means smoothed using a 5 day sliding window.

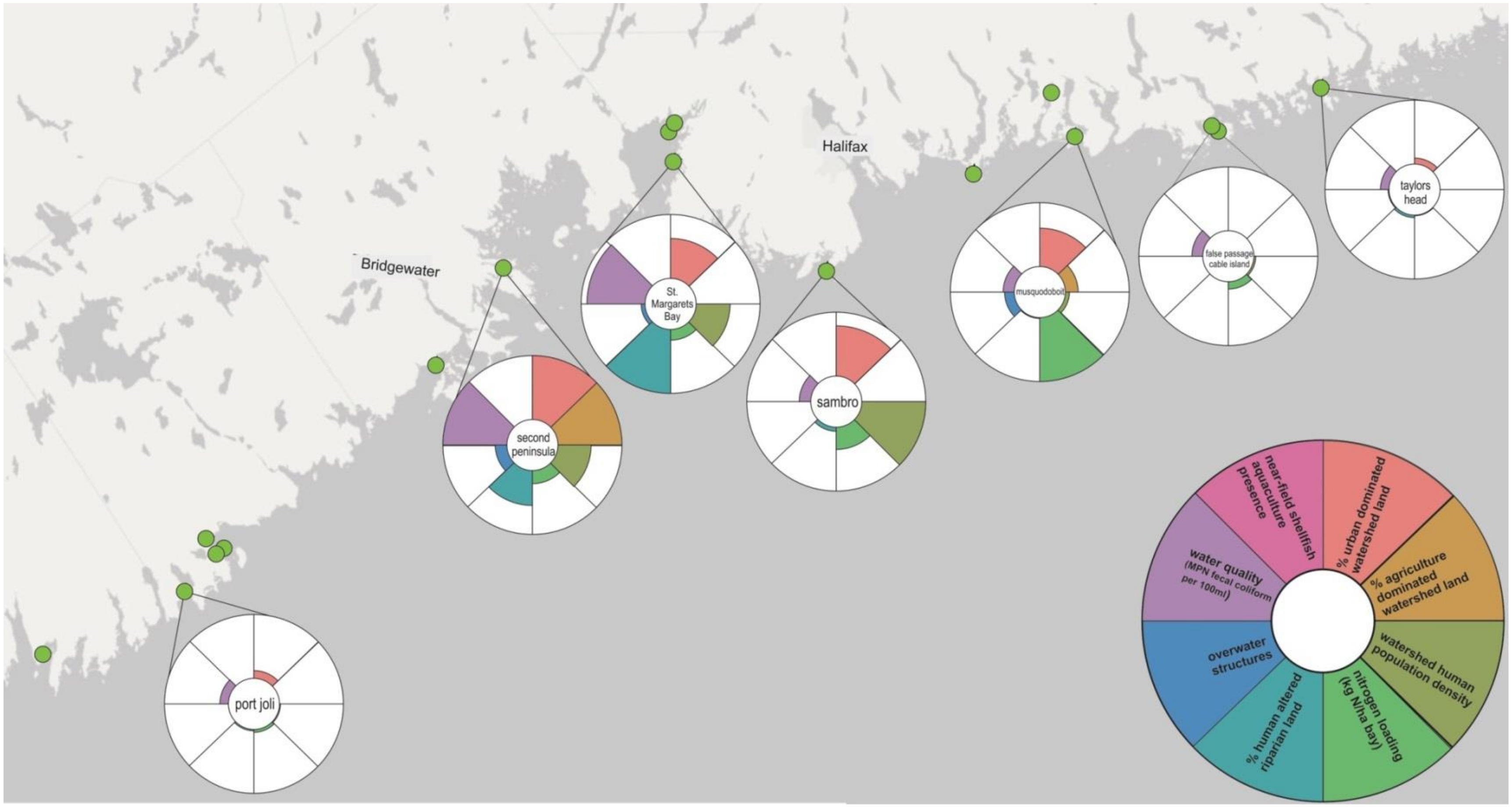

Figure 7. Standardized human impact metric for a subset of sites in the Atlantic coast of Nova Scotia. Each coloured petal represents one human impact measure with the outer ring of each circle representing the maximum possible impact score (i.e. petals that fill up more space represent a higher score of that impact). Impacts scores are relative to all other sites along the Atlantic coast of NS. Green points on map indicate the locations of seagrass beds. The human impact metric was calculated for all points displayed on this map (and for an additional 179 sites along the coasts of Nova Scotia, New Brunswick, and PEI), but for the purposes of this report it is only shown for seven sites. Source: Murphy et al. (2019).

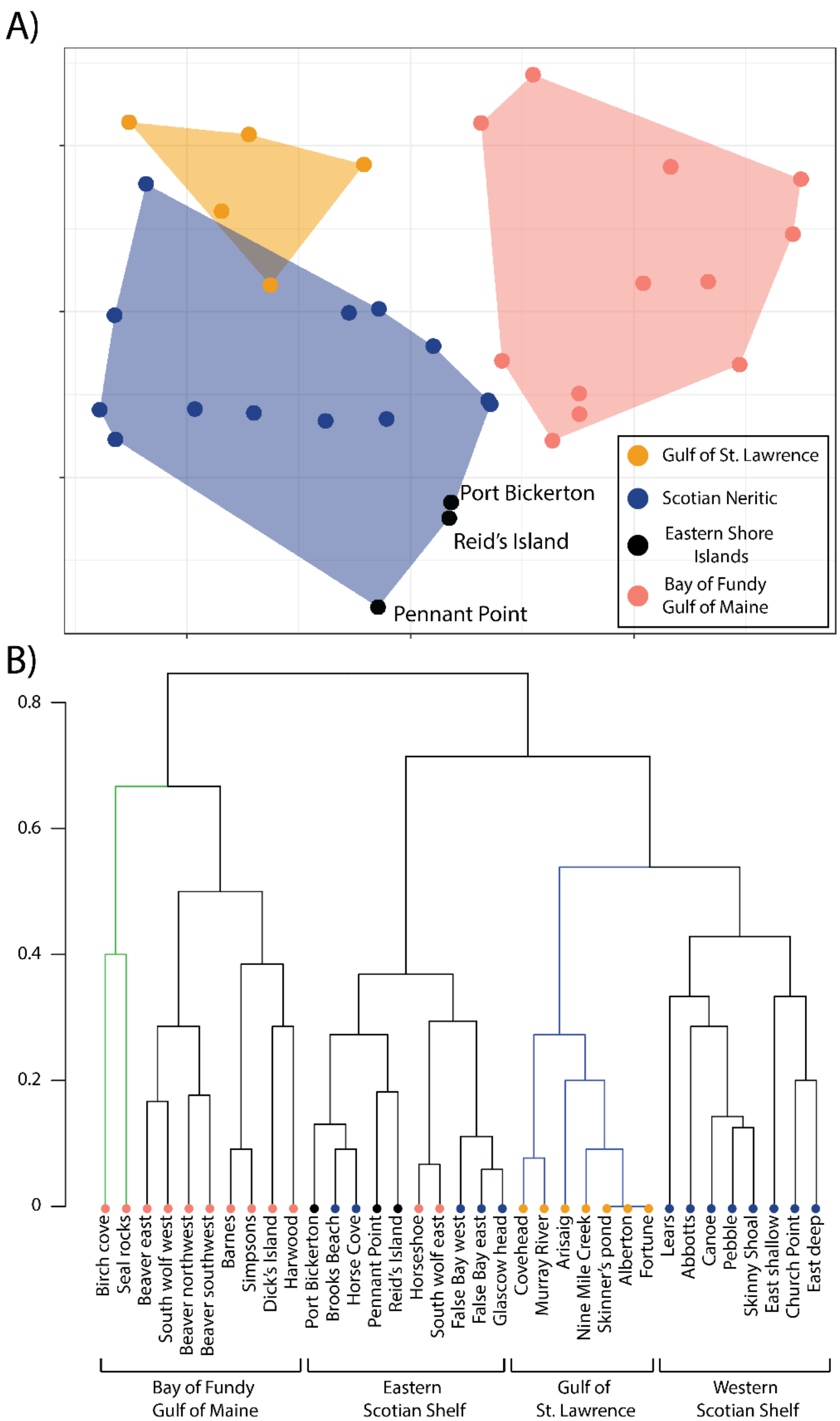

Figure 8. *A) non-metric multidimensional scaling plot of presence-absence data for marine fishes and invertebrates from Hunt et al. (2017) showing unique assemblages among the Scotian Neritic, Gulf of St. Lawrence, and Bay of Fundy/Gulf of Maine. B) dendrogram based on the same data showing that the Eastern Scotian Shelf is distinct from the Western Scotian Shelf, and, specifically, sites adjacent to the Eastern Shore Islands (black dots) form their own unique cluster.*

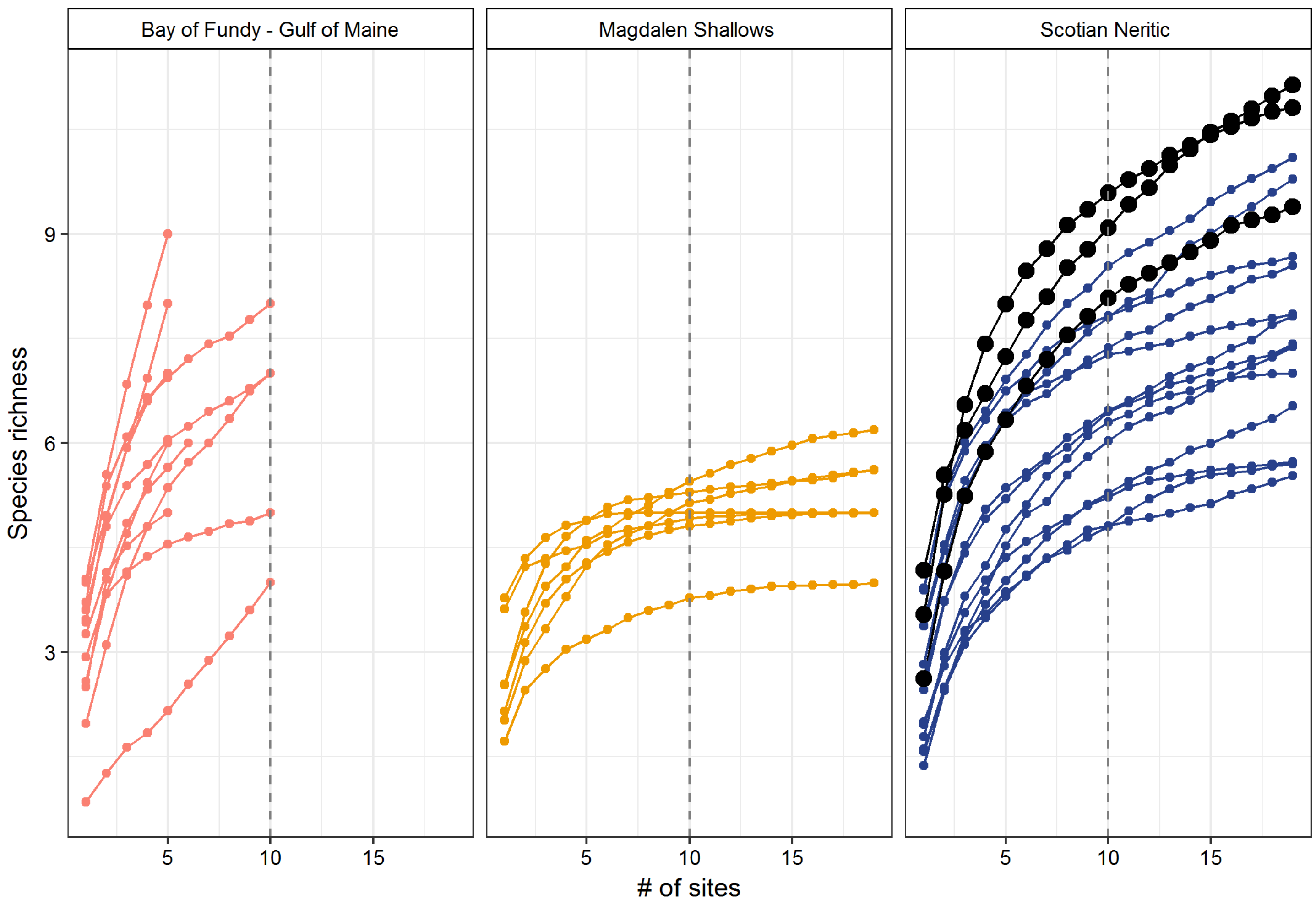

Figure 9. Species accumulation curves using data from Hunt et al. (2017) showing that species richness is highest at sites immediately adjacent to the Eastern Shore (Scotian Neritic black dots) and has not plateaued. The Bay of Fundy/Gulf of Maine similarly did not plateau but sampled fewer sites.

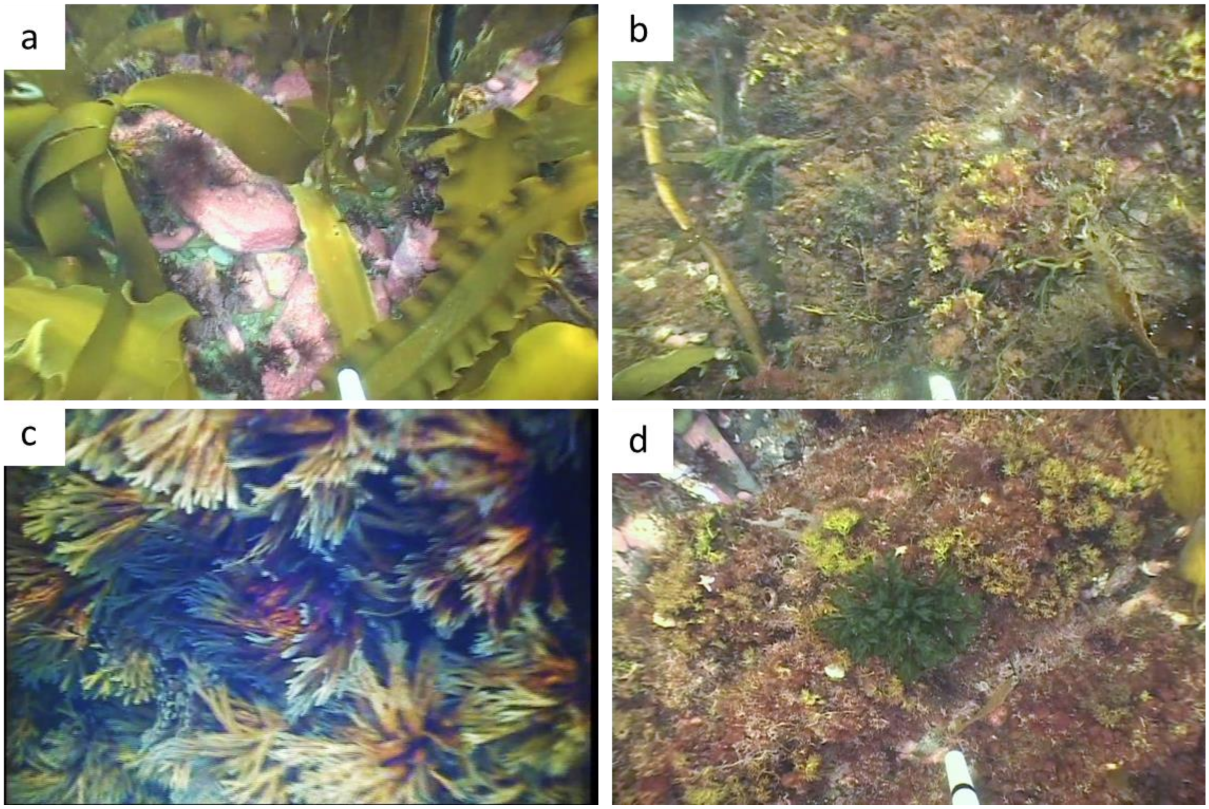

Figure 10. Imagery of: (a) a kelp bed at Goose Island, (b) a turf-dominated benthos at Harbour Island-A, (c) a fucoid dominated benthos at Sober Island, and (d) a patch of Codium fragile at Harbour Island-A, within the Eastern Shore Islands Area of Interest. Images from video recorded in 2007.

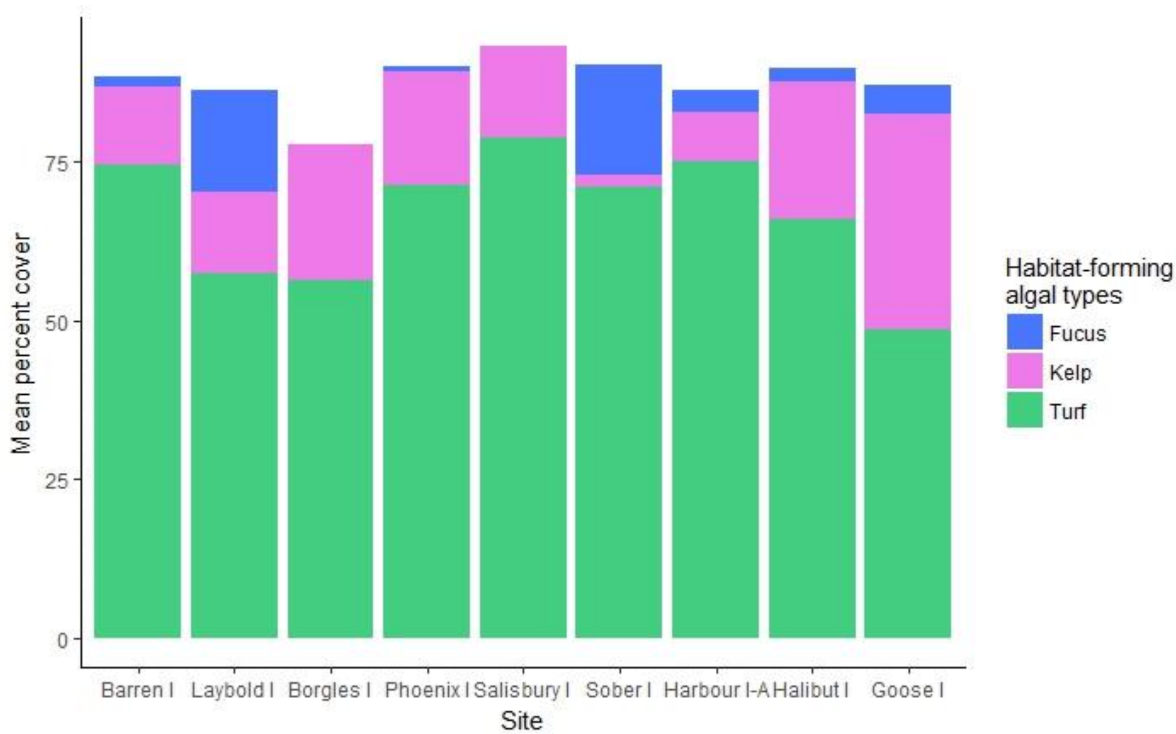

Figure 11. Percent cover of dominant habitat-forming algal types (Fucus sp., kelp, and turf algae) at 9 sites within the Eastern Shore Islands Area of Interest. Data from 2007 video survey.

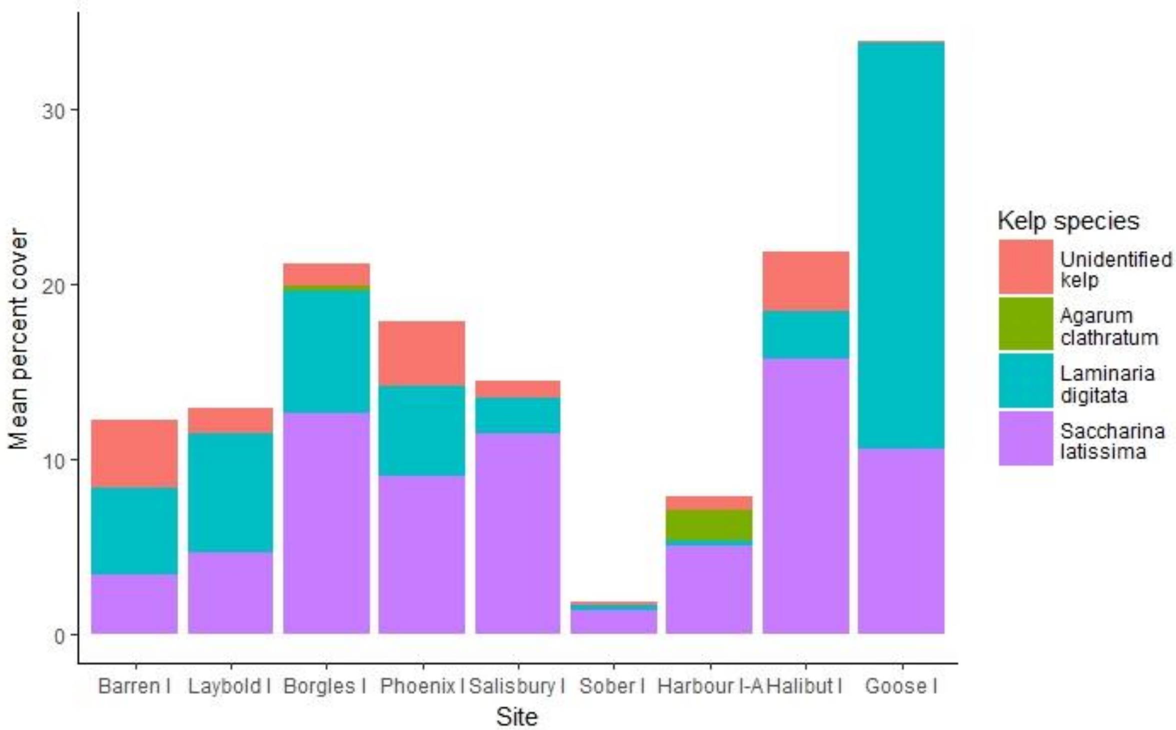

Figure 12. Percent cover of kelp species at 9 sites within the Eastern Shore Islands Area of Interest. Data from 2007 video survey.

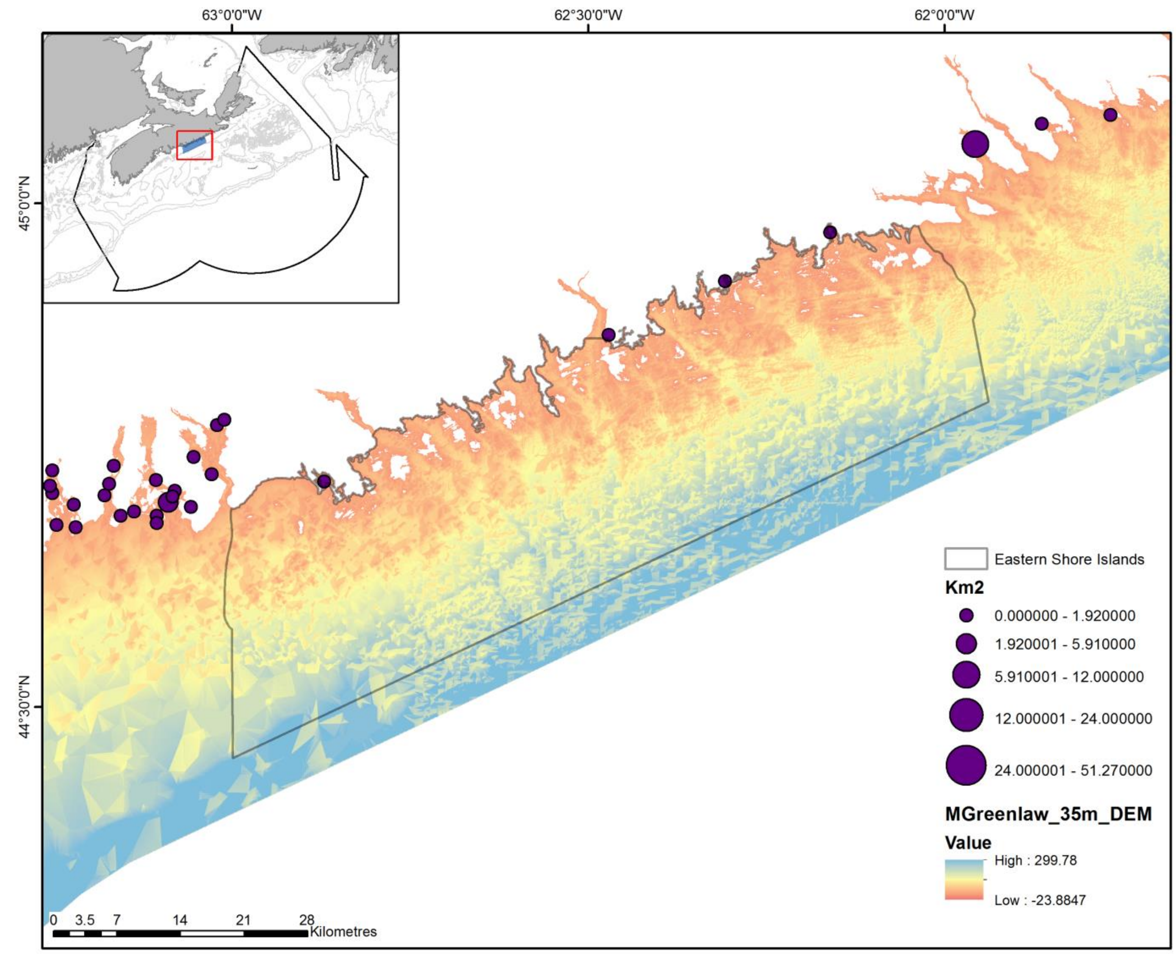

Figure 13. Eelgrass (Zostera marina) locations based on analyses by Allard et al. (2014), original data from Hanson and Calkins (1996). As of 2018, additional Eelgrass beds are known in the Cable Island Ship Harbour region, off Tangier, and at Taylor Head Provincial Park.

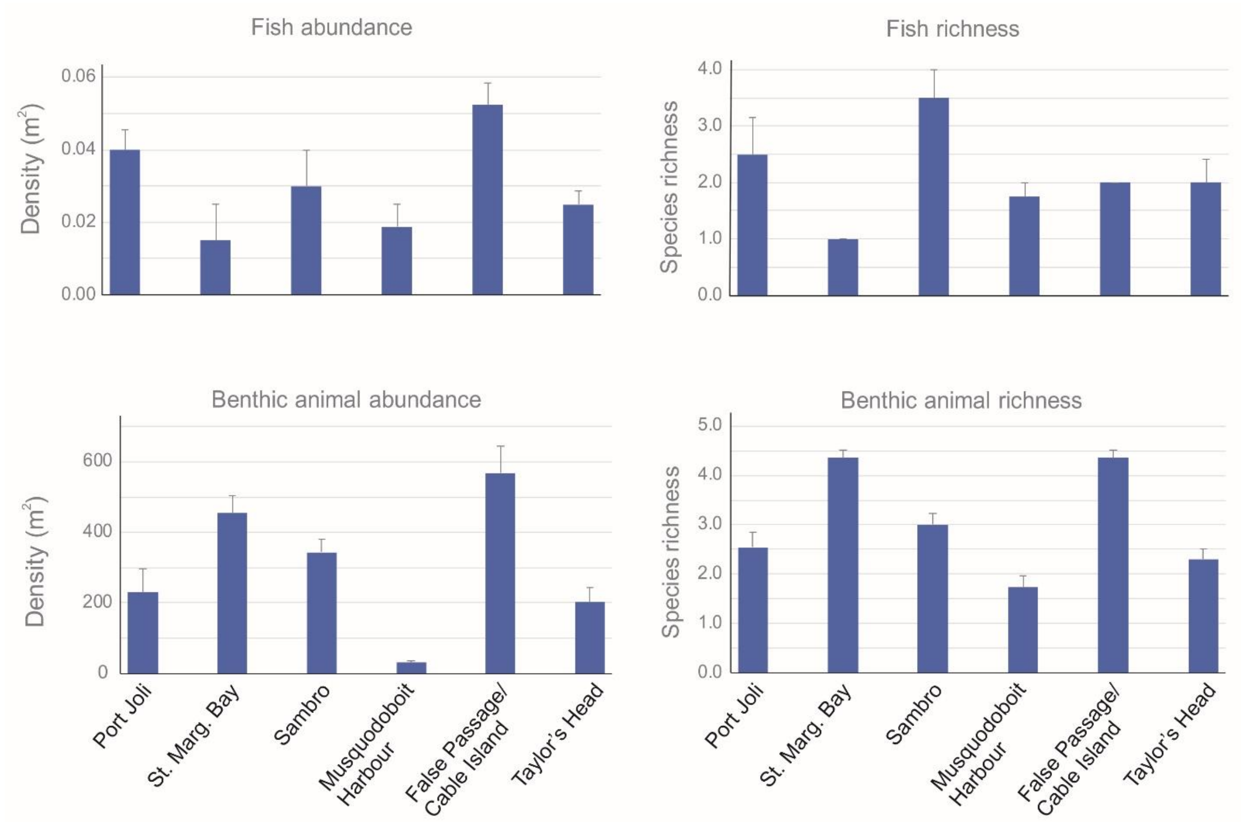

Figure 14. Density and richness of fishes and benthic animals associated with Eelgrass beds at six sites from the South Shore to the Eastern Shore.[6]

[6] Heike Lotze (Dalhousie University, Halifax, NS) – unpublished data, 2007, 2013, 2015.

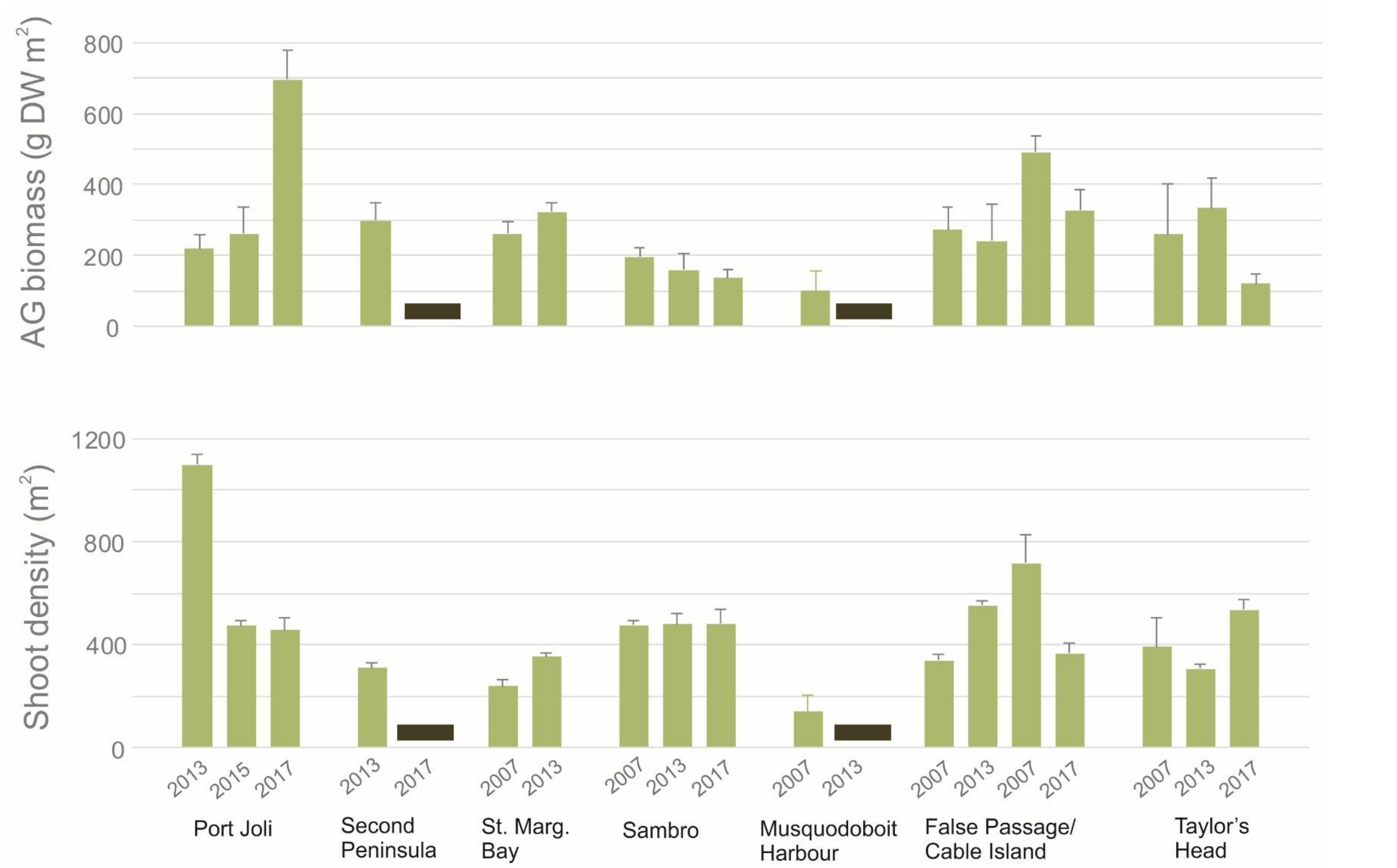

Figure 15*. Average Eelgrass (Zostera marina) above-ground biomass and shoot density in the seven sites referenced in the Human Impact Metrics section. Shoot density was measured in 2007, 2013, 2015, and 2017 during surveys conducted by either Melisa Wong (2013, 2017) or Heike Lotze (2007, 2013, 2015)[6]. Error bars represent 1 Standard Error (SE). Seagrass shoot density was measured in 10–11 replicate quadrats across each seagrass bed. Seagrass beds were found to be no longer present in two locations (Second Peninsula and Musquodoboit Harbour) in subsequent sampling years. Data from Schmidt et al. (2011), Cullain et al. (2017), Wong (unpublished).*

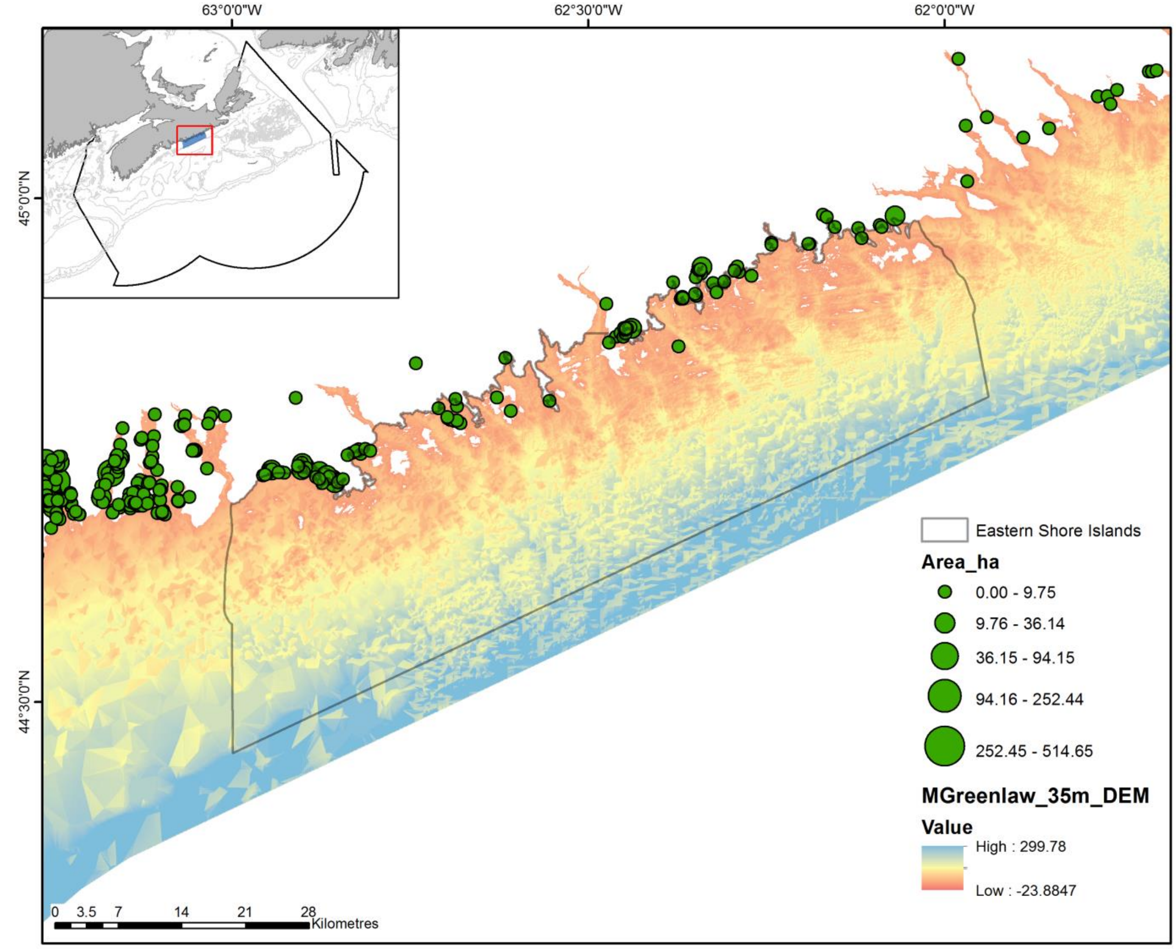

Figure 16. Saltmarsh distribution along the Eastern Shore based on analyses by Allard et al. (2014), original data from Hanson and Calkins (1996).

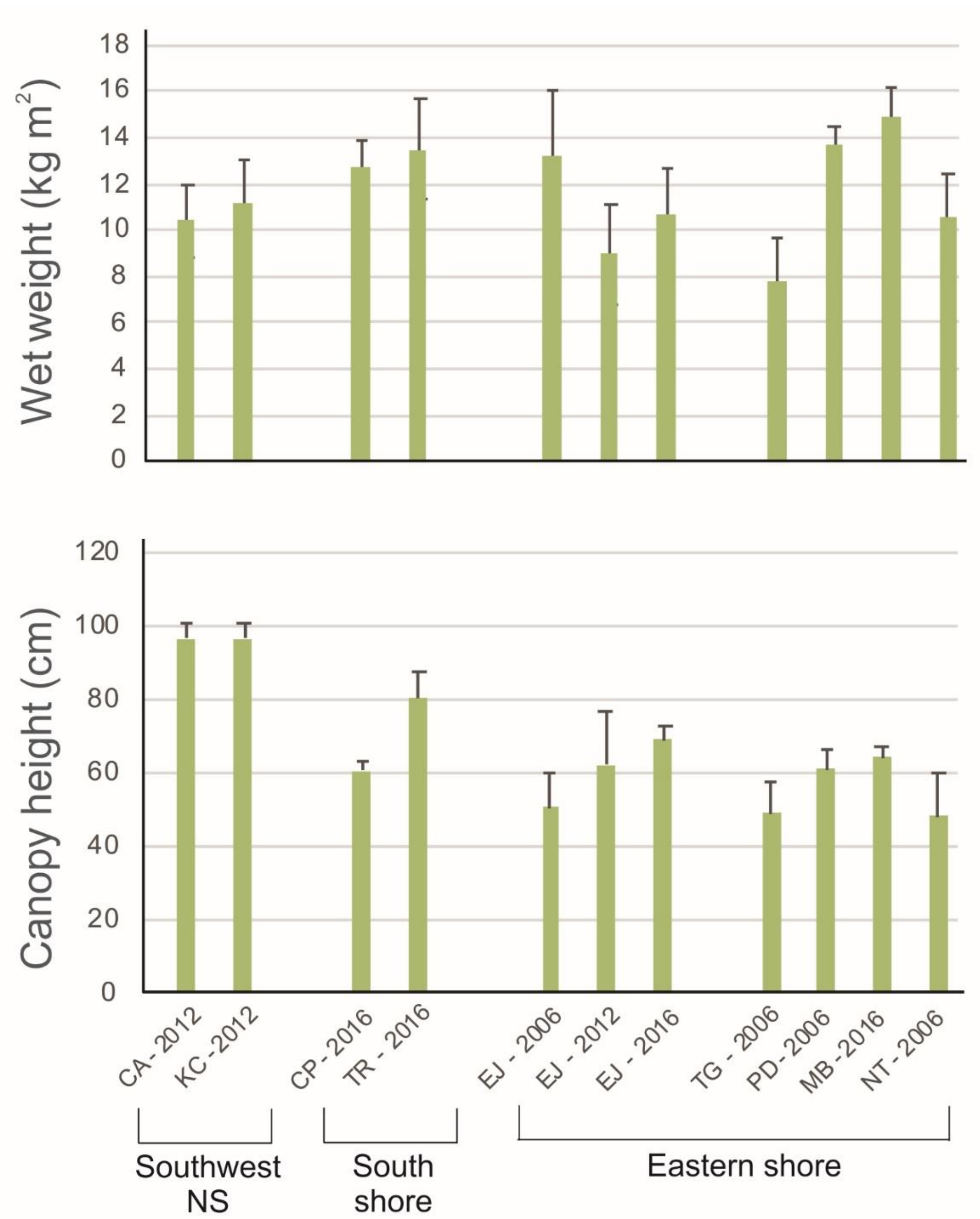

Figure 17. Wet weight and canopy height of Rockweed (Ascophyllum nodosum) from sites in Nova Scotia's South Shore and Eastern Shore. Sites were sampled in 2006, 2012, and 2016, but only East Jeddore was sampled in every year. EJ = East Jeddore; NT = Necum Teuch; PD = Port Dufferin; TG = Tangier; CA = Central Argyle; KC = Kelly's Cove; MB = Mushaboom; TR = Thomas Raddall; CP = Covey's Point. Data from Schmidt et al. (2011), Kay et al. (2016), Lotze et al.[6]

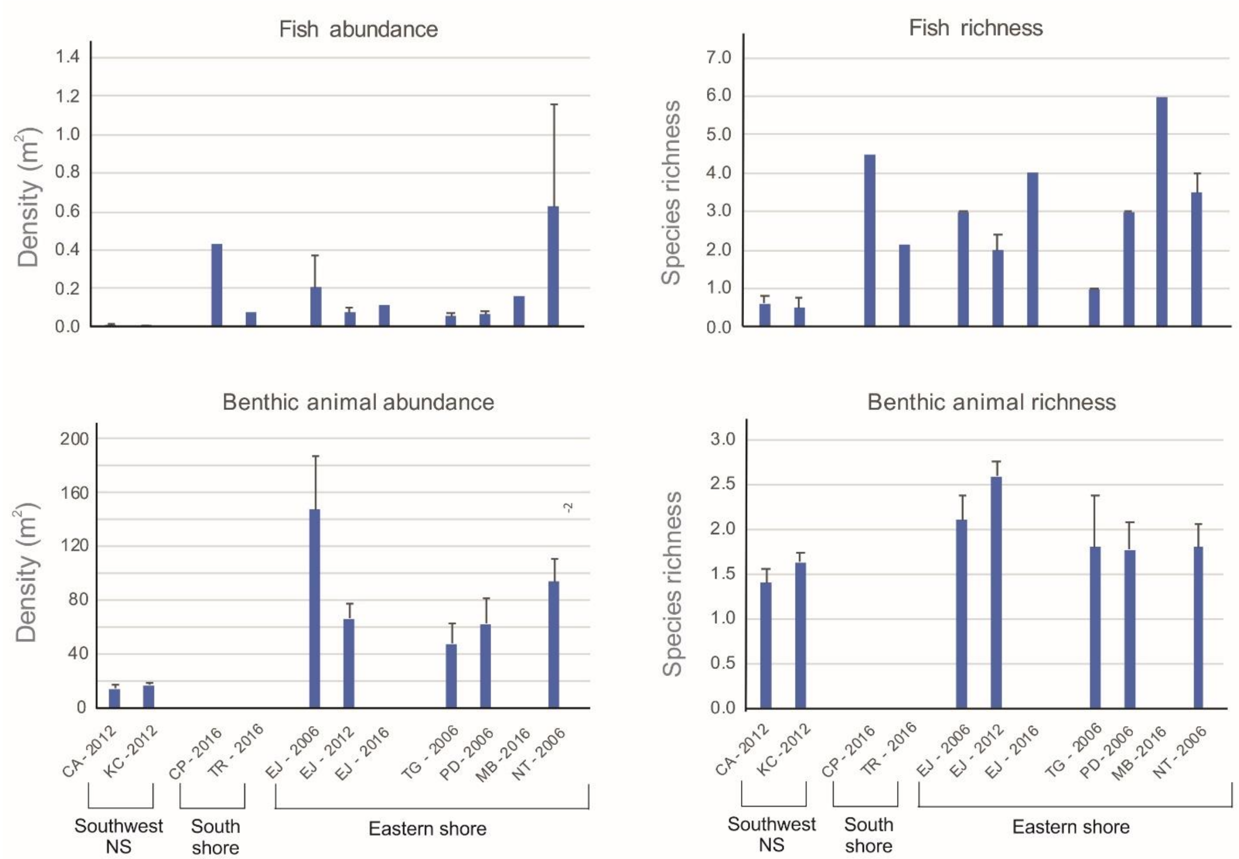

Figure 18. The density and species richness of fish and benthic animals associated with Rockweed (Ascophyllum nodosum) beds in southern Nova Scotia and the Eastern Shore. Richness and abundance tends to be greater in the Eastern Shore. Data from Schmidt et al. (2011), Kay et al. (2016), Vercaemer et al. (2018), and Lotze et al. (unpublished).

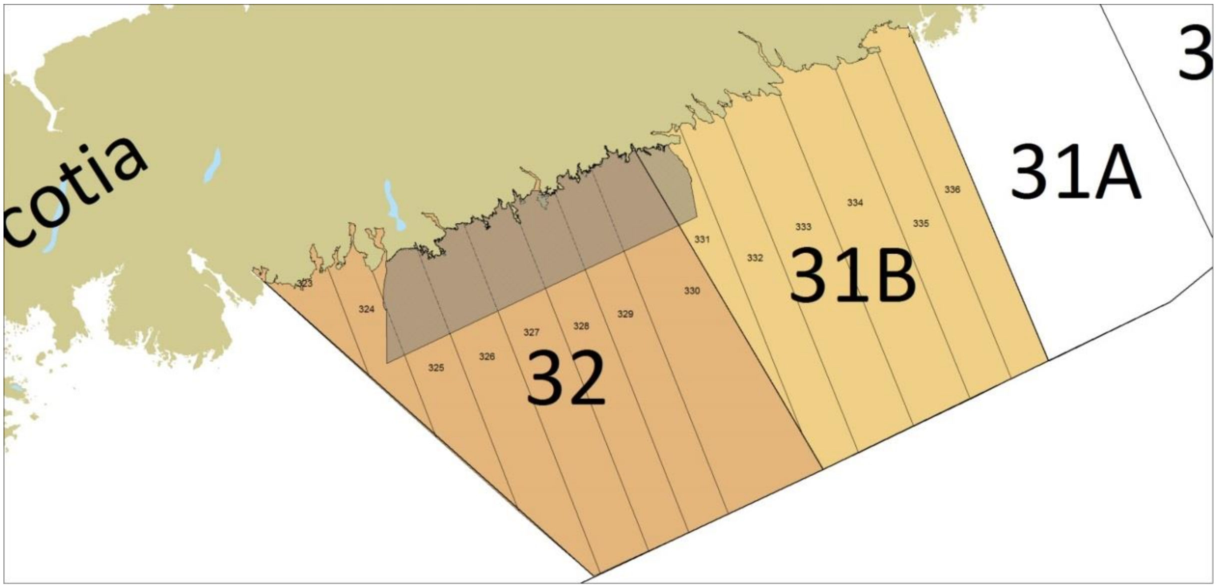

Figure 19. Lobster Fishing Areas (LFAs) 32 and 31B in Nova Scotia and a polygon showing the western portion of the Eastern Shore Islands study area boundary. Most of the Eastern Shore Islands study area is found within LFA 32.

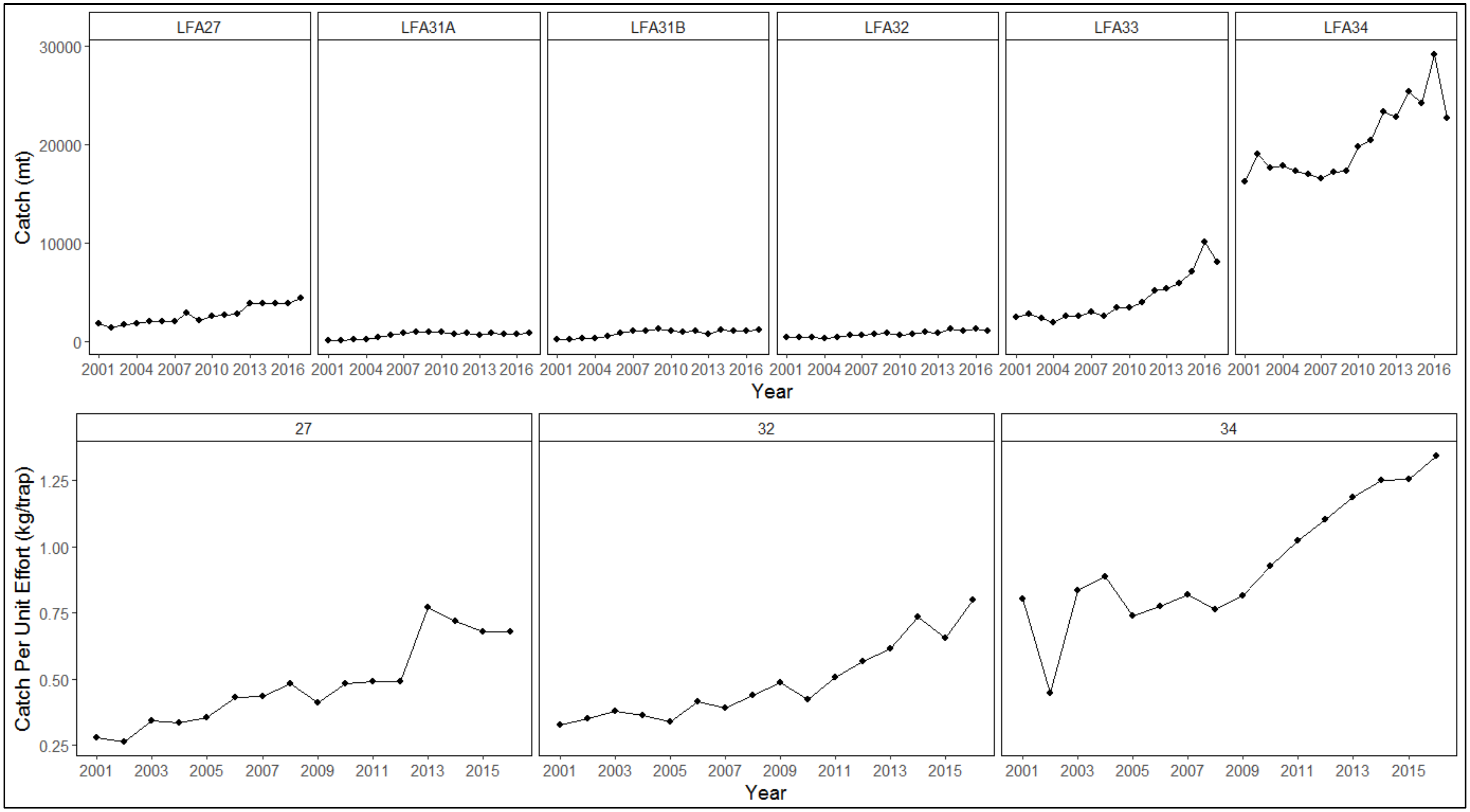

Figure 20. The top panel shows landings for Lobster Fishing Areas (LFAs) 27, 31A, 31B, 32, 33, and 34 for 2001–2017. The bottom panel shows Catch Per Unit Effort (CPUE) for LFAs 27, 32, and 34 from 2001–2016. While trends in catch are slighlty increasing in LFAs 31 and 32, which overlap with the Eastern Shore Islands, these landings are an order of magnitude smaller than LFA 34 and are substantially lower than LFA 27, with CPUE similar between LFAs 32 and 27.

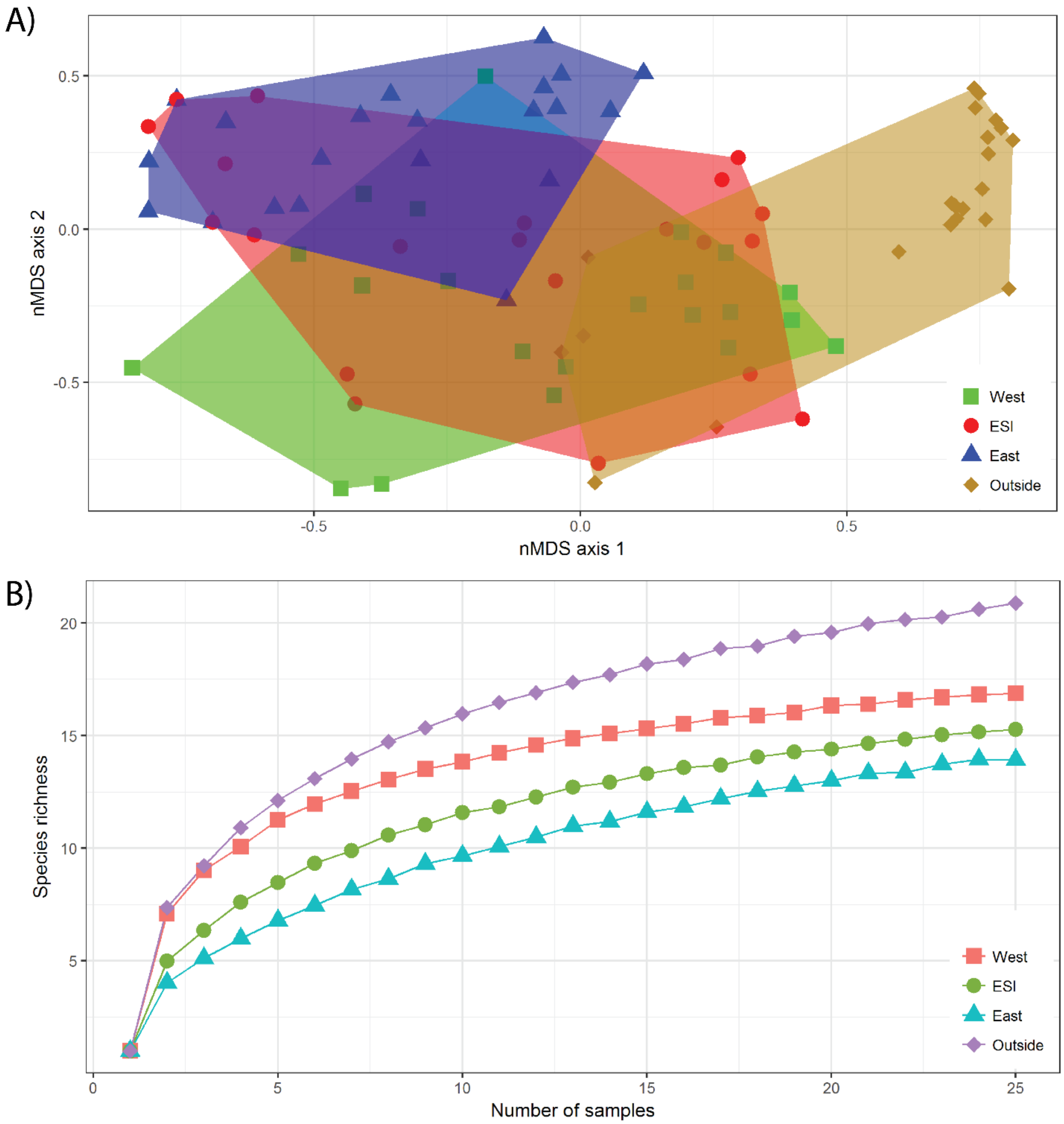

Figure 21. A) A non-metric multidimensional scaling plot of marine fish communities. Data aggregated among regions for each year of sampling (1995:2016). Plot shows significant overlap between coastal areas, with some definition between the offshore and coastal fish assemblage. B) Rarefaction curves of marine fish species. Estimates of species richness derived from 1000 bootstrap iterations. Analyses for both panels are derived from presence-absence data from the FSRS 4VsW sentinel survey aggregated to the coastal zone, east and west of the Eastern Shore Islands AOI and those samples from depths greater than 100 m, outside the coastal planning area.

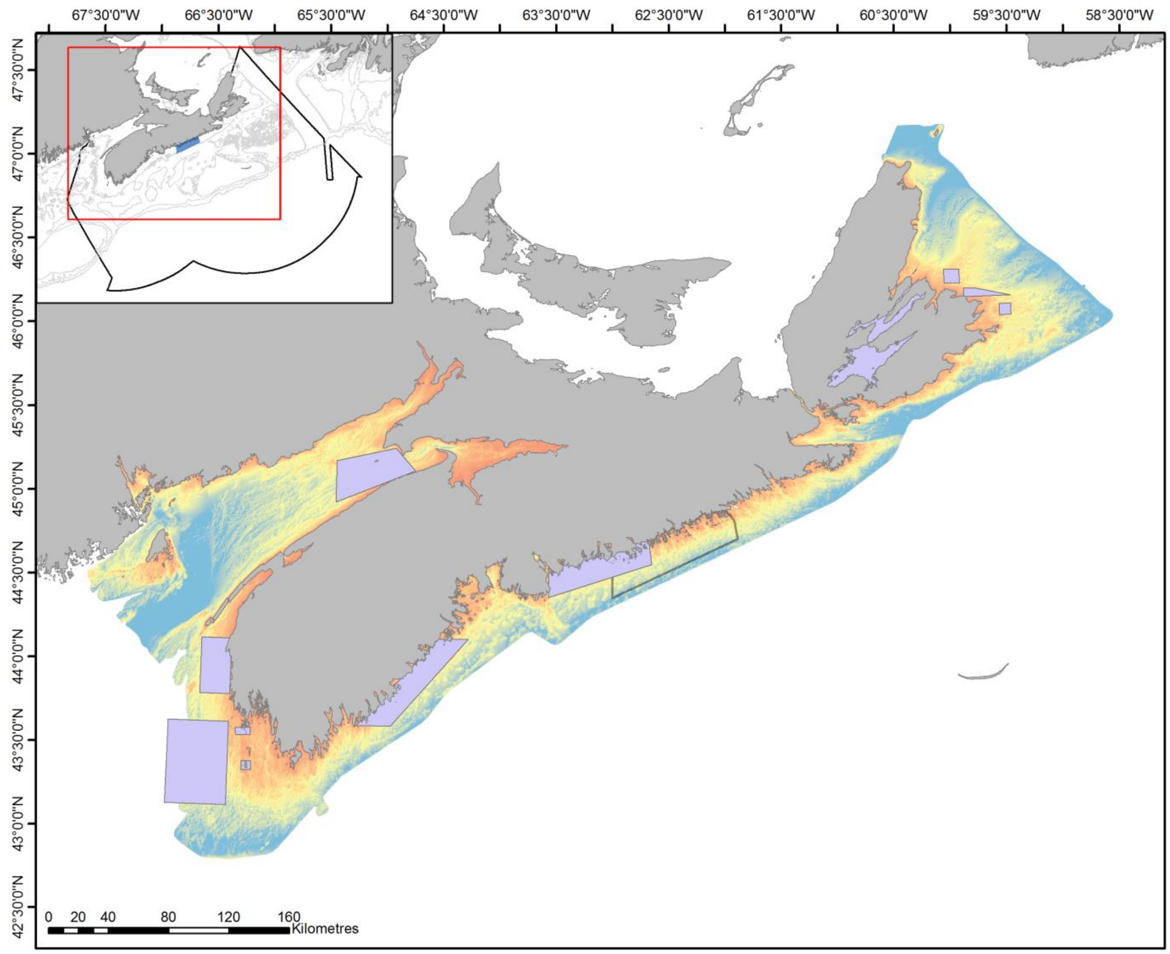

Figure 22. Known spawning areas (shaded polygons) for Atlantic Herring (Clupea harengus) in the Maritimes Region (DFO 1999).

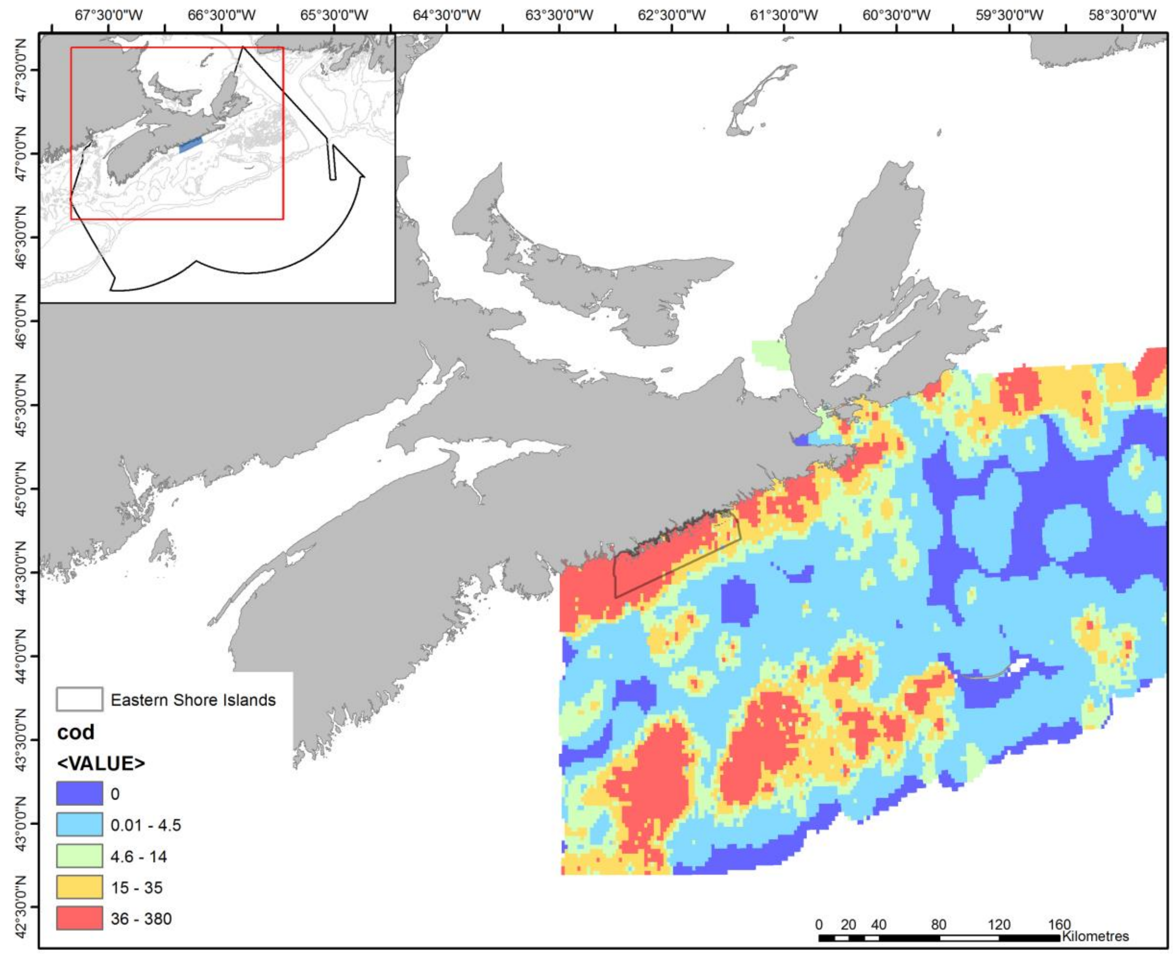

Figure 23. Atlantic Cod (Gadus morhua) biomass distribution based on 4VsW Sentinel Survey data shows a high biomass within the Eastern Shore Islands area. This biomass is based on all years of the Sentinel Survey and does not necessarily reflect the continued decline of Cod in the area (see Figure 24).

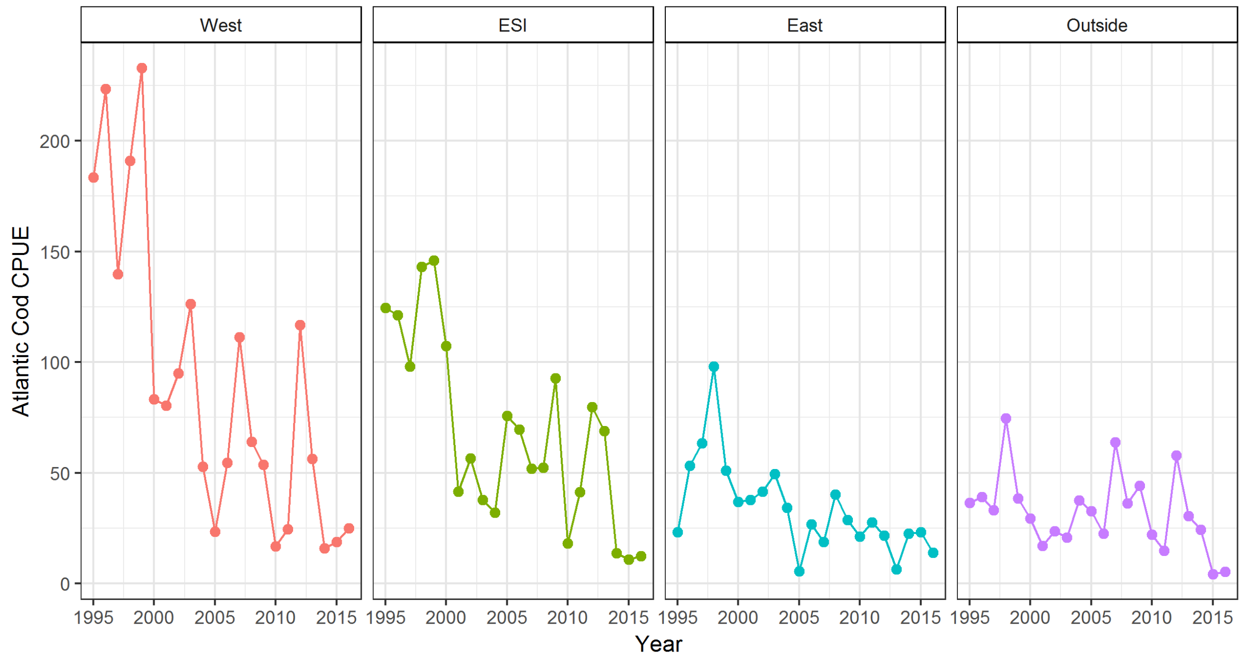

Figure 24.Catch per unit effort (CPUE) of Atlantic Cod (Gadus morhua) from the 4VsW Sentinel Survey. Landings are split into the Eastern Shore Islands AOI, coastal areas to the east and west of the AOI, and offshore landings. A general decline in CPUE is shown.

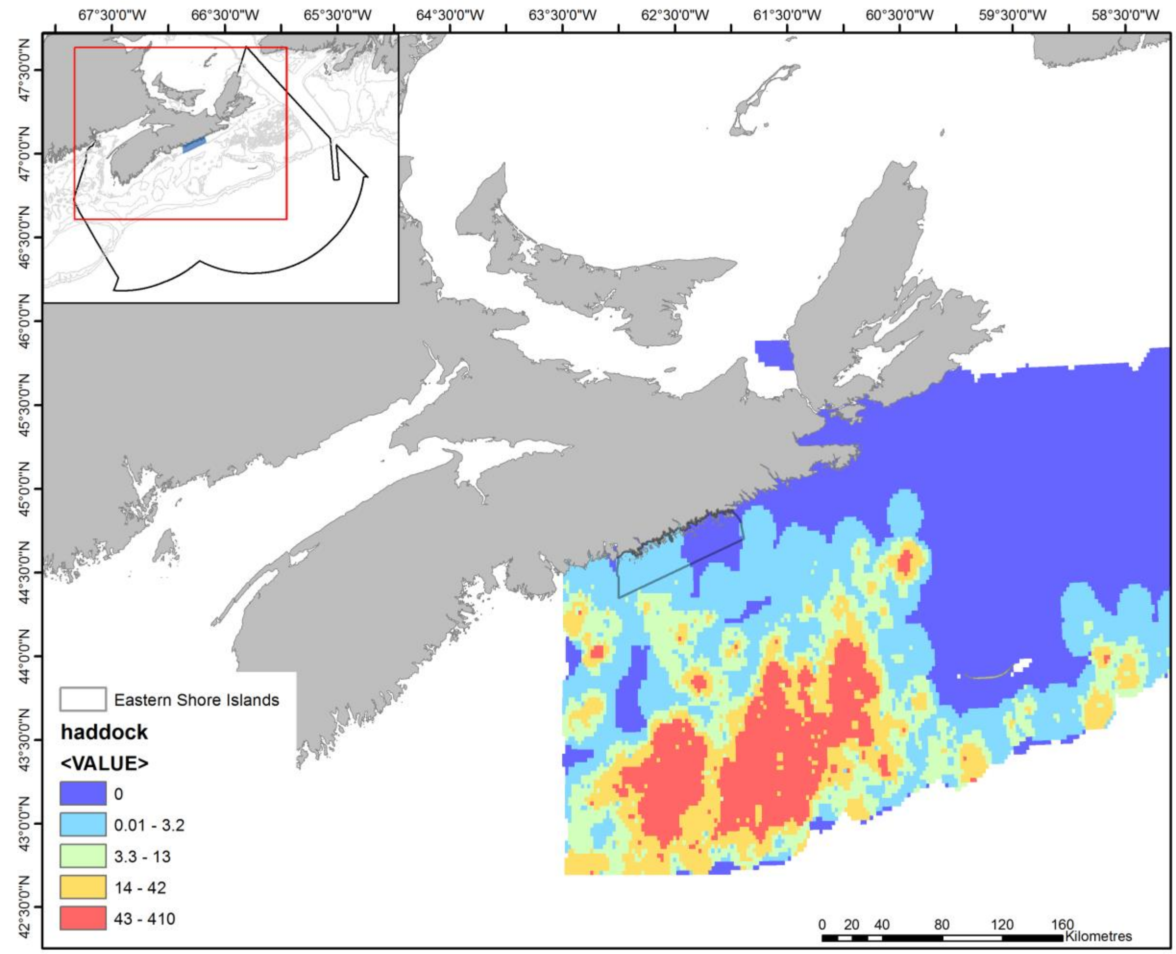

Figure 25. Haddock (Melanogrammus aeglefinus) biomass distribution based on 4VsW Sentinel Survey data shows low adult biomass within the Eastern Shore Islands area relative to offshore areas. These biomass values are based on all years of the Sentinel Survey and may not reflect patterns across individual years.

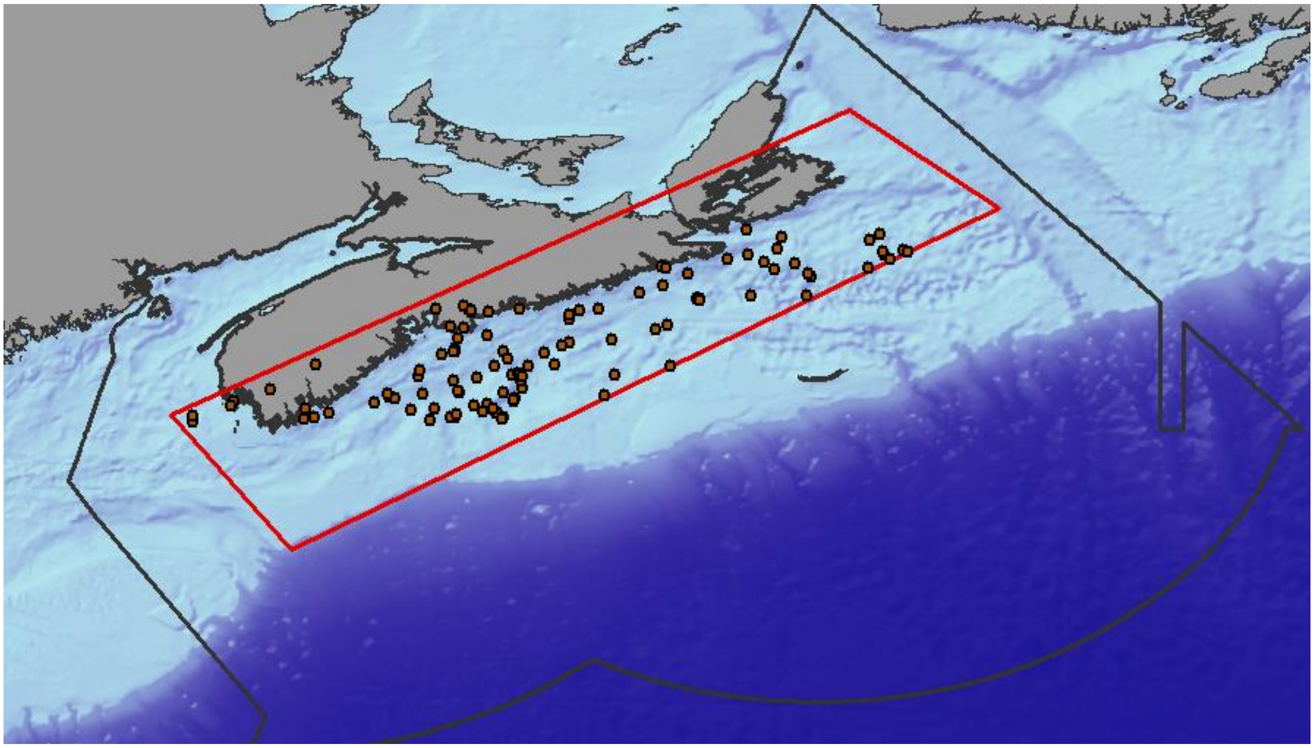

Figure 26. Cetacean and sea turtle sightings along the Scotian Shelf since 2007 from the MarWhalesightings database (MacDonald et al. 2017).

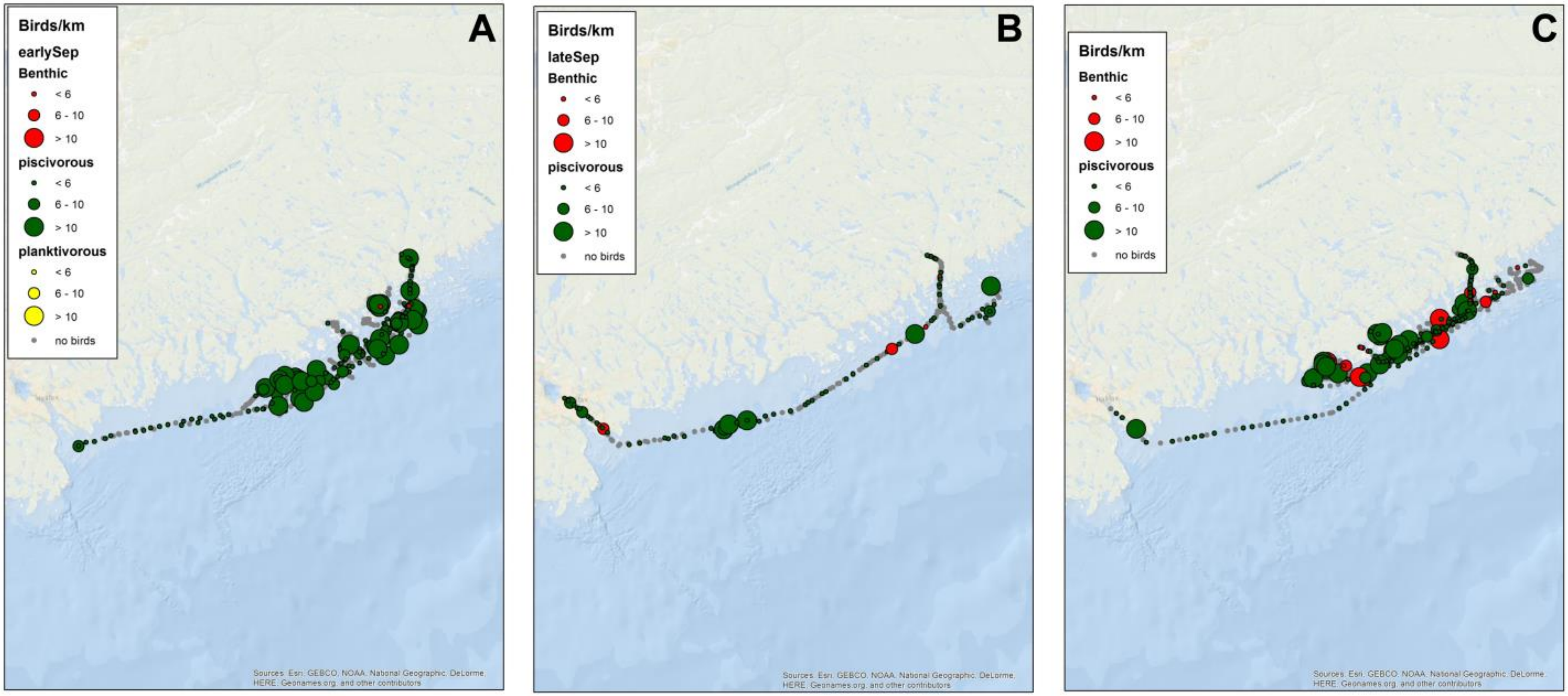

Figure 27. Observations of benthic (red) and piscivorous (green) birds from Halifax to the Eastern Shore Islands observed in early September (A), late September (B), and October (C) in 2017.

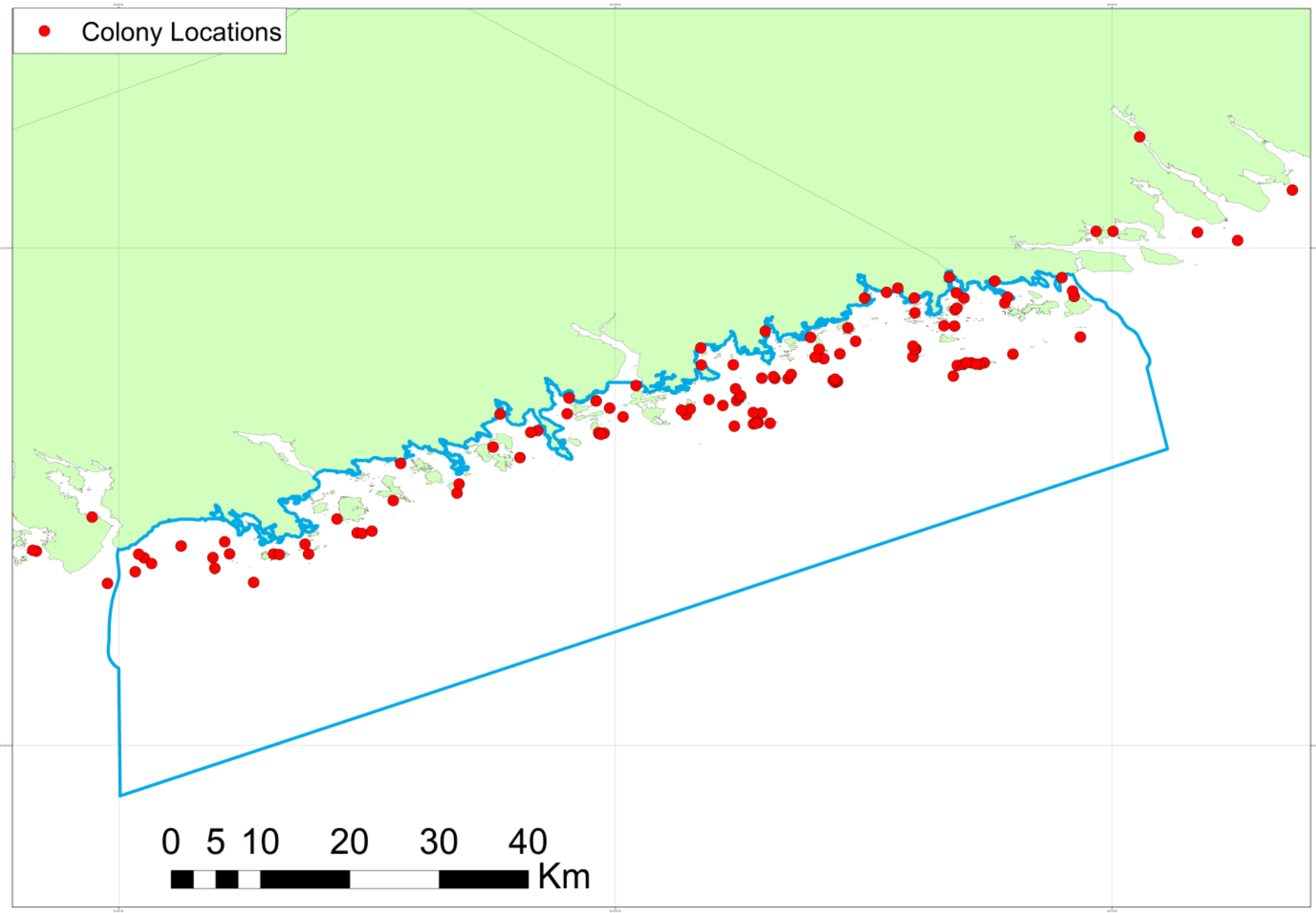

Figure 28. Colony locations for all species of marine birds in the Eastern Shore area observed from 1960 to 2010. A large number of colonies are located on nearshore and fringing islands.

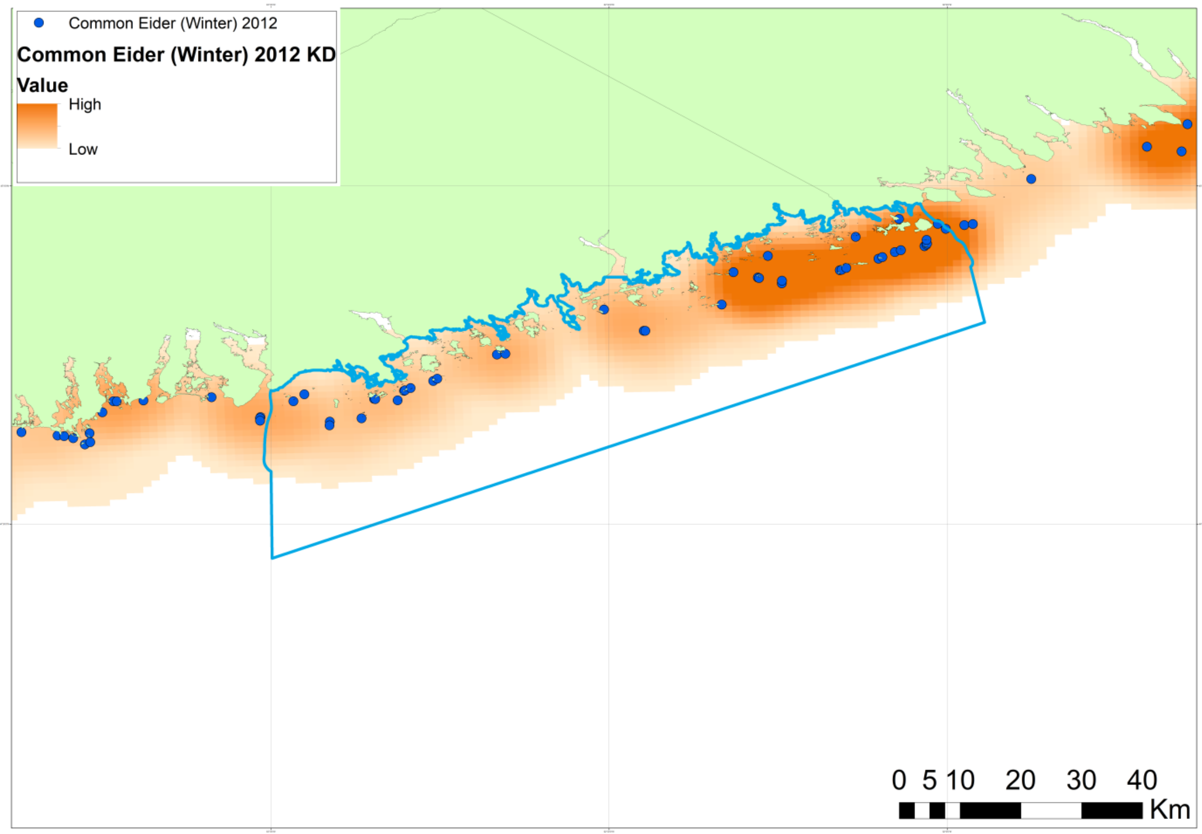

Figure 29. Kernel density estimates of Common Eider (Somateria mollissima) overwintering habitat. Points show the locations of observations, with flock sizes ranging from 1 to 113 individuals.

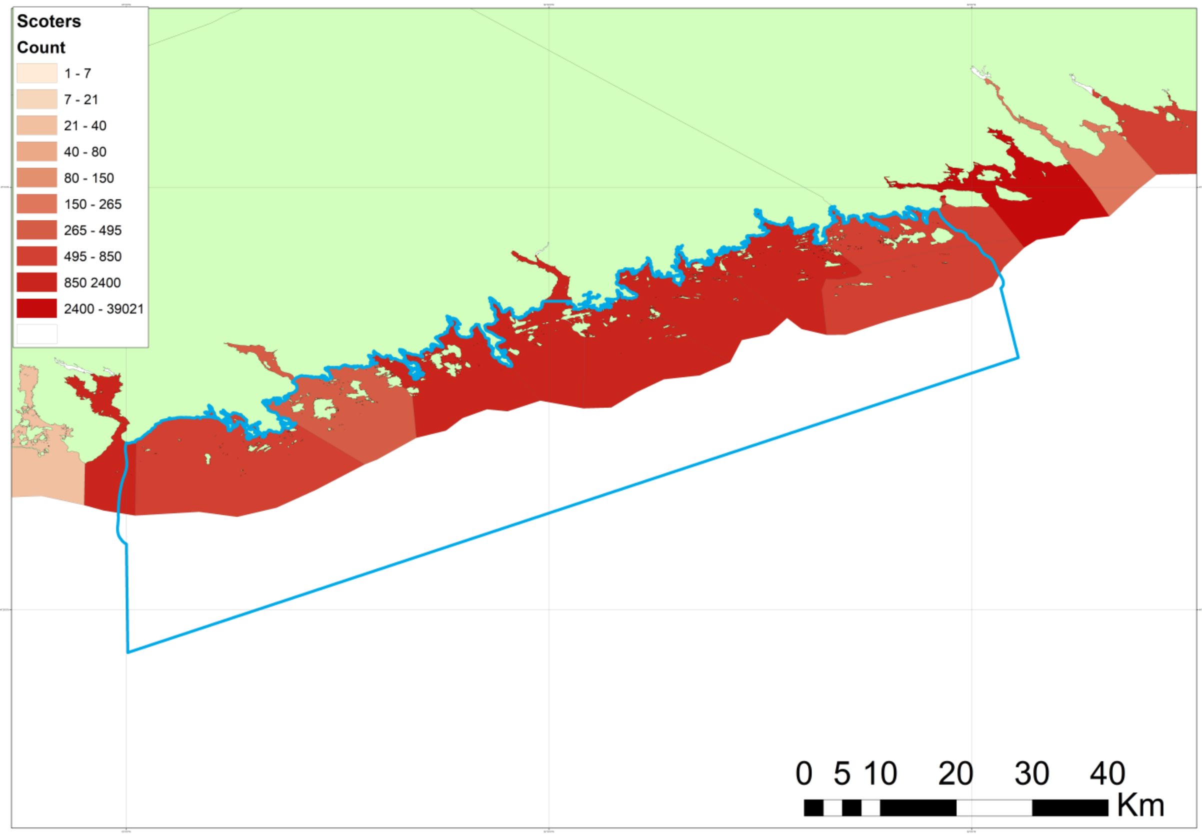

Figure 30. Survey counts of scoters (Melanitta spp.) observed in the Eastern Shore Islands. The counts shown are the maxima for 1960–2008.

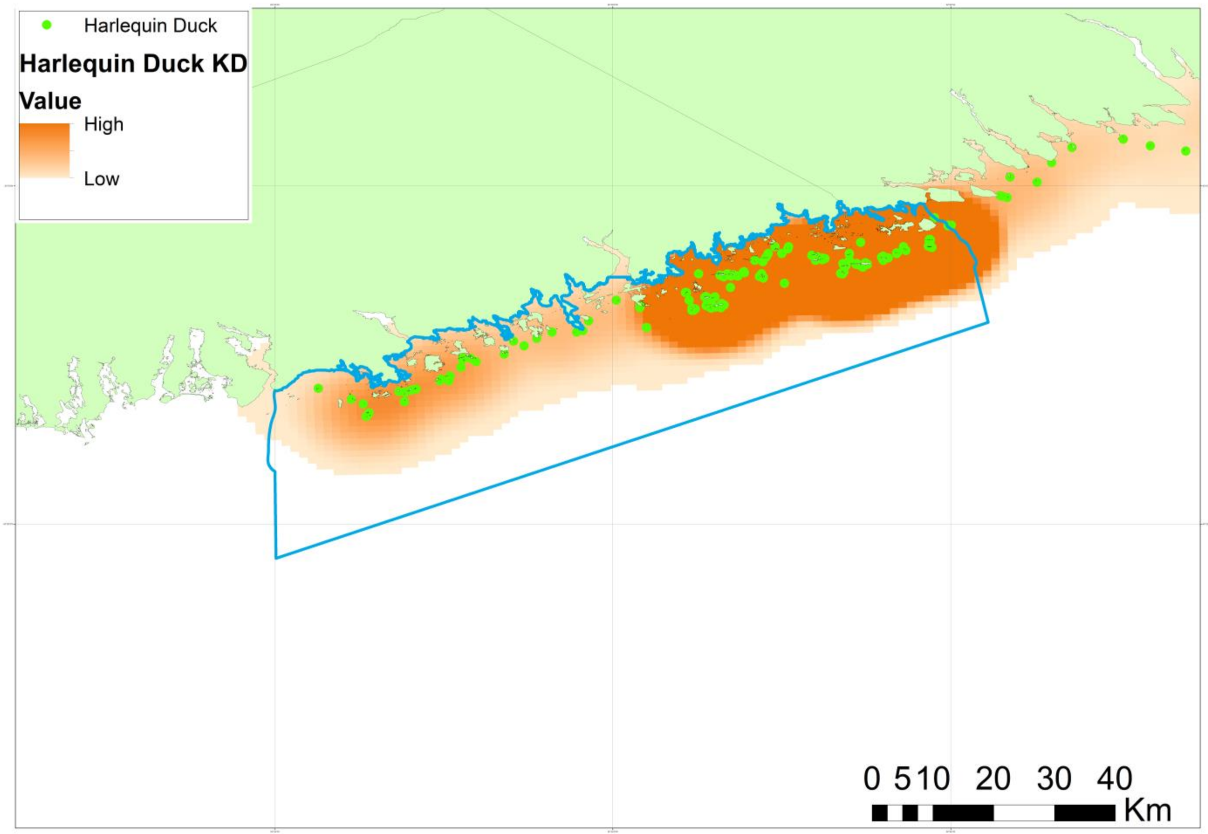

Figure 31. Kernel density estimates of Harlequin Duck (Histrionicus histrionicus) overwintering habitat. Points show the locations of observations, with flock sizes of 0–85 individuals.

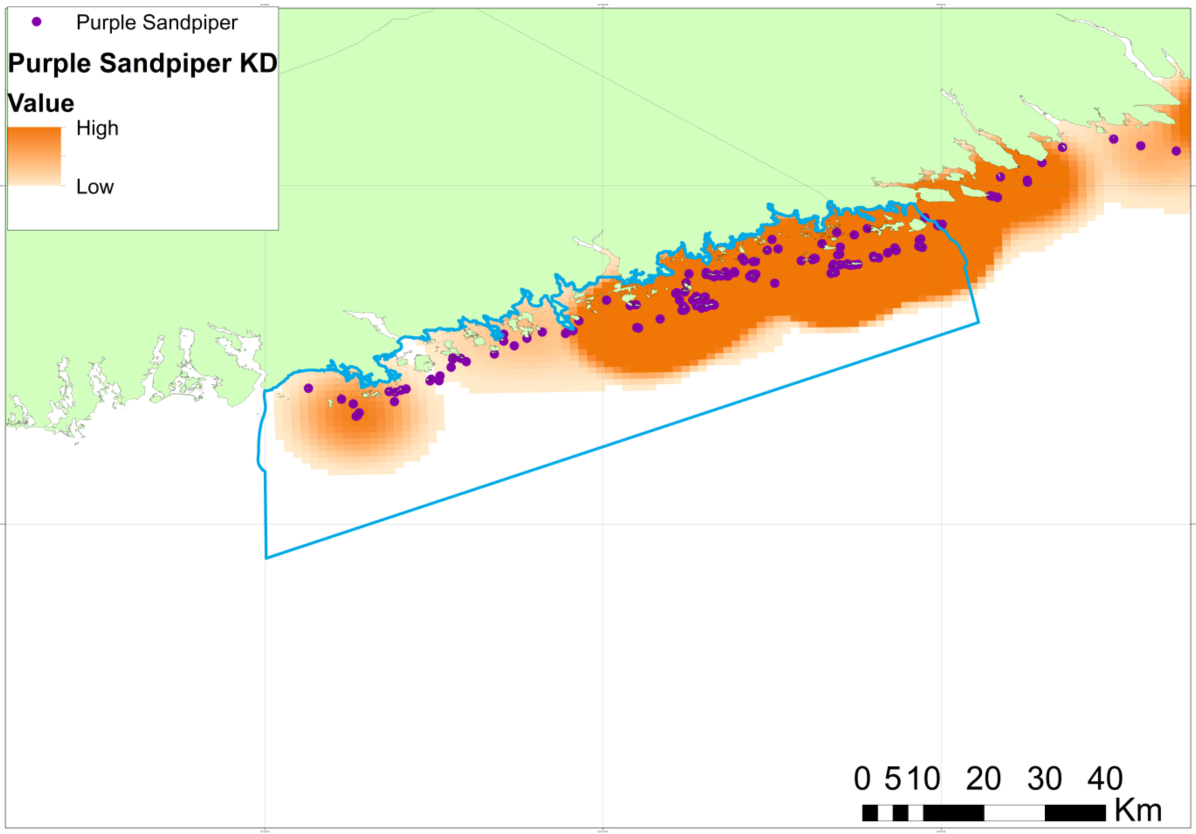

Figure 32. Kernel density estimates of Purple Sandpiper (Calidris maritima) overwintering habitat. Points show the locations of observations, with flock sizes of 0–350 individuals.

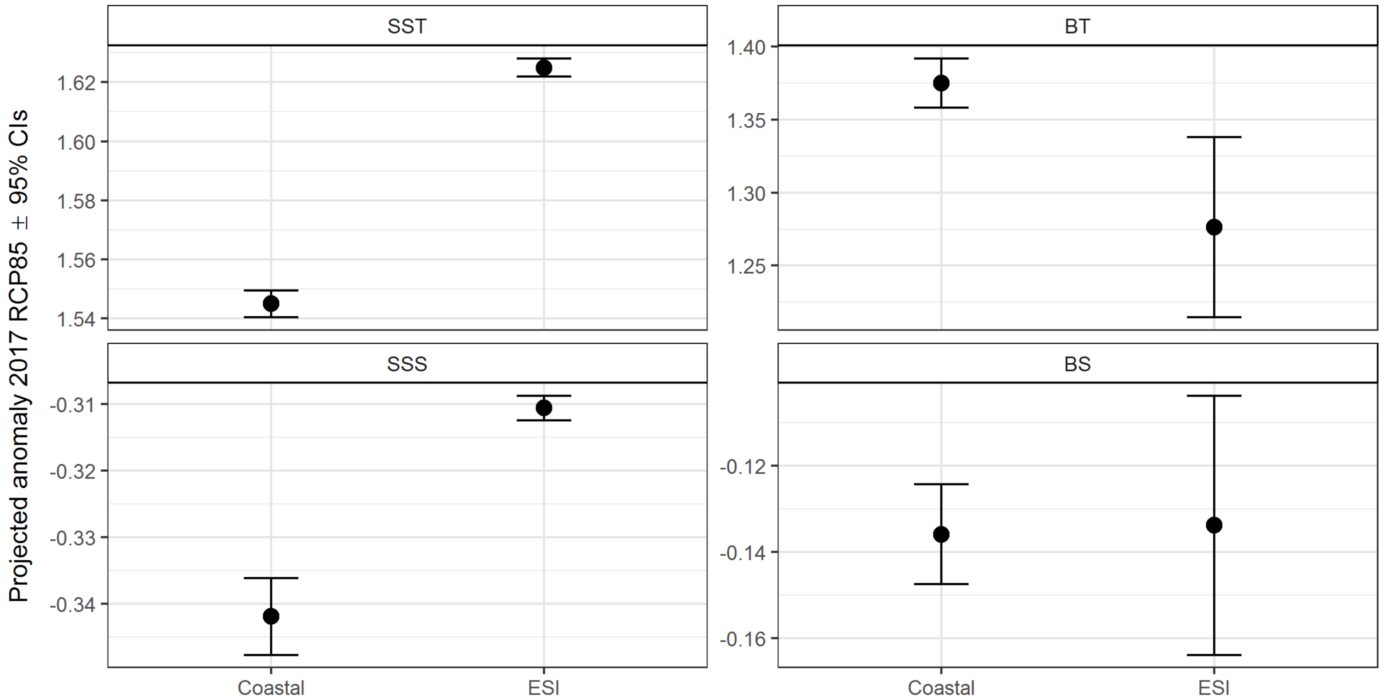

Figure 33. Summaries of 2075 climate projections for the Eastern Shore Islands Area of Interest and the coastal MPA planning area (Coastal). Data are presented as anomalies from current climatology for temperature—Sea Surface Temperature (SST) and Bottom Temperature (BT), and salinity—Sea Surface Salinity (SSS) and Bottom Salinity (BS), modelled at the surface and bottom of the water column.