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Maritimes Region

Canadian Science Advisory Secretariat
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BIOPHYSICAL AND ECOLOGICAL OVERVIEW OF THE EASTERN SHORE ISLANDS AREA OF INTEREST (AOI)

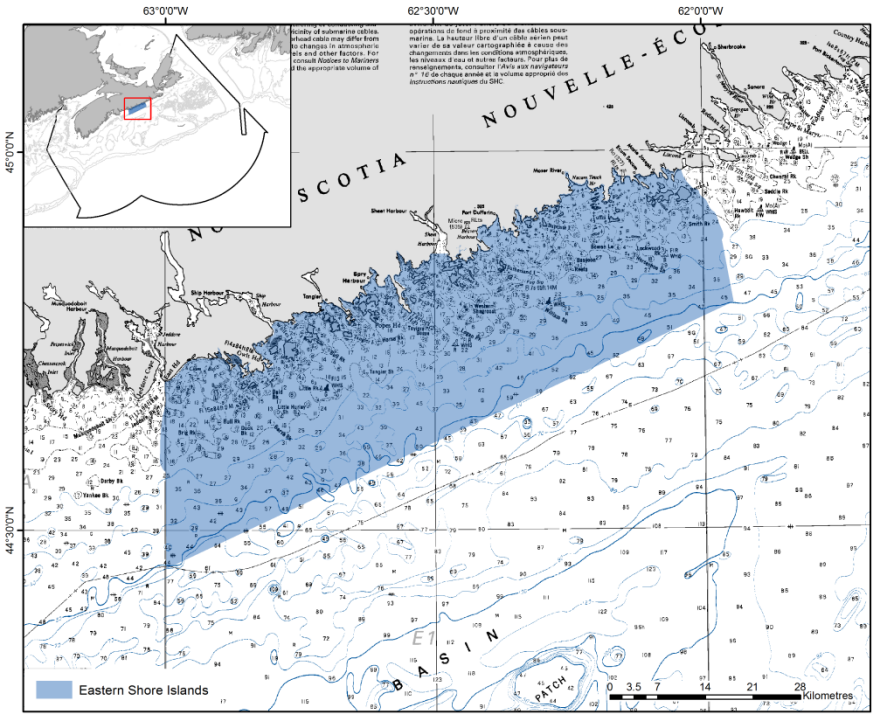

Figure 1. Eastern Shore Islands Area of Interest (AOI; shaded blue) within the Maritimes Region (inset). The AOI boundary is not final, is subject to change, and does not necessarily reflect a proposed Marine Protected Area (MPA) boundary. Basemap: Canadian Hydrographic Service nautical chart 4013 (not to be used for navigation).

Context:

The Government of Canada has agreed to a suite of international biodiversity conservation goals and targets (the Convention on Biological Diversity's 2011–2020 Strategic Plan for Biodiversity) and adopted complementary domestic 2020 Biodiversity Goals and Targets for Canada. Both international and domestic targets (Aichi Target 11 and Canada's Target 1) call for the conservation of 10% of coastal and marine areas by 2020.

The designation of new Marine Protected Areas (MPAs) in Canadian waters has been identified as one part of the national strategy to meet these targets. Under the Oceans Act, Fisheries and Oceans Canada (DFO) is authorized to provide protection to areas of the oceans and coasts through the establishment of MPAs, where the identification of an Area of Interest (AOI) is the first step in this process.

The identification of the Eastern Shore Islands AOI for potential MPA designation in the Maritimes Region was first informed by:

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- *the identification of Ecologically and Biologically Significant Areas (EBSAs; Hastings et al. 2014), which are areas of especially high ecological or biological significance where a greater risk aversion is required in the management of human activities; and*
- *analysis of information at the bioregional scale for the identification of areas that could contribute to MPA network design and/or targets.*

Following the conclusion of a regional site selection process, the Eastern Shore Islands was identified as an AOI for potential MPA establishment within the Maritimes Region. Key ecological features proposed for this area as part of the site selection process were identified as high naturalness; unique geomorphology; biogenic habitat including eelgrass, kelp, and salt marsh; important habitat for several fish species including Atlantic Salmon (Endangered – COSEWIC), Atlantic Cod (Endangered – COSEWIC), and White Hake (Threatened – COSEWIC); an Atlantic Herring spawning area; and significant concentrations of marine birds.

The Oceans Management program of DFO has requested DFO Science provide advice and supporting document(s) through this Canadian Science Advisory Secretariat Regional Peer Review to inform the establishment of this AOI as an MPA. A traditional knowledge study for Eastern Shore Islands will be undertaken separately in 2018.

This Science Advisory Report is from the March 20–21, 2018, Biophysical and Ecological Overview of the Eastern Shore Islands. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule *as they become available.*

SUMMARY

Physical, Geomorphological and Habitat Features of the Eastern Shore Islands

- The Eastern Shore Islands Area of Interest (AOI) extends from Clam Bay near Jeddore Harbour to Barren Island near Liscomb Point, from the low tide line to the 100 m isobath, roughly 25 km from the mainland in the Scotian Shelf bioregion. The AOI includes the nearshore waters surrounding hundreds of islands on the eastern shore of Nova Scotia, many of which are protected through provincial and private conservation efforts.
- The density of islands in the Eastern Shore is three times greater than any other stretch along the Scotian Shelf (1.4 islands per kilometre of coastline). In association with this dense archipelago, a diversity of intertidal habitats are found within the AOI, including rocky and sandy beaches, cliffs, mud flats, and a mix of subtidal substrate types.
- Sea surface and bottom temperatures of waters in the AOI are colder than the Scotian Shelf south of Halifax. These colder temperatures likely have direct impacts on species composition, including limiting invasive species typically introduced from warmer, southern latitudes. The relatively cold water in this region is expected to persist into the future, with projected temperature anomalies lower than other coastal areas in Nova Scotia.
- Surficial geology of the AOI is bedrock overlaid by a mix of thin mud, sand, gravel, cobble, and boulder substrates, which is comparable to other coastal areas in the bioregion. However, the frequency of broad and deep glacially-excavated channels with expansive sand patches is uniquely high within the AOI.
- The AOI is comprised of a heterogeneous mosaic of physical and biological benthic habitat patches, which vary approximately every 400 m across all depths. The scale of these transitions among habitat patches are unique relative to other surveyed areas, such as Sambro Ledges, which has a patch scale of approximately 5 km at depths greater than 30 m, and the Port Joli area, which is predominantly inshore sandy habitat surrounded by rocky patches.

The Eastern Shore Islands as a Relatively Natural Ecosystem

- The Eastern Shore Islands remain highly natural as a result of low population density and correspondingly low human impacts, in terms of pollution and coastal development, relative to areas near Halifax, St. Margarets Bay, and the South Shore.
- Fewer aquatic invasive tunicate species (1–2 species annually) are found at monitoring stations within the AOI compared to Cape Breton, the South Shore, and the Bay of Fundy (3–4 species) and are observed at lower densities (0–50% vs. 25–100% plate cover).
- Eelgrass (*Zostera marina*), Rockweed (*Ascophyllum nodosum*), salt marsh (*Spartina* spp.), and kelp beds found throughout and adjacent to the AOI provide important habitat and food for invertebrates, fishes, and marine birds. Various invertebrates, including crabs and American Lobster (*Homarus americanus*), use Rockweed, Eelgrass, and kelp as shelter from predators, and have been found with Rockweed in their stomachs. The diversity of invertebrates associated with Eelgrass and Rockweed in this area is greater than study areas on the South Shore and in the Gulf of St. Lawrence. Juvenile Atlantic Cod (*Gadus morhua*) and Pollock (*Pollachius virens*) use Eelgrass and Rockweed as nurseries and shelter from predators.
- Common Eider (*Somateria mollissima*) ducklings, especially those too young to dive, feed primarily on invertebrates associated with the floating canopy of submerged Rockweed. Eelgrass and seaweed also provide herring with a suitable spawning substrate to attach their eggs.

Significant Fish and Invertebrate Species

- Invertebrates that provide biogenic habitat, including sponges, anemones, and native tunicates, are widespread but sparse within the AOI.
- American Lobster is a commercially significant species in this area. The AOI overlaps with Lobster Fishery Areas (LFAs) 32 and 31B. Recruitment, measured as the number of sublegal sized lobster per standardized trap from the Fishermen and Scientists Research Society (FSRS), shows slight increases from 1999 to 2016 in both LFAs. This increased recruitment coincides with increased landings over this time period.
- Diadromous fishes including Atlantic Salmon (*Salmo salar*), American Eel (*Anguilla rostrata*), sea run Brown Trout (*Salmo trutta)* and Brook Trout (*Salvelinus fontinalis*), River Herring (*Alosa pseudoharengus* and *A. aestivalis*), Atlantic Smelt (*Osmerus mordax*), and Sea Lamprey (*Petromyzon marinus*) make use of the coastal zone of the AOI, through little is known about this temporal and spatial usage.
- Atlantic Salmon from the Southern Upland Designatable Unit are designated endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) following dramatic declines in abundance over the past several decades. This species is culturally significant to local communities and is of historical socioeconomic importance. Southern Upland Atlantic Salmon spawn in a number of rivers that flow into the AOI. Juvenile salmon inhabit coastal areas adjacent to these rivers in May and June. Adult salmon frequently visit the estuaries within the AOI to check for ideal spawning conditions, and may be present within the AOI year-round, either feeding or migrating through the AOI between the rivers and open ocean.
- Many rivers in the Southern Upland region have undergone some degree of acidification, which has been caused by a combination of acid rain, leaching from the underlying bedrock, and indirect and direct effects of historical gold mining.

- Atlantic Herring (*Clupea harengus*) are an ecologically and commercially significant species in Atlantic Canada. Atlantic Herring spawning has been recorded in the western portion of the AOI, which is part of the Eastern Shore spawning area. The Eastern Shore spawning area (4Wk) is considered to be of equal importance to the other major spawning area, Little Hope (4Xo), to the coastal Nova Scotia spawning component. Atlantic Herring exhibit strong homing fidelity to their spawning grounds, where they deposit their eggs onto gravel, cobble, small boulders, or submerged aquatic vegetation.
- Atlantic Cod are historically a commercially important species on the Scotian Shelf. Cod are more abundant within the AOI and coastal zone in comparison to areas offshore beyond the boundaries of the AOI, based on the 4VsW Sentinel Survey. Though directed fisheries for Cod in the Eastern Scotian Shelf have been under moratorium since 1993, Catch Per Unit Effort (CPUE) reported from the 4VsW Sentinel Survey has steadily declined for the past 20 years for both inshore and offshore areas.
- Historically, spawning of Haddock (*Melanogrammus aeglefinus*) was observed in coastal waters. In the vicinity of the AOI, Jeddore Harbour and the area between East Head and Taylor Head were identified as juvenile Haddock areas. These Haddock areas were previously more extensive and contained more fish. There is currently not sufficient evidence to suggest the Eastern Shore Islands is an important area for Haddock.

Marine Mammals

- There are no recorded observations of cetaceans within the AOI in the DFO MARWhaleSightings database over the past decade; however, this does not necessarily mean that these animals do not use this area, but rather may not have been reported or observed. Harbour Porpoise (*Phocoena phocoena*) are expected to occur within the AOI, as this species is common in coastal areas.
- Harbour Seals (*Phoca vitulina concolor*) are present within the AOI and two breeding colonies of Grey Seal (*Halichoerus grypus*) exist on Bowen's Ledge and on White Island, both situated off Ecum Secum. Grey Seal surveys occur every 3 to 10 years and pupping has historically been observed on both islands, but not in the most recent survey of Bowen's Ledge in 2016.

Depleted Species

- Several fish, bird, and turtle species known to occur in the study area have been identified by COSEWIC and/or the federal *Species at Risk Act* (SARA) for special protection.
- Endangered species include Atlantic Cod, Atlantic Salmon, Bluefin Tuna (*Thunnus thynnus*), Leatherback Sea Turtle (*Dermochelys coriacea*), Great White Shark *(Carcharodon carcharias*), Piping Plover (*Charadrius melodus*), Roseate Tern (*Sterna dougallii*), and Winter Skate (*Leucoraja ocellata*).
- Threatened species include American Eel (*Anguilla rostrata*), American Plaice (*Hippoglossoides platessoides*), Northern Wolffish (*Anarhichas denticulatus*), Spotted Wolffish (*A. minor*), and White Hake (*Urophycis tenuis*). Species of Special Concern present in the AOI include Atlantic Wolffish (*A. lupus*), Barrow's Goldeneye (*Bucephala islandica*), and Harlequin Ducks (*Histrionicus histrionicus*).
- Of these species, Atlantic Salmon, Atlantic Cod, White Hake, Harlequin Duck, and Roseate Tern are suggested as conservation priorities for the AOI. The AOI is unlikely to be more important than other coastal areas in Nova Scotia for American Eel and migratory visitors

such as Bluefin Tuna, Leatherback Sea Turtle, and Great White Shark. Additional data is required to evaluate the importance of the AOI for Piping Plover; Winter Skate; American Plaice; Northern, Spotted, and Atlantic wolffish; and Barrow's Goldeneye.

Birds

- A diversity of marine bird species utilize the AOI at various times of year for foraging, breeding, as a stopover during migration, and as overwintering habitat, largely as a result of varied, abundant, and predictable marine prey resources. Aggregations of breeding marine birds, including Common Eider and endangered Roseate Tern, are associated with productive feeding grounds and habitats with relatively low predation pressure and low human disturbance within the AOI (i.e., small islands with adjacent productive waters for nesting and rearing young).
- Purple Sandpiper (*Calidris maritima*) and Harlequin Duck, though not local breeders, gather to forage along the numerous exposed rocky shorelines in the AOI. The highest winter foraging concentrations for both species in the Scotian Shelf bioregion occur within the AOI.
- Significant congregations (≥1% of the eastern Canadian population) of several species of marine birds occur within the AOI, including Harlequin Duck, Common Eider, Roseate Tern, and Great Cormorant (*Phalacrocorax carbo*). Other species known to congregate in the AOI include scoters (*Melanitta* spp.), Common Tern (*Sterna hirundo*), Arctic Tern (*Sterna paradisaea*), Great Shearwater (*Puffinus gravis*), Sooty Shearwater (*Ardenna grisea*), Cory's Shearwater (*Calonectris borealis*), Wilson's Storm-Petrel (*Oceanites oceanicus*), and Leach's Storm-Petrel (*Oceanodroma leucorhoa*).
- Since the combined mean maximum foraging range of the three tern species known to nest within the AOI are estimated at 20 ±10 km (mean ± Standard Error [SE]), the foraging area used by breeding adults would be encompassed entirely by the AOI boundaries.

Knowledge Gaps and Uncertainties

- Several ecological attributes that require more comprehensive information (data and description) to better characterize the AOI were identified. These knowledge gaps and uncertainties include:
    - comprehensive censuses of phytoplankton, zooplankton, and ichthyoplankton;
    - information on local oceanography and circulation;
    - information detailing the full spatial distribution of Eelgrass, Rockweed, and kelp beds and the environmental and physical conditions regulating their distribution and ecological status for the entire AOI;
    - temporal usage of Eelgrass, Rockweed, and kelp beds by fish, invertebrates, and birds specific to the AOI;
    - temporal usage of the nearshore coastal habitat by Atlantic Salmon and other diadromous fishes;
    - migratory behaviour of fish, cetaceans, and sea turtles;
    - a detailed biodiversity assessment of invertebrates, including epifauna and meiofauna; and
    - links between the complexity and composition of physical habitats and the associated ecological attributes of the AOI (i.e., species diversity).
- Additional baseline and monitoring information is required to understand, predict, and record how current biological and physical attributes of the AOI may respond to natural and/or anthropogenic disturbances, such as climate change and invasive species.

- Programs such as the 4VsW Sentinel Survey, Aquatic Invasive Species Program, and research programs on seaweed and Eelgrass ecology have provided invaluable baseline data for the AOI and could be data inputs to address some of the identified knowledge gaps and uncertainties.

Ecosystem Vulnerabilities

- Potential vulnerabilities of the area include climate change and its associated effects (i.e., ocean warming and acidification, sea level rise, and changes in species distributions) and anthropogenic activities associated with pollution, overharvest, destruction of the benthic environment, and/or the introduction of invasive species or disease.
- 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. This acidification has negative impacts on salmon growth and development.
- Individual spawning groups of Atlantic Herring within the coastal component are considered vulnerable to overfishing because of their relatively small biomass and close proximity to shore. Studies have also demonstrated that larval Atlantic Herring are sensitive to ocean acidification associated with climate change.
- Eelgrass, Rockweed, salt marshes, and kelp beds are particularly sensitive to eutrophication, turbidity, and climate change. In addition, the invasive bryozoan (*Membranipora membranacea)* threatens kelp through defoliation and has been recorded within the AOI boundaries.

Conservation Priorities

- Based on the best available data, conservation priorities for the Eastern Shore Islands AOI include:
    - the relatively high naturalness;
    - 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);
    - an area of importance for Atlantic Salmon;
    - an Atlantic Herring spawning area;
    - an important habitat for juvenile groundfish including Atlantic Cod, White Hake, and Pollock, provided by estuaries, subtidal Rockweed, Eelgrass, kelp, and rocky substrates; and
    - an important area for nesting, foraging, and migratory marine birds.
- 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.

INTRODUCTION

The Eastern Shore Islands Area of Interest (AOI) extends from Clam Bay near Jeddore Harbour to Barren Island near Liscomb Point, from the low tide line to the 100 m isobath, roughly 25 km from the mainland in the Scotian Shelf bioregion. The AOI includes the nearshore waters surrounding hundreds of islands on the Eastern Shore of Nova Scotia, many of which are protected through provincial and private conservation efforts.

The density of islands in the Eastern Shore is three times greater than any other stretch along the Scotian Shelf (1.4 islands per kilometre of mainland coastline; Hill et al. unpublished report[1]). In association with the dense archipelago, a diversity of intertidal habitats are found within the AOI, including rocky and sandy beaches, cliffs, mud flats, and a mix of subtidal substrate types.

To ascertain the necessary breadth and scope of the various components of the ecosystem to be addressed in a biophysical and ecological overview, and to ensure the accurate consideration of the significance of the AOI to the life histories of those species identified for potential conservation, areas within and adjacent to the Eastern Shore Islands AOI were reviewed. The study area for this biophysical and ecological overview is considered as nearshore coastal waters (<100 m depth) along the east coast of Nova Scotia, ranging between Halifax Harbour and the port of Canso, with a specific focus on the AOI.

The overall objective of the biophysical and ecological overview is to summarize the key biological and physical features of the Eastern Shore Islands AOI as they pertain to potential conservation priorities, subsequent development of conservation objectives, and information for the development of management strategies. Key ecological features of the AOI identified during the MPA network site selection process include:

1. high naturalness;
2. unique and/or rare geomorphology;
3. biogenic habitat, including marine plants and macroalgae;
4. juvenile Atlantic Cod (*Gadus morhua*), Haddock (*Melanogrammus aeglefinus*), and other groundfish habitat;
5. Atlantic Salmon (*Salmo salar*) habitat;
6. Atlantic Herring (*Clupea harengus*) spawning area; and
7. designation as an Important Bird Area, based on significant concentrations of migratory, foraging, and nesting marine birds, including endangered species like the Roseate Tern.

The biophysical and ecological overview addresses information pertaining to the study area including predominant and/or unique physical and biological oceanographic characteristics; predominant, unique, and/or sensitive habitat features; and ecologically, socially/culturally and/or commercially significant species; depleted species; and marine mammals and birds (distribution and abundance of species of interest, and information on various aspects of their biology and ecology). The 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 them are considered. Potential sources of risk to these species are also discussed. Known sensitivities, resilience and recoverability of habitats and species of interest within the study area are identified. Sources of 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, are identified where possible. Additional details on each section of the overview are available in the research document (Jeffery et al. 2018).

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[1] Hill, N., Guscott, B., Neily, T., Green, P., Windeyer, T., Pepper, C., and Currie, D. 2012. Eastern Shore Archipelago: Conservation and scientific Assessment – Field. Studies of a Range of Sea Islands on the Eastern Shore of Nova. Nova Scotia Nature Trust. Unpublished report.

ASSESSMENT

An assessment of the Eastern Shore Islands study area was presented and reviewed based on detailed information contained primarily within the working papers by Jeffery et al. (2018), Vandermeulen (2018), and King (2018), in addition to contributed sections by collaborators from Fisheries and Oceans Canada (DFO), Natural Resources Canada (NRCan), Environment and Climate Change Canada, and Dalhousie University.

Bathymetry

The bathymetry of the AOI varies from 0 m (the coastal low tide line) to 100 m depth. Bathymetry is highly variable within the AOI owing to the diversity and density of islands comprising the archipelago. The LiDAR data was collected in winter 2017 by the Canadian Hydrographic Service to provide high-resolution bathymetry of the Eastern Shore, but only a cursory examination of this data was possible at the time of writing.

Geology

The AOI is comprised of a heterogeneous mosaic of physical and biological benthic habitat patches, which vary approximately every 400 m across all depths. The scale of these transitions among habitat patches are unique relative to other surveyed areas, such as Sambro Ledges, which has a patch scale of approximately 5 km at depths greater than 30 m, and the Port Joli area, which is predominantly inshore sandy habitat surrounded by rocky patches. The Eastern Shore, ranging from Halifax Harbour to Liscomb Harbour, is classified as a highly complex, sheltered coastline (Greenlaw et al. 2013).

New (and updated) surficial and sub-surface geology maps and supporting data in the Eastern Shore area are available (King 2018) characterizing the shallow geology in the Eastern Shore Islands AOI and surrounding study area (processed data provided by NRCan). Surficial and shallow geological attributes may be sufficient for broad-scale generalizations related to habitat associations of species of interest that either interact with the bottom for various life-history processes or prey upon the species that live there (King 2018).

The Eastern Shore inner shelf is characterized by extensive bedrock with patchy till and glacial marine mud, generally capped with sand and gravel. This bedrock is occasionally dissected by glacially cut channels filled with sand and glacially-derived mud, offshore muds (deeper than 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.

Surficial geology of the AOI is bedrock overlaid by a mix of thin mud, sand, gravel, cobble, and boulder substrates, which is comparable to other coastal areas in the bioregion. Boulder and ledge substrates within the AOI provide complex habitat for juvenile fish to avoid predation. However, the frequency of broad and deep glacially-excavated channels with expansive sand patches is uniquely high within the AOI. Similarly the frequency of glacial moraines and drumlins shoreward of the deep-water Eastern Shore Moraine is greater within the AOI compared to coastal areas in the bioregion.

The numerous islands within the AOI restrict barrier beach development and affect mud distribution along the coast of the Eastern Shore. The distribution of muds generally extends seaward to the headlands adjacent to the basins and to areas deeper than is otherwise common (i.e., outside a harbour). Barrier beaches of sand, gravel, and cobble are common west of the study area (e.g., Cow Bay and Cole Harbour), while embayments within the AOI (e.g., Jeddore, Ship, Tangier, Spry, Sheet, Mushaboom, and Beaver harbours) lack barrier beaches. Instead, the bedrock islands provide shelter, permitting mud deposition from offshore

(e.g. drumlins and cliffs) rather than from rivers (Forbes et al. 1991, Stea et al. 1994, King 2018), and creating habitat for seabirds that forage on bivalves.

Oceanographic Conditions

The Nova Scotia Current runs offshore of the Eastern Shore Islands, running southwards on the inner half of the Scotian Shelf (Bundy et al. 2014). This current brings water with relatively lower salinity from the Gulf of St. Lawrence to the Scotian Shelf. Surface currents at the boundaries of this 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, more saline water. Winds are also important through Ekman transport, bringing in offshore deep or surface waters inshore, depending on the direction of the wind (Bundy et al. 2014). These processes permit flushing of coastal bays in conjunction with tides, wind, and estuarine inflows. Diurnal tidal ranges in the AOI boundaries are comparable to the rest of the coastal waters of Eastern Nova Scotia, ranging from approximately 1.0 to 2.50 m (Bundy et al. 2014). The combination of upwelling, currents, and winds introduces and mixes nutrients into the coastal region, playing an important role in phytoplankton blooms in the spring, and providing a key component of the coastal food web.

Sea surface and bottom temperatures are colder in this region than the Scotian Shelf south of Halifax. This colder temperature has direct impacts on species composition, including limiting invasive species typically introduced from warmer, southern latitudes. The relatively cold water in this region is expected to persist into the future, with projected temperature anomalies lower than other coastal areas in Nova Scotia (based on projections to 2075, Representative Concentration Pathways (RCP scenario 8.5; Brickman et al. 2016).

Nutrients (i.e., nitrogen, phosphorus, and silicon) in inshore waters result primarily from an exchange with adjacent coastal waters (Bundy et al. 2014). Inputs from the 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 consistent with global trends and have declined since the 1970s along the Scotian Shelf (Yeats et al. 2010). Oxygen levels are lowest in the fall when water temperatures are high and water mixing is low.

Human Impact Metrics

The Eastern Shore Islands remain highly natural as a result of low population density and correspondingly low human impacts, in terms of pollution and coastal development, relative to areas near Halifax, St. Margarets Bay, and the South Shore. In a recent review of human impact on seagrass ecosystem health, Murphy et al.[2] found minimal impacts from human density, overwater structures, agriculture and aquaculture, and water quality (fecal coliforms), nitrogen loading, and human-altered riparian land in the Eastern Shore Islands relative to the Musquodoboit, Sambro, St. Margarets Bay, and Mahone Bay regions. The invasive species extent (percent cover of study site collection plates) is lowest in the Eastern Shore relative to these same sites and Port Joli on the South Shore (Sephton et al. 2017).

[2] Murphy, G., Wong, M., and Lotze, H. In prep. A human impact metric for conservation management of seagrass ecosystems in Atlantic Canada.

The Eastern Shore region is relatively less polluted than more densely populated areas. Trace metal pollution and petroleum residues are lower in the areas sampled in the AOI relative to Halifax, Sydney, and Pictou harbours. Levels of methyl mercury and arsenic from historical gold mining are relatively low along the Eastern Shore, with the exception of elevated levels of both toxins in Harrigan Cove. However, despite these elevated levels, the bioaccumulation of arsenic in bivalves at Harrigan Cove is low, suggesting that arsenic is not in a bioavailable form in this area (Doe et al. 2017).

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 Fisheries and Oceans Canada (DFO). 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 and ongoing monitoring of the classified area for bacteriological water quality and biotoxins, and posting of signs and patrol and enforcement of the area for compliance.

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 closed as a precaution to minimize public health risk if they are not currently being monitored for water quality or biotoxins, or they are areas that are permanently closed due to ongoing pollution sources. Currently, all CSSP resources are committed to maintaining the classification of existing high- and medium-priority harvest areas. Compliance monitoring in all closed areas continues subject to operational capacity. This compliance monitoring includes vehicle, vessel, and foot patrols, as well as the maintenance of all closure notifications (e.g., signage and electronic communications) by DFO Conservation and Protection fishery officers.

All areas may be subject to temporary shellfish closures as a result of elevated biotoxin levels or pollution associated with significant weather events. The current state of closures in the AOI are posted at DFO's shellfish harvesting and safety webpage.

Depleted Species

Several fish, bird, and turtle species known to occur in the study area have been identified by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and/or the federal *Species at Risk Act* (SARA) for special protection. Endangered species include Atlantic Cod, Atlantic Salmon, Bluefin Tuna (*Thunnus thynnus*), Leatherback Sea Turtle (*Dermochelys coriacea*), Great White Shark (*Carcharodon carcharias*), Piping Plover (*Charadrius melodus*), Roseate Tern (*Sterna dougallii*), and Winter Skate (*Leucoraja ocellata*). Threatened species include American Eel (*Anguilla rostrata*), American Plaice (*Hippoglossoides platessoides*), Northern Wolffish (*Anarhichas denticulatus*), Spotted Wolffish (*A. minor*), and White Hake (*Urophycis tenuis*). Species of Special Concern present in the AOI include Atlantic Wolffish (*A. lupus*), Barrow's Goldeneye (*Bucephala islandica*), and Harlequin Ducks (*Histrionicus histrionicus*).

Of these species, Atlantic Salmon, Atlantic Cod, White Hake, Harlequin Duck, and Roseate Tern are suggested as conservation priorities for the AOI. The AOI is unlikely to be more important than other coastal areas in Nova Scotia for American Eel, Bluefin Tuna, Leatherback Sea Turtle, and Great White Shark, as these species are transient or migratory visitors to the coastal zone. Additional data is required to evaluate the importance of the AOI for Piping Plover; Winter Skate; American Plaice; Northern, Spotted, and Atlantic wolffish; and Barrow's Goldeneye.

Marine Plants and Seaweed

The Eastern Shore contains diverse and abundant marine algae, indicating high productivity (Gromack et al. 2010). Eelgrass (*Zostera marina*), Rockweed (*Ascophyllum nodosum*), salt marsh (*Spartina* spp.), and kelp beds found throughout and adjacent to the AOI provide important habitat and food for invertebrates, fishes, and marine birds. Various invertebrates, including crabs and American Lobster (*Homarus americanus*), use Rockweed, Eelgrass, and kelp as shelter from predators, and have been found with Rockweed in their stomachs (Karnofsky et al. 1989, Vercaemer et al. 2018, Wong et al. 2016). Juvenile Atlantic Cod, Pollock, and other groundfish are known to use rocky substrates, Eelgrass, kelp, and Rockweed as nurseries and refuge from predators (Laurel et al. 2003, Gorman et al. 2009, Gotceitas et al. 1997, McCain et al. 2016). Common Eider (*Somateria mollissima*) ducklings, especially those too young to dive, feed primarily on invertebrates associated with the floating canopy of submerged Rockweed (Hamilton 2001). Eelgrass and seaweed beds also provide Herring with a suitable spawning substrate to attach their eggs.

The presence of Eelgrass and Rockweed along the Eastern Shore has been demonstrated to enhance the overall abundance and diversity of associated flora and fauna (Schmidt et al. 2011) and, specifically, the abundance of several commercially important species (Wong and Dowd 2015, Wong et al. 2016, Vercaemer et al. 2018). Juvenile Atlantic Cod and Haddock are known to use Eelgrass as nurseries (Gotceitas et al. 1997, Laurel et al. 2003) and refuge from predators (Gorman et al. 2009). Marine vegetation, particularly Eelgrass, provides feeding grounds to many marine birds, such as geese, ducks, and the Atlantic Brant (*Branta bernicla hrota*), which feeds almost exclusively on Eelgrass (Hastings et al. 2014). In addition, Eelgrass beds provide important settlement and nursery habitat for young fish, shellfish, and crustaceans (Wong and Dowd 2016).

In contrast to some parts of the Scotian Shelf where Eelgrass is in significant decline, Eelgrass beds of the Eastern Shore Islands, including Jeddore Harbour, Taylor Head, Clam Harbour, Gerard Island (Hill et al. unpublished report[3]), and Gegogan Harbour, seem abundant and stable. Data collected by M. Wong (DFO) and H. Lotze (Dalhousie University) between 2007 and 2017 show stable Eelgrass biomass and shoot densities at False Passage/Cable Island and Taylor Head, comparable to densities recorded at Sambro and Port Joli. Coll et al. (2011) determined that Eelgrass meadows in the Eastern Shore at False Passage and Taylor Head were more resilient to invertebrate and fish species loss than those in New Brunswick and Prince Edward Island, likely owing to the relatively low levels of human impact experienced by these beds.

Significant salt marsh coverages are present in Clam Bay, Clam Harbour, Tangier, Owls Head, Kirby River, Quoddy Harbour, and Marie Joseph Harbour, ranging in size from 0.4–100 Ha. These salt marshes support breeding and nursery habitat for terrestrial, near-shore and migratory birds (Bowron et al. 1999), including dabbling ducks, herons, shorebirds, and some passerine birds, such as Nelson's Sharp-tailed Sparrow (Allard et al. 2014). Salt marshes also provide shelter, foraging and breeding habitat for marine invertebrates, such as shrimp and crabs, and small fish.

[3] Hill, N., Guscott, B., Neily, T., Green, P., Windeyer, T., Pepper, C., and Currie, D. 2012. Eastern Shore Archipelago: Conservation and scientific Assessment – Field. Studies of a Range of Sea Islands on the Eastern Shore of Nova. Nova Scotia Nature Trust. Unpublished report.

In the intertidal zone of Nova Scotia, Rockweed (*Ascophyllum nodosum*) and *Fucus* spp. dominate, as they are both resistant to desiccation. *A. nodosum* is typically found in sheltered waters, whereas *Fucus* spp. is found in more exposed areas. Vercaemer et al. (2018) documented greater Rockweed biomass in Mushaboom relative to sites sampled west of the AOI (East Jeddore and the South Shore). Vercaemer et al. (2018) further demonstrate that fish and invertebrate species richness is up to six times higher within Rockweed beds relative to bare sediments in all sampled sites. Rockweed, despite being characterized by shorter overall growth, shows a higher associated fish and invertebrate species richness and abundance in the Eastern Shore than areas in southern and southwestern Nova Scotia (H. Lotze, unpublished data).

Kelps (*Laminaria digitata, Saccharina* spp., *Alaria esculenta,* among others) are highly productive ecosystem components (Filbee-Dexter et al. 2016) and have an abundant but patchy distribution throughout the AOI (Vandermeulen 2018). Kelps in the region are known to harbour high abundances of mobile and sessile invertebrates in their fronds and holdfast structures (Schmidt and Scheibling 2007, Kelly et al. 2011). The density of American Lobster, for example, was shown to be up to 10 times higher in sites with kelp than in unstructured control sites (Bologna and Steneck 1993). Kelps also form habitat for various fish species, including Cunner (*Tautogolabrus adspersus*), Sculpin (*Myoxocephalus aenus*), Flounder (*Pseudopleuronectes americanus*), Lumpsucker (*Cyclopterus lumpus*), and Rock Gunnel (*Pholis gunnellus;* Lazzari and Stone 2006).

Seaweed (red, green, and brown algae) diversity is generally highest the subtidal zone. Red calcareous (coralline) crusting algal species are abundant in the Eastern Shore Islands (Vandermeulen 2018), and they play an important role stabilizing substrate permitting conspecific species (e.g., invertebrate epifauna) to flourish (Bundy et al. 2014). Drop camera surveys of the Eastern Shore indicated that species of coralline algae were the only algal species detected at depths >50 m in the Eastern Shore drop camera survey, likely since other species cannot survive at low light levels (Vandermeulen 2018).

The invasive green alga *Codium fragile* has been observed in the Eastern Shore, but abundances have declined following the initial invasion in the early 2000s. *C. fragile* is often found where the invasive bryozoan (*Membranipora membranacea)* has defoliated native kelps, which permits its establishment. Fortunately, the presence of *C. fragile* may not necessarily prevent re-colonization of native algae and kelps, but continued monitoring of its presence or absence is nonetheless important (Watanabe et al. 2010). Another invasive red alga, *Dasysiphonia japonica*, has expanded its range west of the AOI to the Mahone Bay area but has not yet been documented in the AOI. Absence of *D. japonica* is likely related to the colder temperatures characterizing the area (Savoie and Saunders 2013).

Invertebrates

The Eastern Shore contains a diverse invertebrate assemblage, including crustaceans, tunicates, echinoderms, molluscs, annelids, cnidarians, and other phyla. The diversity of invertebrates associated with Eelgrass and Rockweed in this area is greater than study areas on the South Shore and in the Gulf of St. Lawrence (Coll et al. 2011, Cullain et al. 2018, Schmidt et al. 2011, Vercaemer et al. 2018, Wong and Dowd 2015).

The stalked tunicate, *Boltenia ovifera,* was commonly, albeit sparsely, detected during a drop camera survey conducted in 2017 (Vandermeulen 2018). Invertebrates that provide biogenic habitat, including sponges, anemones, and native tunicates, are widespread but sparse within the AOI (Vandermeulen 2018).

American Lobster is a commercially significant species in this area. The AOI overlaps with Lobster Fishery Areas (LFAs) 32 and 31B. Recruitment, measured as the number of sublegal sized lobster per standardized trap from the Fishermen and Scientists Research Society (FSRS), show slight increases from 1999 to 2016 in both LFAs. This increased recruitment coincides with increased landings over this time period.

The invasive bryozoan *M. membranacea* has been detected in the AOI on kelps. Overall, its distribution within the AOI seems patchy in nature (Vandermeulen 2018). Monitoring of aquatic invasive species suggests that the invasive crustaceans Green Crab (*Carcinus maenas*) and *Caprella mutica* are established in the AOI (Sephton et al. 2017). Green Crab have been observed digging through and dislodging Eelgrass (Garbary et al. 2014) and distributing fine sediments (Matheson et al. 2016) in localized areas in eastern Canada. The presence of Green Crabs has also been linked to both 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 invertebrate species nonetheless may represent a threat to the Eelgrass beds found within the AOI.

Fewer aquatic invasive tunicate species (1–2 species annually) are found at monitoring stations within the AOI compared to Cape Breton, the South Shore, and the Bay of Fundy (3–4 species) and are observed at lower densities (0–50% vs. 25–100% plate cover; DFO Aquatic Invasive Species Biofouling Monitoring Program and Sephton et al. 2017).

Fish

Data from the FSRS 4VsW Sentinel Survey and studies by O'Connor (2008), Schmidt et al. (2011), Wong et al. (2016), and Hunt et al. (2017) were used to determine which species of fish are most commonly detected in the Eastern Shore. The MARWhaleSightings database was used to determine which species of cetaceans have been detected within the AOI boundaries and in the vicinity over the past decade. **Diadromous fishes** including Atlantic Salmon (*Salmo salar*), American Eel (*Anguilla rostrata*), sea run Brown Trout (*Salmo trutta)* and Brook Trout (*Salvelinus fontinalis*), River Herring (*Alosa pseudoharengus* and *A. aestivalis*), Atlantic Smelt (*Osmerus mordax*), and Sea Lamprey (*Petromyzon marinus*) make use of the coastal zone of the AOI, through little is known about this temporal and spatial usage. Atlantic Salmon from the Southern Upland Designatable Unit are designated endangered by COSEWIC following dramatic declines in abundance over the past several decades (COSEWIC 2010a). This species is culturally significant to local communities and is of historical socioeconomic importance. Southern Upland Atlantic Salmon spawn in a number of rivers that flow into the AOI. Juvenile salmon inhabit coastal areas adjacent to these rivers in May and June. Adult salmon frequently visit the estuaries within the AOI to check for ideal spawning conditions, and may be present within the AOI year-round, either feeding or migrating through the AOI between the rivers and open ocean (B. Rutherford, Pers. Comm.).

Many rivers in the Southern Upland region have undergone some degree of acidification, which has been caused by a combination of acid rain, leaching from the underlying bedrock, and indirect and direct effects of historical gold mining (Amiro 2000, Bowlby et al. 2014, Watt et al. 1983). This acidification has negative impacts on salmon growth and development. Rivers in the Southern Upland Designatable Unit that are known to have salmon returns (as of 2008/09) are the Salmon River (Port Dufferin), Quoddy, Moser, Ecum Secum rivers, and West River in Sheet Harbour, which is undergoing remediation by the Nova Scotia Salmon association (Bowlby et al. 2014) with recent support from DFO and the Nova Scotia Department of Fisheries and Aquaculture. While these rivers are of a pH suitable for the survival of juvenile salmon (i.e., pH >5.0), recovery has been protracted and may require an additional 50–100 years before stocks start to recover (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; and 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 compared with a conservation spawning requirement of about 2,000 salmon (Gibson et al. 2010). Potential threats with high levels of concern identified in the Recovery Potential Assessment for Southern Upland Atlantic Salmon in the freshwater environment include acidification, altered hydrology, invasive fishes, physical obstructions, and illegal fishing (Bowlby et al. 2014). In the marine environment, changes in oceanographic conditions, salmonid aquaculture, and shifts in predator-prey regimes leading to at-sea mortality were identified as potential threats of high concern (Bowlby et al. 2014).

Atlantic Herring (*Clupea harengus*) are an ecologically and commercially significant species in Atlantic Canada. Atlantic Herring spawning has been recorded in the western portion of the AOI, which is part of the Eastern Shore spawning area. The Eastern Shore spawning area (4Wk) is considered to be of equal importance to the other major spawning area, Little Hope (4Xo), to the coastal Nova Scotia spawning component. Atlantic Herring exhibit strong homing fidelity to their spawning grounds, where they deposit their eggs onto gravel, cobble, small boulders, or submerged aquatic vegetation. Over the past five years, spawning biomass estimates from acoustic surveys ranged from 6,870 t (2013) to 68,562 t (2015) and are highly variable over the past decade (DFO 2015). Atlantic Herring are identified as a Type 1 Ecologically Significant Species and Community Property, meaning they are a forage species with a crucial trophodynamic role (DFO 2006). This species provides an important prey resource for marine birds and mammals, and larger fish within the AOI. A gillnet fishery for Herring exists in the western half of the AOI.

Atlantic Mackerel (*Scomber scombrus*; herein Mackerel) are a migratory species that spawn in the Gulf of St. Lawrence. Mackerel overwinter in offshore waters in depths of 70–200 m and migrate to the Gulf in May and June. Coastal areas comprise the migratory habitat for Mackerel in the spring and summer, whereas in the fall and winter they remain further offshore (Grégoire 1999, Scott and Scott 1988). Mackerel are an important forage species for birds and larger fish within the AOI. A gillnet fishery for Mackerel exists primarily in the western portion of the Eastern Shore AOI.

Bluefin Tuna (*Thunnus thynnus*) are an endangered species of economic importance in Canadian and North Atlantic waters (COSEWIC 2011). Bluefin Tuna have been observed nearshore within the AOI, presumably feeding on Herring that were aggregating in the area at the time (N. Jeffery, Pers. Obs. August 2017). Other species of tuna, including Bigeye, Yellowfin, and Albacore, also occur in eastern Canada, but little data on these species is available for the Eastern Shore.

Shortfin Mako Shark (*Isurus oxyrinchus*) and **Great White Shark** are occasional visitors to the Eastern Shore Islands. A tagged Shortfin Mako shark was reported near Taylor Head in August 2015 and two Great White sharks were detected near Liscomb Mills in August and October 2017. These species, in addition to Blue Shark (*Prionace glauca*) and Porbeagle (*Lamna nasus*), follow prey such as Herring inshore. Shortfin Mako likely migrate through the Eastern Shore Islands to the Gulf of St. Lawrence to forage in the summer (H. Bowlby, Pers. Comm.).

Atlantic Cod are historically a commercially important species on the Scotian Shelf. Cod are more abundant within the AOI and coastal zone in comparison to areas offshore beyond the boundaries of the AOI, based on the 4VsW Sentinel Survey (Figure 2). Though directed fisheries for Cod in the Eastern Scotian Shelf have been under moratorium since 1993, CPUE reported from the 4VsW Sentinel Survey has steadily declined for the past 20 years for both inshore and offshore areas. 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 2010b). 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. Survival during the juvenile life history of cod is tightly tied to the availability of structurally complex habitat (e.g., rocky reefs, macroalgae, and Eelgrass patches; Gotceitas et al. 1997, Laurel et al. 2003, McCain et al. 2016, Tupper and Boutilier 1995).

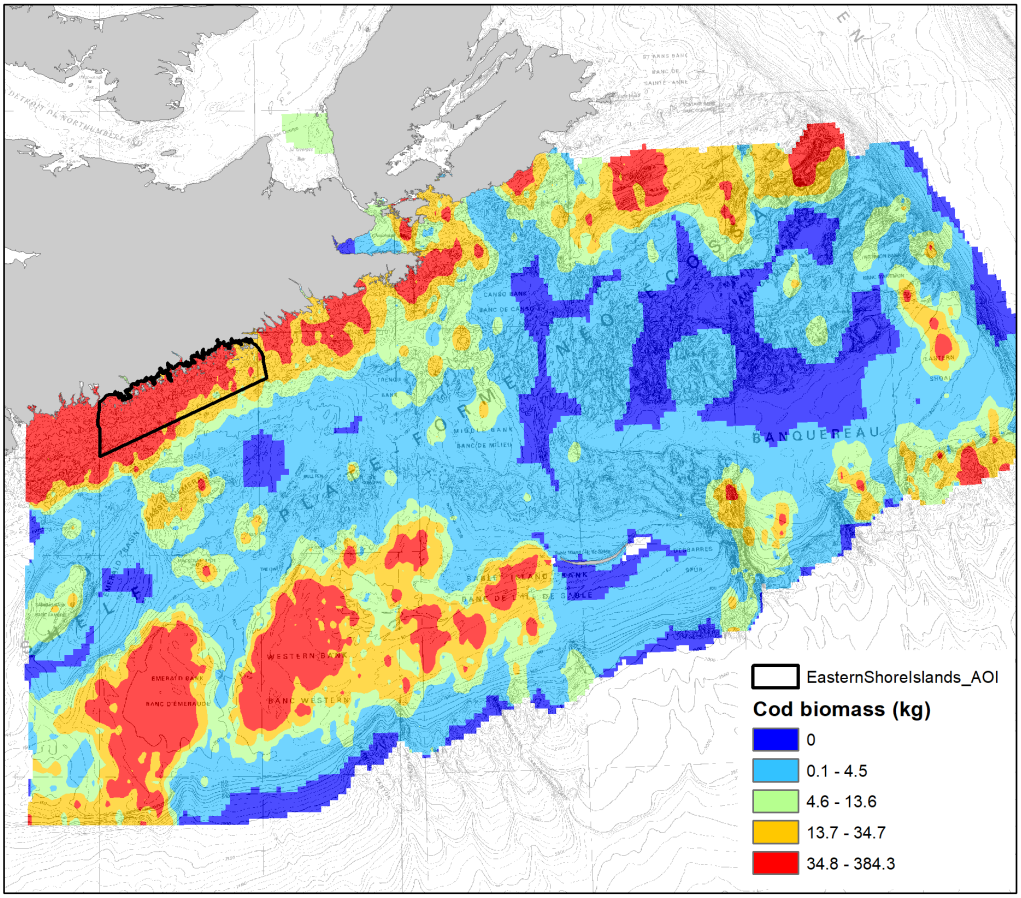

Figure 2. Average Atlantic Cod (Gadus morhua) biomass from the 4VsW Sentinel Survey data from 1995 to 2016.The AOI boundaries are shown with a black border. A greater biomass of Cod is found inshore relative to offshore areas, though catch per unit effort has continued to decline over the past 20 years.

Haddock (*Melanogrammus aeglefinus*) prefer rocky or hard bottoms, ranging from the inshore to the continental shelf (McCullough et al. 2005, Scott and Scott 1988). Historically spawning of Haddock was observed in coastal waters. In the vicinity of the AOI, Jeddore Harbour and the area between East Head and Taylor Head were identified as juvenile Haddock areas (Bundy et al. 2014, Gromack et al. 2010, McCullough et al. 2005). These Haddock areas were previously more extensive and contained more fish. There is currently not sufficient evidence to suggest the Eastern Shore Islands is an important area for Haddock.

Pollock prefer depths of 35–380 m but may be found inshore at depths of <10 m (Scott and Scott 1988). Spawning for Pollock predominantly occurs in offshore waters (>100 m) of the Scotian Shelf, though some inshore spawning does occur. In particular, St. Margarets Bay and waters adjacent to Necum Teuch, near the edge of the AOI boundary, are noted as important inshore spawning areas for Pollock. Inshore bays and estuaries provide nursery and refuge

habitat for juvenile Pollock (McCain et al. 2016). In the Eastern Shore, Vercaemer et al. (2018) found that juvenile Pollock were highly associated with Rockweed beds.

White Hake (*Urophycis tenuis*) are a demersal species found on the continental shelf and upper continental slope in the Atlantic (Hurlbut and Clay 1998, Scott and Scott 1988) from Labrador south to North Carolina. White Hake older than two years tend to be found in depths between 50 and 200 m, and spawn in the offshore pelagic zone. Juvenile White Hake predominantly utilize inshore areas, including estuaries (Hare et al. 2001), Eelgrass beds, and various substrates such as sand, gravel, mud, and/or clay. 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. This species is divided into two main stocks with the Eastern Shore belonging to the Atlantic and Northern Gulf of St. Lawrence population, which was designated as threatened by COSEWIC in 2013.

Cunner (*Tautogolabrus adspersus*) are a species of wrasse that are common in inshore, shallow waters. Cunner reside near the bottom of the water column, have a broad temperature tolerance, and are found in the intertidal or shallow water. They are often associated with complex habitat, such as wharves, shipwrecks, and biogenic habitat, including marine plants and seaweeds. Cunner feed upon invertebrates (i.e., molluscs and crustaceans), fish eggs, and macrophytes, and are in turn preyed upon by larger benthic fishes and birds such as cormorants (Scott and Scott 1988). Vandermeulen (2018) found that Cunner were common on rocky bottoms in the Eastern Shore to depths of 25 m.

Sand Lance (*Ammodytes* spp.) are key non-commercial species associated with sandy substrates and are distributed both inshore and on offshore banks (Scott and Scott 1988). Sand Lance are both cryptic, burrowing into sandy bottoms to avoid predators and while overwintering, and schooling, forming dense aggregations while feeding. Little recent information exists for this species, despite its importance as prey for groundfish such as Atlantic Cod, Haddock, and White Hake; marine birds; and marine mammals. To date there have been few observations of Sand Lance in the Eastern Shore, which is not unexpected given their behaviour. Systematic beach seining of areas with a sandy substrate would be required to potentially evaluate the distribution and abundance of Sand Lance in the AOI. Unlike other forage species (e.g., Herring), Sand Lance do not possess a swim bladder, making hydroacoustic surveying of their biomass difficult.

Marine Mammals

Harbour Seals (*Phoca vitulina concolor*) are present within the AOI, and two breeding colonies of **Grey Seal** (*Halichoerus grypus*) exist on Bowen's Ledge and on White Island, both situated off Ecum Secum. Grey Seal surveys occur every 3 to 10 years and pupping has historically been observed on both islands, but not in the most recent survey of Bowen's Ledge in 2016. Both species of seal prey upon forage fish and groundfish including Mackerel, Herring, Sand Lance, Atlantic Cod, Pollock, White Hake, and various flatfish (Hammill et al. 2014). 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 will likely be conducted in 2019 or 2020.

Cetaceans may use the AOI as a migration corridor or as ephemeral habitat. There are no recorded observations of cetaceans within the AOI in the DFO MARWhaleSightings database over the past decade; however, this does not necessarily mean that these animals do not use this area, but rather may not have been reported or observed. Harbour Porpoise (*Phocoena phocoena*) are expected to occur within the AOI, as this species is common in coastal areas.

Sea Turtles

Leatherback Turtles undergo annual migrations from southern nesting grounds to the Gulf of St. Lawrence to feed. The coastal zone, including the Eastern Shore Islands, is an important migration route for sea turtles moving to and from the Gulf. The Eastern Shore Islands is expected to be ephemeral habitat for Leatherback Turtles, as they do not nest or forage in this region.

Marine Birds

The Canadian Wildlife Service Colonial Waterbird database shows records of at least 101 distinct colony locations within the AOI. A diversity of marine bird species utilize the AOI at various times of year for foraging, breeding, as a stopover during migration, and as overwintering habitat, largely as a result of varied, abundant, and predictable marine prey resources. Aggregations of breeding marine birds, including Common Eider and endangered Roseate Tern, are associated with productive feeding grounds and habitats with relatively low predation pressure and low human disturbance within the AOI (i.e., small islands with adjacent productive waters for nesting and rearing young). Purple Sandpiper (*Calidris maritima*) and Harlequin Duck, though not local breeders, gather to forage along the numerous exposed rocky shorelines in the AOI. The highest winter foraging concentrations for these species in the Scotian Shelf bioregion were recorded within the AOI.

Significant congregations (≥1% of the eastern Canadian population) of several species of marine birds occur within the AOI, including Harlequin Duck, Common Eider, Roseate Tern, and Great Cormorant. Other species known to congregate in the AOI include scoters (*Melanitta* spp.), Common Tern, Arctic Tern, Great Shearwater (*Puffinus gravis*), Sooty Shearwater (*Ardenna grisea*), Cory's Shearwater (*Calonectris borealis*), Wilson's Storm-Petrel (*Oceanites oceanicus*), and Leach's Storm-Petrel (*Oceanodroma leucorhoa*). Since the combined mean maximum foraging range of the three tern species known to nest within the AOI are estimated at 20±10 km (mean ± Standard Error [SE]), the foraging area used by breeding adults would be encompassed entirely by the AOI boundaries (Rock et al. 2007a, Rock et al. 2007b).

The Eastern Shore Islands are characterized by a broad functional diversity of marine bird species including 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, and 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. 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. The endangered Roseate Tern has occupied 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 the current status of these colonies being unknown (Hastings et al. 2014). Additionally, Martinique Beach to the west of the AOI and Clam Harbour Beach within the AOI are identified as critical habitat for the Piping Plover (Endangered – SARA).

Sources of Uncertainty

Several ecological attributes that require more comprehensive information (data and description) to better characterize the AOI were identified. These knowledge gaps and uncertainties include:

- comprehensive censuses of phytoplankton, zooplankton, and ichthyoplankton;
- information on local oceanography and circulation;
- information detailing the full spatial distribution of Eelgrass, Rockweed, and kelp beds and the environmental and physical conditions regulating their distribution and ecological status for the entire AOI;
- temporal usage of Eelgrass, Rockweed, and kelp beds by fish, invertebrates, and birds specific to the AOI;
- temporal usage of the nearshore coastal habitat by Atlantic Salmon and other diadromous fishes;
- migratory behaviour of fish, cetaceans, and sea turtles;
- a detailed biodiversity assessment of invertebrates, including epifauna and meiofauna; and
- links between the complexity and composition of physical habitats and the associated ecological attributes of the AOI (i.e., species diversity).

Knowledge gaps could be addressed using field studies to create a scientific baseline where little data exists.

Updated coastal bathymetric information with higher resolution and increased coverage in shallow areas (i.e., through multi-beam and/or coastal LiDAR surveys) and vertical profiling of water properties could be used to improve the description of physical features of the AOI. This improved information could then be used in conjunction with data collected from Acoustic Doppler Current Profilers (ADCPs) to develop, validate, and update circulation models for the Eastern Shore and to explore the association of fine scale oceanographic features of the archipelago with ecological processes.

Detailed field studies to quantify invertebrate and fish diversity within the AOI (e.g., using plankton surveys, beach seines, baited traps, or diver surveys) could help determine how the physical habitat characteristics (i.e., complex bathymetry associated with the archipelago) of the AOI contribute to patterns of species diversity and abundance. Novel techniques such as environmental DNA (eDNA) sampling can be explored to evaluate the feasibility of non-traditional survey techniques that may reveal cryptic or rare species otherwise missed by traditional survey techniques.

Detailed *in situ* mapping of Eelgrass, Rockweed, and kelp beds could help determine areas of significant concentrations of biogenic habitat that may be associated with high animal diversity and/or abundance. Studies on the animal diversity associated with these habitats could also help articulate seasonal and ontogenetic usage of these habitats by fishes, invertebrates, and birds in the AOI. An understanding the distribution of biogenic habitat and how it relates to species diversity would provide an essential baseline for future monitoring.

Information on population sizes, residency within the boundaries of the AOI, and association with habitat features could be gained through tagging studies. Specifically, tagging of diadromous fishes and large bodied fishes (e.g., tuna and sharks) would help reveal the importance of coastal habitats for migratory and feeding behaviours. Similarly, aerial surveys of marine mammals and sea turtles would help describe the usage of the AOI as migratory habitat.

There remains some uncertainty about how key biological and physical attributes of the AOI will respond to potential and future disturbances. Uncertainties and disturbances identified include:

- impacts of new invasive species on the ecology of the area;
- the resilience of animal, plant and algal communities within the AOI, to anthropogenic stressors, including coastal development, pollution, and seafloor disturbance; and
- the impacts of climate change and sea level rise on the unique physical attributes of the AOI and the associated diversity of marine plant, algal and animal species.

Additional baseline and monitoring information is required to understand, predict, and record how current biological and physical attributes of the AOI may change in response to natural and/or anthropogenic disturbances such as climate change and invasive species. Programs such as joint DFO-industry fisheries surveys (e.g. 4VsW Sentinel Survey), Aquatic Invasive Species Program, and research programs on seaweed and Eelgrass ecology have provided invaluable baseline data for the AOI and could be data inputs to address some of the identified knowledge gaps and uncertainties.

CONCLUSIONS AND ADVICE

The Eastern Shore Islands AOI ranges from Clam Harbour to Liscomb Point and extends from the low tide line to 100 m isobath. The geology of this area is complex and unique in terms of offshore features (drumlin and moraine fields) and the prevalence of bedrock covered in a thin till in the form of sand and gravel, with inshore and offshore mud. Hundreds of islands make up this archipelago, providing habitat for nesting, roosting and migrating marine birds, and haulout sites for seals. The density of islands in this area is unique, having up to three times as many islands per kilometre of coast relative to any other region on the Scotian Shelf.

Habitat complexity associated with the archipelago and an overall heterogeneous mosaic of subtidal substrates and seaweed/algae species, is a key feature of this AOI. Patch sizes of habitat vary roughly every 400 m based on drop camera surveys, which is more heterogeneous relative to Sambro Ledges (5 km patch size) and Port Joli, where the substrate is primarily sand with fringing rock. This subtidal heterogeneity complements the complex intertidal zone of the Eastern Shore Islands, which has a variety of rocky and sandy beaches, mud flats, cliffs, salt marshes, and Eelgrass and Rockweed beds.

The physical and chemical oceanography of the AOI is consistent with the inshore Scotian Shelf, driven by the Scotian Current, surface mixing, and season upwelling. Surface and bottom temperatures are colder in the Eastern Shore than the South Shore and Bay of Fundy. Plankton assemblages are similar to other areas of the Scotian Shelf. Pollution and other human impacts in this area are lower relative to other regions, largely owing to the low population density and relatively low levels of coastal development.

Macrophytes, including salt marsh, Eelgrass, Rockweed, and kelps are diverse and abundant, but patchy. Salt marshes provide habitat and foraging grounds for shorebirds and a variety of fish and invertebrate species, and act as natural pollution filters and carbon sinks. Eelgrass, Rockweed, and kelp provide habitat and food for juvenile fish, including Atlantic Cod, and invertebrates, such as crabs, shrimps, and lobster, and birds such as Common Eider, geese, and ducks (Vercaemer et al. 2018). Kelps and other algae provide shelter and food for marine invertebrates and fishes. Studies have demonstrated increased species richness associated with macrophyte beds compared to bare sediment. The primary threats to macrophytes in this region include reduced growth rates, recruitment, and survival associated with increases in turbidity, eutrophication, sedimentation, habitat disturbance, invasive species, climate change.

Numerous invertebrate phyla are found in the Eastern Shore, including crustaceans, echinoderms, molluscs, annelids, and cnidarians. The diversity of invertebrates associated with Eelgrass and Rockweed in this area is greater than areas on the South Shore and in the Gulf of St. Lawrence; however, it is unknown how the diversity of invertebrates in this area compares to other regions in terms of overall species richness. Lobster, in particular, represents an important fishery to this relatively sparsely populated coastal region.

At least 16 depleted species of fishes, birds, and sea turtles can be found within the AOI boundaries. Of these, there is enough evidence to suggest that the AOI is of high importance for Atlantic Salmon, Atlantic Cod, White Hake, Harlequin Duck, and Roseate Tern. For other depleted species, the AOI is either not of particular importance relative to other coastal areas, or there is not enough data to determine the relative importance of the AOI.

Atlantic Salmon that spawn in rivers within the Eastern Shore AOI are considered part of the Southern Upland Designatable Unit. These rivers also represent important habitat for diadromous fish including Brown Trout, Brook Trout, Sea Lamprey, River Herring, and juvenile American Eels before migrating to offshore spawning areas. Atlantic Salmon are in decline and the Southern Upland DU is considered Endangered by COSEWIC. 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. This acidification has negative impacts on salmon growth and development. Potential threats of high concern in the freshwater environment for Atlantic Salmon, as outlined in the Recovery Potential Assessment, include acidification, altered hydrology, invasive species, physical obstructions, and illegal fishing (importance not implied by order) (Bowlby et al. 2014, DFO 2013). In marine and estuarine habitats, changes in oceanographic conditions, at-sea mortality, and salmonid aquaculture were identified as potential threats of high concern (Bowlby et al. 2014, DFO 2013).

Atlantic Herring, Mackerel, and Bluefin Tuna are ecologically important pelagic fish found in the Eastern Shore. Herring and Mackerel provide forage for larger pelagic fish and marine birds and mammals. Atlantic Cod are relatively common in the AOI but CPUE has steadily declined over the past 20 years based on data from the 4VsW Sentinel survey. Observations of Haddock in the area are infrequent and in low abundance relative to Atlantic cod. Pollock, White Hake, flounders, skates, and other ground and forage fish have been documented in the AOI. The usage of the area by large pelagic animals, including marine mammals, sea turtles, and sharks is largely unknown, and represents a knowledge gap.

Uncertainties and knowledge gaps identified include the extent and resilience of Eelgrass, Rockweed, and kelp beds; the full diversity of animals that use Rockweed, Eelgrass, and kelp as biogenic habitat; comprehensive census of fish and invertebrate diversity; use of the AOI by marine mammals, sea turtles, and sharks; use of the marine coastal zone by diadromous fishes; phytoplankton, zooplankton, and ichthyoplankton diversity; the influence of the numerous islands within the AOI on the distributions of macrophytes and animals, and detailed information on physical oceanography. Knowledge gaps may be addressed with additional baseline science in the AOI, including biodiversity assessments, fish tagging studies, long-term chemical and oceanographic monitoring, and the use of emerging technologies such as environmental DNA sampling.

Potential vulnerabilities of the area include climate change and its associated effects (i.e., ocean warming and acidification, sea level rise, and changes in species distributions) and anthropogenic activities associated with pollution, overharvest, destruction of the benthic environment, and/or the introduction of invasive species or disease.

Climate change may influence macrophyte abundance, distribution, and community structure, which may in turn drive changes in associated animal and plant assemblages. Eelgrass,

Rockweed, salt marshes, and kelp beds are particularly sensitive to eutrophication, turbidity, and climate change. In addition, the invasive bryozoan (*Membranipora membranacea)*threatens kelp through defoliation and has been recorded within the AOI boundaries. The area is at moderate risk of sea level rise from climate change; however, projected increases in bottom temperature are lower than other coastal regions.

Many of the rivers in the Eastern Shore have been impacted by acidification with loss of salmon production. This acidification is the result of acid rain, mining activities, and natural leaching from bedrock, which negatively impacts salmon growth and development (Bowlby et al. 2014). Marine survival is also depressed, but at-sea mortality rates of Atlantic Salmon for rivers in this area are unknown. Individual spawning groups of Atlantic Herring within the coastal component are considered vulnerable to overfishing because of their relatively small size (biomass) and close proximity to shore (DFO 2015). Studies have also demonstrated that larval Herring are sensitive to ocean acidification associated with climate change (Franke and Clemmesen 2011). Monitoring of animal, plant, and algae communities in the AOI is required to predict and evaluate the potential responses of species to marine climate change for the Eastern Shore ecosystem.

Based on the best available data, conservation priorities for the Eastern Shore Islands AOI include:

- the relatively high naturalness;
- 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);
- an area of importance for Atlantic Salmon;
- an Atlantic Herring spawning area;
- an important habitat for juvenile groundfish including Atlantic Cod, White Hake, and Pollock, provided by estuaries, subtidal Rockweed, Eelgrass, kelp, and rocky substrates; and
- an important area for nesting, foraging, and migratory marine birds.

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.

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SOURCES OF INFORMATION

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