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Maritimes Region

Canadian Science Advisory Secretariat
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BIOPHYSICAL AND ECOLOGICAL OVERVIEW OF THE FUNDIAN CHANNEL – BROWNS BANK AREA OF INTEREST (AOI)

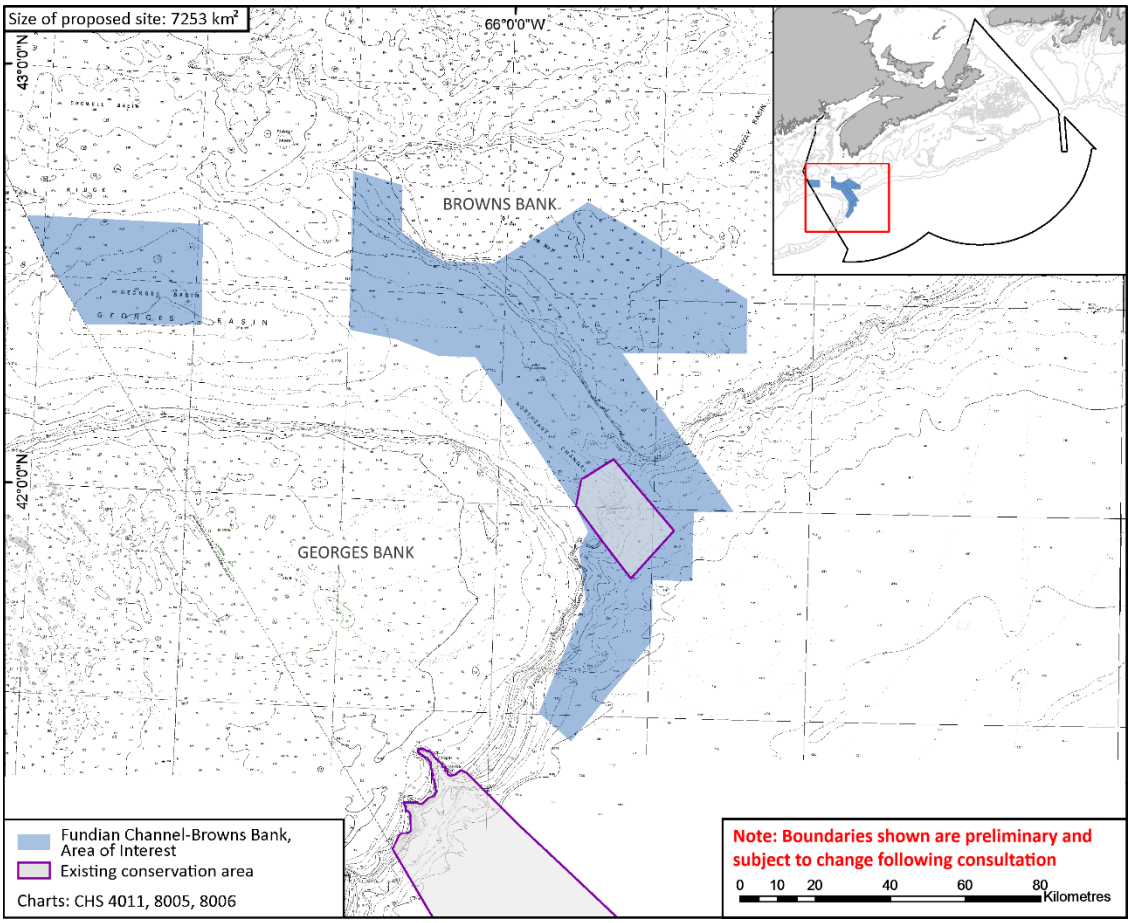

Figure 1. Fundian Channel – Browns Bank Area of Interest (AOI; shaded blue) within the Maritimes Region (inset). The AOI boundary is not final, is subject to change, and does not necessarily reflect a proposed Marine Protected Area (MPA) boundary. Basemap: Canadian Hydrographic Service nautical charts 4011, 8005, and 8006 (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 2011–2020 Strategic Plan for Biodiversity's Aichi Targets) 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. Further, to highlight these targets as a priority, the Government of Canada identified an interim target of 5% protection by 2017.

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 protect selected coastal and ocean areas through the establishment of MPAs, where the identification of an Area of Interest (AOI) is the first step in this process. The Fundian Channel–Browns Bank area was announced as an AOI on March 22, 2018. It was identified, in part, through an MPA network design analysis for the Scotian Shelf Bioregion that considered available ecological and economic information. Discussions with other government agencies, First Nations and Indigenous groups and key stakeholders also informed the selection of this AOI.

The identification of an AOI is a first step in the assessment process towards formal MPA designations. Once an AOI is identified, more detailed information on the key biophysical and ecological attributes of the area is required, especially as it pertains to potential conservation priorities and their linkages to other key ecosystem components and processes.

The Oceans Management Program has requested science information and advice on the Fundian Channel – Browns Bank AOI to inform next steps in the MPA establishment process, including future consultations.

This Science Advisory Report is from the Regional Peer Review Process of the Biophysical and Ecological Overview of the Fundian Channel – Browns Bank Area of Interest held November 27–29, 2018, with follow up meetings on December 19th, 2018, and February 26, 2019. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

Physical Features of the Fundian Channel – Browns Bank Area of Interest (AOI)

- The Fundian Channel – Browns Bank is an offshore AOI of approximately 7,200 km^2 composed of two geographically separate components. The western component of the AOI is centered on Georges Basin and the larger eastern component includes portions of Browns Bank, Fundian Channel[1], and the continental slope.
- The AOI is primarily located within Northwest Atlantic Fisheries Organization (NAFO) Division 4X. Several existing fisheries closures overlap with the AOI, including the Northeast Channel Coral Conservation Area (NECCCA); nearly 50% of Lobster Fishing Area (LFA) 40, which is currently closed to lobster fishing; and portions of the Browns Bank groundfish spawning seasonal closure.
- The bathymetry of the AOI varies from approximately 50 m on Browns Bank to 370 m in Georges Basin, with depths up to 2,200 m, extending from the eastern section of the AOI to the continental slope.
- The Fundian Channel is similar to other shelf-crossing troughs that have been eroded by past glacial ice streams. The Channel is more energetic compared to other shelf-crossing troughs in the region.

[1]The Fundian Channel includes the Northeast Channel, which denotes the portion of channel proximate to the continental slope that separates Browns and Georges banks.

- Seabed classification divides the AOI into four main areas: Outer Gulf of Maine Shelf Basin and Channel; Scotian Slope West – Fan; Outer Scotian Shelf – Saddle; and Outer Scotian Shelf – Bank.

Significant Fish and Invertebrate Species

- There has been an overall change in zooplankton abundance and community composition on the Western Scotian Shelf in recent years, including within the AOI.
- Changes in the copepod community could lead to shifts in the distribution of other pelagic zoo- and ichthyoplankton, marine mammals, pelagic fishes, and other species that depend on large copepods as prey.
- The relatively high diversity of benthic invertebrates found within the AOI corresponds to the variety and complexity of habitats associated with the Fundian Channel, Georges Basin, southern Browns Bank, the continental slope, and deeper waters.
- Two prominent deep-water corals in the AOI are the Alcyonacea species *Primnoa resedaeformis* and *Paragorgia arborea*. Some of the densest aggregations of these two taxa on the Scotian Slope are found in the NECCCA within the AOI that was established specifically to protect them.
- Significant sponge concentrations have been identified on Southern Browns Bank, partially overlapping the AOI. The Russian Hat Sponge (*Vazella pourtalesi*) is known to inhabit the Fundian Channel, but in non-significant concentrations based on kernel density estimates.
- Sea pens (Pennatulacea) are concentrated in deep basins and along the continental slope, with a high probability of occurrence along the slope and in deep, offshore waters. Sea pens have been observed throughout the AOI, though additional studies are needed to determine their full distribution.
- Biogenic habitat-forming species, such as corals, sponges, and sea pens, provide important habitat and refuge from predation, as well as feeding and nursery grounds for a variety of fishes and invertebrates.
- Offshore American Lobster (*Homarus americanus*) populations, in particular within LFA 40, have been shown to have a higher proportion of large, ovigerous female lobsters than observed inshore. Abundances of lobster recorded in the vicinity of the AOI during the Summer Research Vessel (RV) Survey is consistently amongst the highest on the Scotian Shelf.
- The Summer RV Survey has documented 71 fish species within the AOI between 1970 and 2017. The top 20 most abundant species, including Haddock (*Melanogrammus aeglefinus*), Atlantic Cod (*Gadus morhua*), Silver Hake (*Merluccius bilinearis*), Yellowtail Flounder (*Pleuronectes ferruginea*), and Pollock (*Pollachius virens*), comprised nearly 80% of all observations.
- The 4X Atlantic Cod (Endangered – The Committee on the Status of Endangered Wildlife in Canada (COSEWIC)) stock has been in the Critical Zone since 2011, and biomass has remained low since this time, with very low recruitment. The AOI includes representative habitat for Atlantic Cod including a portion of the persistent top quintile habitat identified in the Browns Bank portion of the AOI over the past four decades.

- On the Scotian Shelf, White Hake (*Urophycis tenuis*; Threatened – COSEWIC) show the highest abundances in the Bay of Fundy and along the deep waters along the shelf break. Adult and juvenile White Hake are commonly found on fine substrates, such as mud at the bottom of basins on the Scotian Shelf. The deeper portions of Georges Basin encompassed by the AOI boundaries are identified as a persistent top quintile habitat for White Hake on the Scotian Shelf.
- On the Scotian Shelf, Browns Bank represents persistent top quintile habitat for Atlantic Wolffish (*Anarhichas lupus;* Special Concern – The Species at Risk Act (SARA)).
- Atlantic Halibut (*Hippoglossus hippoglossus*) in Canadian waters are experiencing a period of high recruitment and population growth. The AOI includes one of two distinct areas of persistent juvenile Atlantic Halibut abundance within the Scotian Shelf Bioregion. These regions of high juvenile abundance are consistently observed irrespective of the overall stock abundance, suggesting they are persistent and resilient.
- Cusk (*Brosme brosme;* Endangered – COSEWIC) are considered to have been in the Cautious Zone since 2011. The Fundian Channel, including a large portion of the AOI, has among the highest probabilities of Cusk presence based on habitat suitability models.
- Thorny Skate (*Amblyraja radiata*; Special Concern – COSEWIC) are considered a single Designatable Unit in Canadian waters and have undergone severe population declines over the southern part of their historic distribution. This decline has continued in the southern portion of their range despite a reduction in fishing mortality. Georges Basin has been shown to be persistent top quintile habitat for Thorny Skate in the vicinity of the AOI.
- Winter Skate (*Leucoraja ocellata*) in Canada are found in three main concentrations, including the Western Scotian Shelf/Bay of Fundy. Browns Bank, including part of the AOI, and the Bay of Fundy are the only areas of persistent top quintile habitat for Winter Skate on the Western Scotian Shelf.
- A diversity of large pelagic fishes, including tunas, billfishes, and sharks are seasonally present and may forage within the AOI.
- Distinct oceanographic processes, including upwelling at the mouth of the Fundian Channel, internal waves generated within the Channel, and local gyres, in conjunction with dynamic features associated with the Gulf stream, concentrate plankton and forage species such as squid and Atlantic Herring (*Clupea harengus*), attracting large pelagic fishes to the AOI and continental slope.

Marine Mammals

- At least 22 species of cetaceans are known to occur in the waters of Atlantic Canada. Many of these species have been observed off the southwestern coast of Nova Scotia; however, no comprehensive systematic surveys on the occurrence or distribution of cetaceans in the AOI have been conducted, and the abundance of cetaceans has not been estimated for this area.
- The continental shelf edge has been identified as an important foraging area for Blue Whale (*Balaenoptera musculus*; Endangered – SARA), including a portion of the AOI.
- Sowerby's Beaked Whale (*Mesoplodon bidens*; Special Concern – COSEWIC) and Northern Bottlenose Whale (*Hyperoodon ampullatus*; Endangered – SARA) are distributed along the

Scotian Shelf slope near the Fundian Channel, and in submarine canyons on the eastern Scotian Shelf. These species are present within the AOI and their presence is supported by recent acoustic and visual detections.

Marine Birds

- The abundance and diversity of marine birds in the vicinity of the AOI is reflective of an abundant and varied prey base. The AOI has supported top decile (i.e., top 10th percentile) concentrations of most marine bird functional guilds at various annual and decadal timescales based on bird observer data from the 1960s onward.
- The avifaunal community includes species that access prey on the near-surface, such as storm-petrels, phalaropes, gulls, terns, skuas, and jaegers; plunge divers, such as Northern Gannet (*Morus bassanus*); shallow divers, such as shearwaters; and deep divers such as auks that can reach nearly 200 m in depth.

Species at Risk

- A variety of marine fish, mammals, turtles, and birds that have been observed in the AOI are assessed as at risk by COSEWIC and/or listed under SARA and the International Union for the Conservation of Nature (IUCN).

Knowledge Gaps

- Data documenting the full distribution of corals and sponges within the AOI, knowledge of the infaunal community composition, and population genetic information for most fish and invertebrate populations is not currently available. While this information could assist boundary delimitation and zoning within a potential MPA, its absence does not preclude the development of conservation priorities.
- The Summer RV Survey provided the majority of the groundfish and benthic invertebrate diversity information used in this ecological overview. Therefore, seasonal migrations, variations in abundance, and changes in groundfish and invertebrate community composition within the AOI remain largely unknown.
- Observations of faunal composition in deep water slope habitat are limited to adjacent strata in the Summer RV Survey. There have been no Summer RV Survey sets conducted deeper than 400 m within the AOI.
- Many species occur in the summer months and are presumed to be feeding based on the productivity and oceanographic features of the AOI; however, no direct observations of feeding in association with the features of the AOI have been recorded.

Climate Change Considerations

- There is some uncertainty about how key biological and physical attributes of the AOI have been responding, or will respond to, changing climate conditions.
- Specifically, we acknowledge the uncertainty regarding the impacts of:
    - the observed shift in zooplankton communities within and in the vicinity of the AOI on productivity and distribution of predators, and overall use of the area by pelagic species;

- ocean acidification and warming on corals and sponges, which are noted as conservation priorities;
- climate change and associated warming temperatures on the distribution, biomass, and resilience of groundfish and invertebrate communities within the AOI; and
- changing fish and invertebrate community composition associated with the increased prevalence of warm-water species and loss of habitat for some colder adapted species on the Scotian Shelf, especially in the Western Scotian Shelf.

Conservation Priorities

- Potential conservation priorities for the Fundian Channel – Browns Bank AOI were identified prior to the Canadian Science Advisory Secretariat (CSAS) review by the Oceans Management Program. These conservation priorities were assessed through this CSAS Science Peer-Review process and were either recommended to be retained, modified, or rejected based on the strength of available scientific evidence. Features were assessed against the Ecologically and Biologically Significant Area (EBSA) criteria of aggregation, uniqueness, and fitness consequences, or the species-based vulnerability, conservation status, and Ecologically Significant Species criteria.
- The following features were supported as conservation priorities by the majority of participants, based on the information that was available for review:

  Habitat

  - Diverse representation of habitat types, including basin, bank, deep water slope and channel habitats, and their associated fish and invertebrate communities
  - Persistent habitat for juvenile Atlantic Halibut
  - Concentrations of large mature female lobster
  - Suitable habitat for Sowerby's Beaked Whale and Northern Bottlenose Whale

  Biodiversity

  - Deep-water corals
  - Significant concentrations of sponges
  - Representative habitat for Atlantic Cod, Atlantic Wolffish, Winter Skate, Thorny Skate, and White Hake
  - Highly suitable habitat for Cusk

  Productivity

  - The collection of oceanographic features, such as internal waves, areas of upwelling, and occasional presence of Gulf current and warm-core rings, at the mouth of the Fundian Channel that make it a highly productive area that is associated with the presence of large pelagic fishes, sea turtles, and cetaceans
  - A Blue Whale foraging area
  - Foraging ground for most functional guilds of marine birds, including Leach's Storm Petrel (*Oceanodroma leucorhoa*)

INTRODUCTION

The Fundian Channel – Browns Bank is an offshore AOI of approximately 7,200 km^2 composed of two geographically separate components (Figure 1). The western component of the AOI is centered on Georges Basin and the larger eastern component includes portions of Browns Bank, Fundian Channel, Northeast Channel, and the continental slope. The western most boundary of the AOI lies along the international boundary between Canada and the United States, transecting Georges Basin and is the principal hydrodynamic connection point between the Gulf of Maine and offshore waters. The AOI is primarily located within Northwest Atlantic Fisheries Organization (NAFO) Division 4X. Several existing fisheries closures overlap with the AOI, such as the Northeast Channel Coral Conservation Area (NECCCA); nearly 50% of Lobster Fishing Area (LFA) 40, which is currently closed to lobster fishing; and portions of the Browns Bank groundfish spawning seasonal closure.

Areas within and adjacent to the AOI were reviewed to ascertain the breadth and scope of the various ecosystem components and to summarise the significance of the AOI to the life histories of those species identified as potential conservation priorities. The general study area for the biophysical and ecological overview includes NAFO divisions 4X5Y and the northern Gulf of Maine, with a specific focus on the AOI itself.

The overall objective of the biophysical and ecological overview is to provide advice on key biological and physical features of the AOI (and adjacent areas as required) as they pertain to potential conservation priorities, the 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 included:

- significant concentrations of gorgonian corals (e.g., Bubblegum Coral – *Paragorgia arborea*);
- significant concentrations of sponges;
- areas of high diversity and productivity for fish and invertebrate species, including larvae;
- important foraging habitat for various seabird species;
- distinctive oceanographic processes, such as upwelling that creates unique ecological conditions;
- a migratory corridor to and from the Gulf of Maine;
- habitat for a variety of species of concern including Atlantic Cod (*Gadus morhua*; Endangered – Committee on the Status of Endangered Wildlife in Canada (COSEWIC)), Atlantic Wolffish (*Anarhichas lupus*; Special Concern – SARA), Cusk (*Brosme brosme*; Endangered – COSEWIC), Spiny Dogfish (*Squalus acanthias*; Special Concern – COSEWIC), Smooth Skate (*Malacoraja senta*; Special Concern – COSEWIC), Thorny Skate (*Amblyraja radiata*; Special Concern – COSEWIC), and White Hake (*Urophycis tenuis*; Threatened – COSEWIC); and
- the wide range of habitats the AOI spans, including bank, basin, channel, shelf edge, and upper slope.

The biophysical and ecological overview (Jeffery et al. In prep.) addresses information pertaining to the study area including: predominant and/or unique physical and biological oceanographic characteristics; predominant, unique, and/or sensitive habitat features;

ecologically, socially/culturally and/or commercially significant species; depleted species; and marine mammals and marine birds (distribution and abundance of species of interest, as well as information on various aspects of their biology and ecology). Where appropriate, the relevance of the study area to the life histories of species of interest, species distribution and abundance (including status and trends where available), and the local abiotic and biotic factors influencing them were identified. 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 uncertainty and knowledge gaps as they pertain to the current understanding of the existing environment and species of interest within the study area, and ways to address these gaps, are identified where possible.

ASSESSMENT

An assessment of the study area was presented and reviewed based on detailed information contained within the working paper (Jeffery et al. In prep.). This working paper consisted of contributed sections from collaborators with Fisheries and Oceans Canada (DFO), Natural Resources Canada (NRCan), Environment and Climate Change Canada (ECCC), and Dalhousie University.

Bathymetry

The bathymetry of the AOI varies from approximately 50 m on Browns Bank to 370 m in Georges Basin, with depths up to 2,200 m, extending from the eastern section of the AOI to the continental slope. The “Hell Hole” is a distinct oceanographic feature of the AOI with depths up to 500 m. The seaward sill of the channel raises to approximately 230 m, and the channel mouth is incised by submarine canyons leading to the deepest portions of the AOI on the continental slope. This wide range in depths within the AOI contributes to its overall habitat complexity, and this creates distinct invertebrate and fish communities that prefer different depths and associated substrates.

Geology

The seabed geology within the boundaries of the AOI is typical of much of the Scotian Shelf. Thin deposits of glacially-derived muds, sands, and gravels overlie an eroded and truncated sedimentary bedrock surface. Muddy sediments have been deposited and preserved at the seabed in the deeper portions of the channels and on the continental slope. Sand and gravel deposits on the shallow, flat bank tops in the AOI are frequently disturbed and redistributed by both tidal currents and storm waves.

The Fundian Channel is similar to other shelf-crossing troughs that have been eroded by past glacial ice streams, hosting a thick sequence of sediment overlying bedrock including glacial till, postglacial sands and muds, and a surface veneer of reworked sand or mud, in deeper water. The Channel is more energetic compared to other shelf-crossing troughs in the region. Strong currents have produced migrating sand waves in parts of the channel. In places, glacial deposits are exposed at the seabed in morainal ridges that protrude tens of meters above the surrounding seafloor. Boulders, cobbles, and pebbles create an irregular surface on these moraines.

Glacially-carved, shelf-crossing troughs are common geomorphic elements along the glaciated east coast of Canada and the northeast United States, thus the Fundian Channel is not

singularly unique. Most shelf-crossing channels are filled with till with preserved relict iceberg scours, patches of sand (sometimes mobile), and mud-filled basins.

The strong currents of the Channel continue to influence/evolve its surficial sediments. Large bedform fields on the inner reaches of the Channel appear relict. In contrast, bedform fields on the flanks of the Channel appear active, with bedform migration occurring in complex patterns in response to currents.

Oceanographic Conditions

The circulation on the Scotian Shelf is characterized by a general northeast-southwest flow where waters adjacent the Atlantic Canadian shelf are a confluence zone between the warm northeast flowing Gulf Stream and the cold southwest flowing Labrador Current. The overall nutrient budget for the Gulf of Maine is strongly controlled by nutrient-rich, offshore, deep-water input through the Channel, with up to 44% of new nitrates entering the Gulf through this Channel.

Persistent oceanographic features including a clockwise gyre over Browns Bank, upwelling at the continental slope into the Fundian Channel, and internal waves that concentrate phytoplankton, make the AOI a relatively highly productive area. These features attract various trophic levels, including small fish such as Atlantic Herring (*Clupea harengus*) and Atlantic Mackerel (*Scomber scombrus*), and larger predators including tunas, billfish, and cetaceans. Gulf Stream features (meanders and warm-core rings) likely do not play a significant role in driving the currents through the Channel, though this warmer water is likely what attracts tropical tunas such as Albacore and Yellowfin to the area.

Temperature across the bioregion decreases with increased latitude and correspondingly the AOI and surrounding waters are generally warmer than waters of a similar depth in the Bay of Fundy and Eastern Scotian Shelf. Particularly in the winter months (January–March), bottom temperatures in the AOI are among the warmest in the region with average temperatures over the past decade (2008–2017) reaching 6.53°C (± 1.23) and 4.74°C (± 1.89) for the rest of the region. Within the AOI, bottom temperatures are generally warmer (7.38 ± 0.73°C) on the Shelf (Browns Bank, Northeast Channel, and Georges Basin) than the slope (approximately 200–1500 m; 3.85 ± 0.06°C) and deeper waters (>1500 m; 4.59 ± 0.66°C). Surface temperatures exhibit a more uniform north-south temperature gradient across the bioregion and are more seasonally variable than at the bottom. Averaged over the last decade (2008–2017), seasonal sea-surface temperatures recorded in the AOI (2008–2017) were warmer (+1.37 ± 0.35°C) than those on the Scotian Shelf.

The Gulf of Maine and Scotian Shelf waters have a reduced capacity to buffer against pH changes because of relatively high nutrient loading and high freshwater input from the Gulf of St. Lawrence and Labrador current (Gledhill et al. 2015). Generally, minimum monthly aragonite concentrations, a mineral important for some shellfish and corals to grow, in the Gulf of Maine and Fundian Channel are lower than waters to the south because of the colder temperatures and lower salinity, which reduce the availability of aragonite.

Contaminants in the Gulf of Maine and southern Nova Scotia region include sewage point sources, agricultural runoff, mercury and other trace metals, petroleum residues, polychlorinated biphenyls (PCBs), and pesticides. Heavy metals are introduced into the marine environment by natural processes and human activities, including river runoff, precipitation, hydrothermal vents, mining, and industrial uses of heavy metals. In the Gulf of Maine region, total mercury inputs are primarily from oceanographic circulation, atmospheric deposition, wastewater or industrial

sources, and rivers. Potentially >5000 kg of mercury enter the Gulf of Maine each year through natural circulation from the Scotian Shelf and through the Fundian Channel.

The AOI is considered an area of relatively high scope for growth, an index which considers environmental factors that influence physiological functioning (i.e., food availability, average annual bottom temperature, temperature variability, and oxygen saturation), limiting growth and reproduction of the organisms in a particular area (Kostylev and Hannah 2007).

Plankton

Shifts in zooplankton richness and abundance have been observed under warming ocean temperatures in the Gulf of Maine and on the Scotian Shelf. There has been an overall change in zooplankton abundance and community composition on the Western Scotian Shelf in recent years, including within the AOI. This change is characterized by lower abundance of large calanoid copepods, especially *Calanus finmarchicus*, higher abundance of small, warm water copepods (both subtropical and offshore species) and non-copepods, including larvae of benthic macroinvertebrates (DFO 2017b). Negative anomalies of both *C. finmarchicus* and *Pseudocalanus* spp. occurred across the Scotian Shelf and Browns Bank, though positive anomalies for *Pseudocalanus* occurred in the Gulf of St. Lawrence and off Newfoundland (DFO 2017b). Positive anomalies of warm and deep water copepod species are likely the result of warming temperatures in the Maritimes Region and changes in on-shelf transport, connecting these species into the Gulf of Maine and Scotian Shelf and allowing them to thrive. Changes in the copepod community could lead to shifts in the distribution of other pelagic zoo- and ichthyoplankton, marine mammals, pelagic fishes, and other species that depend on large copepods as prey.

Benthic Communities and Invertebrates

Seabed classification divides the AOI into four main areas: Outer Gulf of Maine Shelf Basin and Channel; Scotian Slope West – Fan; Outer Scotian Shelf – Saddle; and Outer Scotian Shelf – Bank (WWF Canada 2009). The AOI is further characterized by a variety of geomorphic units that include shelf channel, shelf basin, shelf bank, shelf flat, and continental slope (DFO 2016a). The relatively high diversity of benthic invertebrates found within the AOI corresponds to the variety and complexity of habitats associated with the Fundian Channel, Georges Basin, southern Browns Bank, the continental slope, and deeper waters. Ward-Paige and Bundy (2016) identified the Channel as an area of persistently high fish and invertebrate diversity, suggesting this ecosystem may be resilient to disturbance and change.

Browns Bank can further be divided into six communities based on depth, substrate type, and energetics, and each of these communities contains different assemblages of benthic invertebrates. Suspension feeders, including Atlantic Sea Scallop, Sea Cucumber, and sabellid worms are predominant on the western, shallower part of the bank. Soft corals (Alcyonacea) are also common in these shallow areas. Deposit feeders, including nothriid worms, are more abundant with increasing depth towards the eastern portion of the bank. Complex gravel habitats with a wide range in grain size in the central and eastern parts of the bank showed the highest diversity and abundance of sessile epifauna. Barnacle tests have also been found in deep portions of the bank. Sandy portions of the bank were relatively barren, with solitary hydroids (*Corymorpha pendula*) and sand dollars being the most common epifauna.

Two prominent deep-water corals in the AOI are the Alcyonacea species *Primnoa resedaeformis* and *Paragorgia arborea*. Some of the densest aggregations of these two taxa on

the Scotian Slope are found in the NECCCA within the AOI that was established specifically to protect them. Although abundance of these corals can vary greatly across different sections within the NECCCA, it generally increases with depth. Records of these corals also exist from outside the NECCCA, but within the AOI channel and slope habitats. Species distribution models have predicted areas of suitable habitat to occur on steeply sloping regions along the shelf break and shallow continental slope for *P. arborea*, but wider swaths that extend onto the shelf for *P. resedaeformis* (Bryan and Metaxas 2007). Some of the largest corals within the AOI are estimated to be hundreds of years old. Biogenic species are slow to recover from physical damage and have a relatively low recruitment rate, making them susceptible to anthropogenic disturbance and climate change.

Megaepifauna other than deep-water corals are sparsely distributed for the most part across the areas of the AOI that have been sampled visually. Overall, cnidarians (mainly anemones) and sponges dominated the fauna in these regions. Significant sponge concentrations have been identified on Southern Browns Bank, partially overlapping the AOI (Kenchington et al. 2016b). The Russian Hat Sponge (*Vazella pourtalesi*) is known to inhabit the Fundian Channel but in non-significant concentrations based on kernel density estimates (Kenchington et al. 2016a). Sponges, dominated by the family Polymastiidae, were present in all stations sampled during the 2017 Summer RV Survey within the AOI. In some samples, up to 7 specimens of the Russian Hat Sponge were recorded. Deeper portions of southern Browns Bank (>100 m) are covered predominantly by a thin layer of mud creating habitat for sessile invertebrates, including Leafy Bryozoans (*Flustra foliacea*), sponges, and tunicates. Sea pens (Pennatulacea) are concentrated in deep basins and along the continental slope, with a high probability of occurrence along the slope and in deep, offshore waters. Sea pens have been observed throughout the AOI, though additional studies are needed to determine their full distribution. The 2017 Summer RV Survey collected sea pens at two stations in Georges Basin, one of which was defined as a significant catch based on Kenchington et al. (2016a). A crinoid, the sponge *Stylocordila borealis,* and an ophiuroid were the most abundant morphotaxa in Georges Basin (Lacharité and Metaxas 2018). Biogenic habitat-forming species, such as corals, sponges, and sea pens, provide habitat and refuge from predation, as well as feeding and nursery grounds for a variety of fishes and invertebrates (Beazley et al. 2017, Buhl-Mortensen and Buhl-Mortensen 2018).

Offshore American Lobster (*Homarus americanus*) fishing in LFA 41 occurs within the NAFO Divisions 4X (Browns Bank and adjacent slope and basins) and within Canadian waters of 5Z (Georges Bank). The AOI overlaps with approximately half of LFA 40, an area closed to Lobster fishing, and parts of LFA 41. The Summer RV Survey in Division 4X show that over the last 36 years (1980–2016) the stratified mean number of lobsters per tow were the highest ever recorded, with pronounced increases in 2014. Offshore American Lobster populations, in particular within LFA 40, have been shown to have a higher proportion of large, ovigerous female lobsters than observed inshore. Abundance in the offshore varies seasonally with peaks in the summer months associated with the onset of spawning. Abundances of lobster recorded in the vicinity of the AOI during the Summer RV Survey are consistently amongst the highest on the Scotian Shelf. Based on the 2018 stock status update (DFO 2019a), the LFA 41 Lobster is in the Healthy Zone.

In the Maritimes Region, Atlantic Sea Scallop (*Placopecten magellanicus*) are distributed across Georges and Browns banks, in the Bay of Fundy, the offshore mid Scotian Shelf, and sporadically throughout the region. The Browns Bank portion of the AOI overlaps with two Atlantic Sea Scallop offshore management areas (Browns Bank north and Browns Bank south),

which divide one contiguous scallop population. The AOI encompasses the entire scallop fishing area in Browns Bank south and overlaps a small portion of the Browns Bank north Scallop Fishing Area.

Fish

The Summer RV Survey has documented 71 fish species within the AOI between 1970 and 2017. The top 20 most abundant species, including Haddock (*Melanogrammus aeglefinus*), Atlantic Cod, Silver Hake (*Merluccius bilinearis*), Yellowtail Flounder (*Pleuronectes ferruginea*), and Pollock (*Pollachius virens*), comprised nearly 80% of all observations. Species richness varies among habitats within the AOI (65 and 40 fish species for the channel-bank and basin components, respectively). Total species richness was lower in the channel (46) than on Browns Bank (58; <200 m depth), and the majority of survey sets with the highest species richness (i.e., those with 16–20 species) were found on Browns Bank (Figure 2). Based on species accumulation curves, the number of unique species has not leveled off, suggesting richness has not been completely characterized within each of the AOI components and the AOI overall. Within the AOI, it is likely that fish diversity will be highest in areas within and immediately surrounding complex topographic features, such as slopes, boulders, and deep-water coral concentrations. Redfish (*Sebastes* spp.), in particular, have been noted in close association with gorgonian corals in the Northeast Channel.

Habitat preferences for finfish species are a combination of depth, temperature, and to a lesser extent sediment type. The AOI is characterized by a diverse seascape of depth and temperature. With warm water inflows through the Channel and over Browns Bank, and rapid transitions of depth associated with the northeastern side of the channel, community assemblages on the bank correspondingly change as a function of depth.

For some species, depth is an important defining characteristic of habitat. Haddock, Atlantic Cod, and Yellowtail Flounder are restricted primarily to Browns Bank at depths shallower than 200 m; Greenland Halibut (*Reinhardtius hippoglossoides*) and White Hake are generally found deeper (>250 m). Other species, such as redfish spp. and Spiny Dogfish, can be found across a broad depth gradient.

Small areas of persistent high diversity (hotspots) have been recorded throughout the Bay of Fundy, the deeper waters of the Northeast Channel and Georges Basin, pockets along the shelf edge, the shallow coastal zone, and areas in northern NAFO Divisions 4VW (Ward-Paige and Bundy 2016).

Cluster analysis revealed two distinct groundfish groups, partitioning at approximately 207 m depth. Non-metric multidimensional scaling (nMDS) was used to visualize the distribution of these partitions. Species centroids in nMDS space also agree with the recorded depth preference for the species within the AOI. Partitioning identified by k-means clustering was clearly differentiated in nMDS space, with the Browns Bank fish community distinct from the Fundian Channel and Georges Basin. Overall, group dispersion (ß-diversity) is significantly lower in Georges Basin compared to the Channel and Browns Bank (permutation test for constrained correspondence analysis – $p<0.0001$ for each comparison), agreeing with measurements of species richness and species accumulation trajectories for each partition and the nMDS projection.

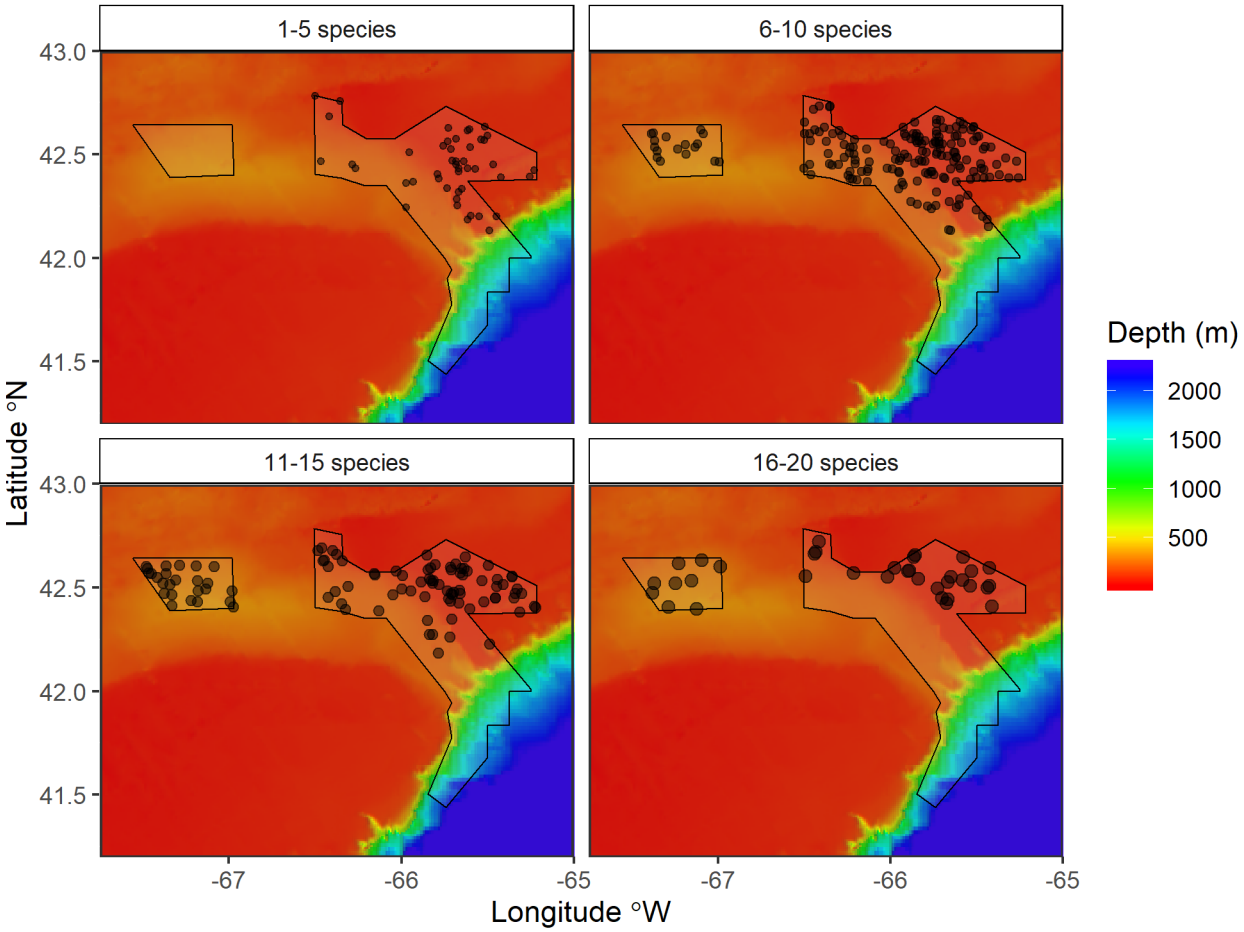

Figure 2. Distribution of species richness (360 sets classified into four discrete intervals of species richness, e.g., sets with 1–5 species) from the Summer RV Survey (1970–2017) within the AOI, and overlaid on bathymetry scaled to the maximum depth within the AOI (2251 m).

Horsman and Shackell (2009) identified important habitat for a variety of fish species on the Scotian Shelf, including forage species, predators, depleted species, and other dominant species observed in the Summer RV Survey. Forage species and influential predators represent Type 1 Ecologically Significant Species (DFO 2006), while dominant species occurred in >10% of all RV trawl sets. The top quintile (i.e., top 20th percentile) habitats for seven fish species that have been assessed by COSEWIC are shown in Figure 3, following the statistical approach outlined in Horsman and Shackell (2009) with RV data updated to include 2009–2016.

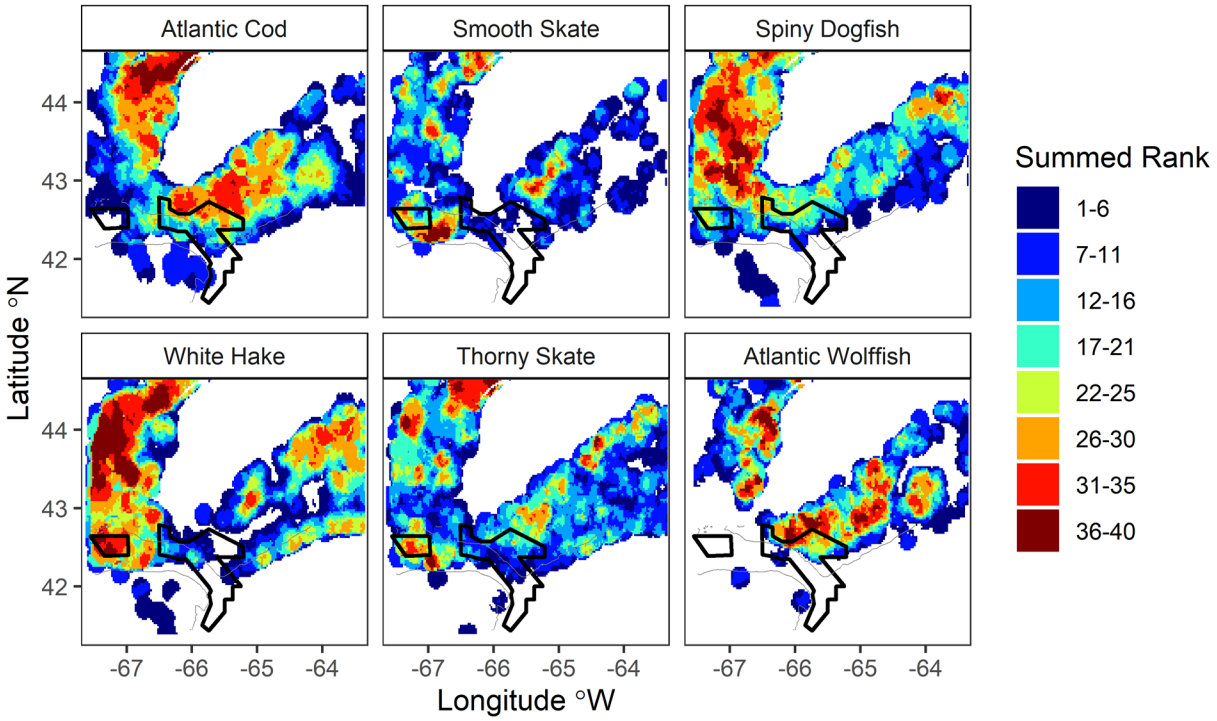

Figure 3. Persistent habitats represented as summed ranks (sum of distribution quantiles calculated within four time periods between 1970 and 2006) for Atlantic Cod, Smooth Skate, Spiny Dogfish, White Hake, Thorny Skate, and Atlantic Wolffish on the Scotian Shelf (for more details refer to Horsman and Shackell 2009). The black polygon denotes the boundary for the Area of Interest. Each of these species of concern has some persistent top quintile habitat within the AOI.

Atlantic Cod are a bottom dwelling fish found from Georges Bank to northern Labrador in Atlantic Canada. In 2010, the Maritimes Designatable Unit (DU) was split into the Laurentian South DU and the Southern DU (COSEWIC 2010a). The 4X Atlantic Cod (Endangered – COSEWIC) stock has been in the Critical Zone since 2011, and biomass has remained low since this time, with very low recruitment (DFO 2018b). Trends in survey biomass show a decline since the mid-1990s; though survey biomass increased from 2058 t in 2013 to 3068 t in 2017. These biomass estimates are the lowest in a time series since 1970 (DFO 2018b). The number of mature individuals remains below pre-1992 levels. An increase in total mortality on Cod in the 4X portion of the DU has contributed to the decline and subsequent lack of recovery for this stock. Cod were historically distributed across the inshore and offshore of the Bay of Fundy and Scotian Shelf. However, Cod along the Scotian Shelf have disappeared from the shelf edge, and are now concentrated almost exclusively on Browns, LaHave, Roseway, and Baccaro banks. The AOI includes representative habitat for Atlantic Cod including a portion of the persistent top quintile habitat identified in the Browns Bank portion of the AOI over the past four decades.

Haddock are a commercially important species that range from Cape Hatteras to southern Greenland in the western Atlantic. A major stock exists in NAFO Divisions 4X5Y, overlapping with the AOI. Browns Bank is a major spawning ground where spawning generally occurs from April to May. The 2017 biomass index is well below the short- (5 year; 49,967 t) and long-term (since 1970; 52,161 t) averages. High catches of Haddock within 4Xp are thought to reflect periods when above average year classes (i.e., 2000 and 2003) from Georges Bank (NAFO 5Z)

expanded into the Fundian Channel. The increase in landings from 4Xp also reflects directed fisheries for larger Haddock in the deeper waters of the Fundian Channel.

Pollock spawn offshore in several identified areas on the Scotian Shelf and one major area in the western Gulf of Maine (Stone 2012). Two management areas in the Maritimes Region exist for Pollock within the NAFO Divisions 4VWX5 (Canadian waters only). Within these management units, there are two population components: a slower-growing Eastern Component (4VW and 4Xmn) and a faster-growing Western Component (4Xopqrs and Canadian portions of Area 5) that overlaps with the AOI. In general, there has been a declining trend in the Western Component Pollock index since the late 1980s, an increasing trend from 2003–2007, followed by another decline to 2012. Since 2012, the survey biomass index has generally remained low (DFO 2018a).

White Hake are a demersal fish species that are caught in all groundfish fisheries in NAFO Divisions 4VWX5Zc. White Hake are found from North Carolina to Labrador, with the highest abundances in the Gulf of Maine and on Georges Bank (COSEWIC 2013). On the Scotian Shelf, White Hake (Threatened – COSEWIC) show the highest abundances in the Bay of Fundy and along the deep waters along the shelf break (Horsman and Shackell 2009). Adult and juvenile White Hake are commonly found on fine substrates, such as mud at the bottom of basins on the Scotian Shelf. White Hake are found over a wide range of depths (50–325 m) but prefer warmer, more saline waters with a temperature range of 5–9°C. Based on Horsman and Shackell (2009), the deeper portions of Georges Basin encompassed by the AOI boundaries are identified as a persistent top quintile habitat for White Hake on the Scotian Shelf (Figure 3).

Acadian Redfish (*Sebastes fasciatus)* are found exclusively in Canadian Atlantic waters and range from the Gulf of Maine (including the AOI) to the Gulf of St. Lawrence and Newfoundland. Acadian Redfish primarily live along continental slopes and in deep channels at depths of 150 to 300 m and are the most frequently observed fish taxa associated with cold-water corals (Gordon Jr and Kenchington 2007). Buhl-Mortensen and Mortensen (2005) found that, in the Northeast Channel, redfish were almost four times as common in video sequences with corals than sequences with boulders and no corals. In 2010, the Atlantic DU of Acadian Redfish was assessed as Threatened because of a decline in abundance of mature individuals by 99% over two generations. A time series of biomass indices for Unit 3 Acadian Redfish shows large inter-annual fluctuations. Smoothing of this time series shows a general decline from 1970 to 2000 but a general increase from 2000 onward, remaining above the upper stock reference point since 2004 (DFO 2019b). Since the 1990s, there has been no long-term trend in any one area, though it seems that the populations have been stable or shown slight increases since the initial decline (COSEWIC 2010b).

Atlantic Wolffish are found both inshore and offshore, preferring temperatures between 0.5–3°C and depth between 100–500 m, and they are captured as bycatch in various fisheries. Atlantic Wolffish have been observed on a variety of substrates including sand, gravel, and boulders. In 2012, COSEWIC re-evaluated the status of wolffish in Canada and concluded that Atlantic Wolffish continue to meet the criteria for a species of Special Concern under the *Species at Risk Act* (SARA) due to steep declines in abundance and area of occupancy. On the Scotian Shelf, Browns Bank represents persistent top quintile habitat for Atlantic Wolffish (Special Concern – SARA) (Horsman and Shackell 2009).

Atlantic Halibut (*Hippoglossus hippoglossus)* in Canadian waters are experiencing a period of high recruitment and population growth (DFO 2018c). They are most abundant at depths of 200 to 500 m in deep-water channels between banks and along the edge of the continental

shelf. Spawning sites for Halibut are unknown in the Northwest Atlantic, and data on egg and larval distributions are lacking. The AOI includes one of two distinct areas of persistent juvenile Atlantic Halibut abundance within the Scotian Shelf Bioregion (Figure 4; Boudreau et al. 2017). These regions of high juvenile abundance are consistently observed irrespective of the overall stock abundance (i.e., hotspot during periods of high and low population abundance), suggesting they are persistent and resilient. These two hotspots have persisted for more than three decades and are separated by more than 500 km, whereas connectivity in Atlantic Halibut is estimated to be <250 km.

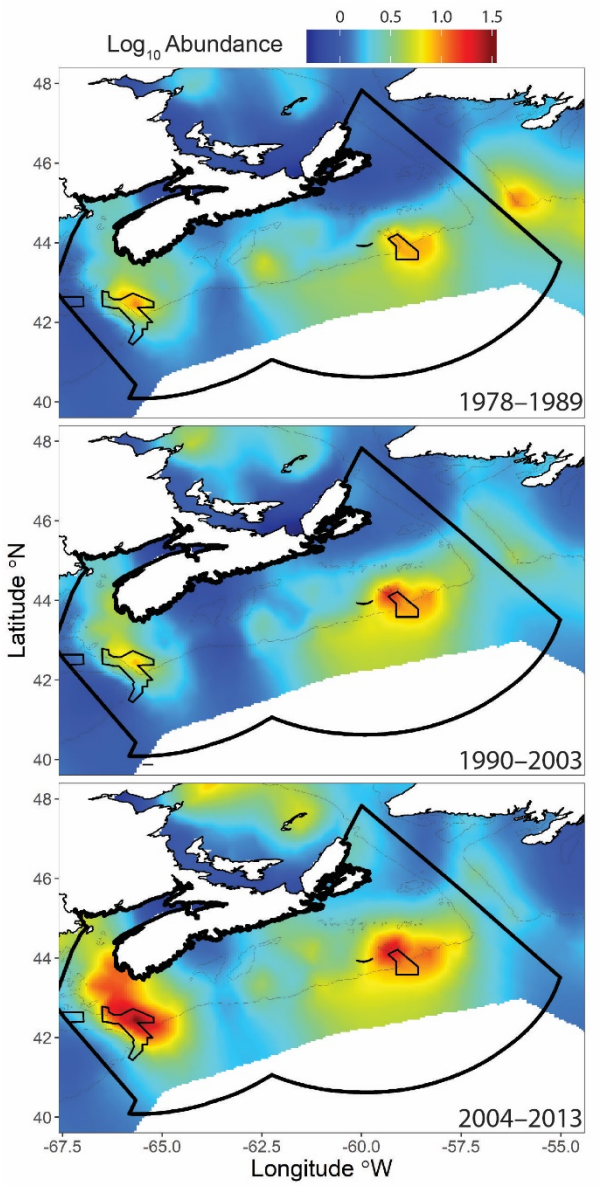

Figure 4. Distribution of juvenile Atlantic Halibut (Hippoglossus hippoglossus) abundance in Atlantic Canada showing two persistent areas of high abundance on the Scotian Shelf — one in Southwest Nova Scotia that overlaps with the AOI and one to the east that overlaps with the Gully Marine Protected Area (modified from Boudreau et al. 2017). The black polygons denote the boundary for the AOI, the Gully MPA, and the Maritimes Region (thicker black line).

Cusk (Endangered – COSEWIC) have undergone a loss of 85% of mature individuals over the past three generations as of their 2012 COSEWIC assessment (COSEWIC 2012a). Cusk are currently under consideration for addition to Schedule 1 of SARA. Cusk are considered to have been in the Cautious Zone since 2011, based on information from the Halibut Industry Survey. Based on a habitat suitability model, Harris et al. (2018) revealed that the Fundian Channel, including a large portion of the AOI, has highly suitable habitat for Cusk (Figure 5). Runnebaum et al. (2017) demonstrated that Georges Basin is also modeled as highly suitable habitat for Cusk based on National Oceanic and Atmospheric Administration (NOAA) spring and fall surveys. There is no evidence of spatially separated populations of Cusk. The Recovery Potential Assessment for Cusk recommends closing areas of high Cusk abundance or areas where Cusk is the main species caught in the longline and lobster fisheries, which includes the channel portion of the AOI (DFO 2014).

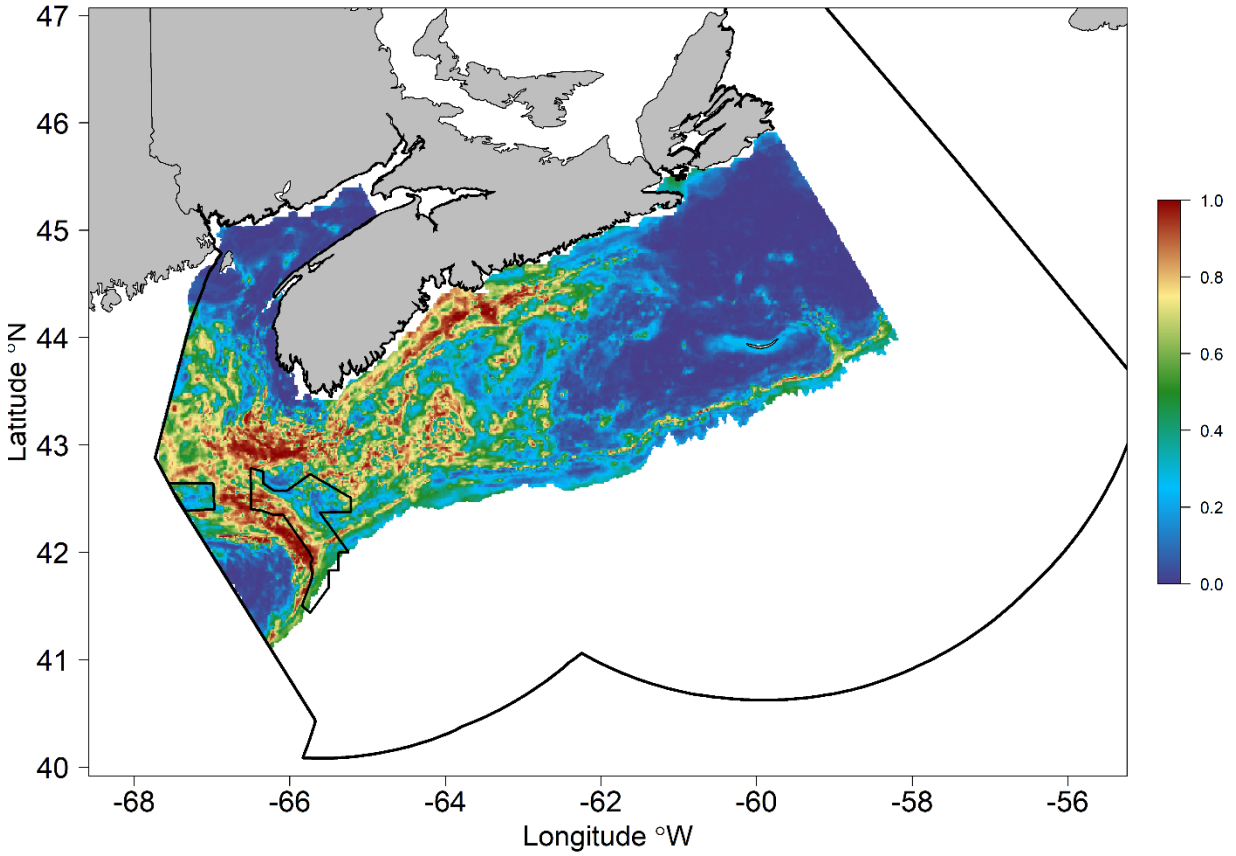

Figure 5. Habitat suitability model (predicted presence) for Cusk (Brosme brosme) for the Maritimes Region predicted using a random forest method. The probability of presence is shown, with red indicating 100% probability of presence, and blue indicating 0% probability of presence (modified with permission from Harris et al. 2018). The black polygons denote the boundary for the AOI and the Maritimes Region.

Smooth Skate (Special Concern – COSEWIC) are endemic to North America and prefer soft mud and clay substrates, with the densest concentrations between 150 m and 550 m, though they may also be found on sand, gravel, and pebbles on the offshore banks in the Gulf of

Maine. Smooth Skate within the AOI are part of the Laurentian-Scotian DU COSEWIC (2012b). Georges Basin, specifically the region between the two proposed components of the AOI, has been shown to be persistent top quintile habitat since the 1970s (Horsman and Shackell 2009).

Thorny Skate (Special Concern – COSEWIC) are found in the greatest densities on the Grand Banks, and they are less abundant in southern areas such as the Western Scotian Shelf. Thorny Skate are considered a single DU in Canadian waters, and they have undergone severe population declines over the southern part of their historic distribution. This decline has continued in the southern portion of their range despite a reduction in fishing mortality (COSEWIC 2012c). Georges Basin has been shown to be persistent top quintile habitat for Thorny Skate in the vicinity of the AOI (Horsman and Shackell 2009).

Winter Skate (*Leucoraja ocellata*) in Canada are found in three main concentrations, including the Western Scotian Shelf/Bay of Fundy. Browns Bank, including part of the AOI, and the Bay of Fundy are the only areas of persistent top quintile habitat for Winter Skate on the Western Scotian Shelf (Horsman and Shackell 2009). The Western Scotian Shelf – Georges Bank population was re-assessed as Not At Risk by COSEWIC (2015). However, in the Gulf of St Lawrence and Eastern Scotian Shelf/Southern Newfoundland, declines of 99% over the last three generations and 98% over the last 2.4 generations have occurred, respectively.

Large Pelagic Fishes

A diversity of large pelagic fishes, including tunas, billfishes and sharks, are seasonally present and may forage within the AOI. Given the highly migratory nature of many of these species, which spend only part of the year foraging in Canadian waters as they track prey and suitable temperature conditions, abundance trends are conducted on broad geographic scales. Fisheries independent monitoring of pelagic species is not conducted in Atlantic Canada; however, significant information on species presence and distribution can be gained from examining Canadian longline fleet catch data. A query of the Maritime Fisheries Information System landings database, from 2010 to 2017, included 10 large pelagic species with landings from sets in the AOI. These species include Swordfish (*Xiphias gladius*), Albacore Tuna (*Thunnus alalunga*), Bigeye Tuna (*Thunnus obesus*), Atlantic Bluefin Tuna (*Thunnus thynnus*), Skipjack Tuna (*Katsuwonus pelamis*), Yellowfin Tuna (*Thunnus albacares*), Blue Marlin (*Makaira nigricans*), White Marlin (*Kajikia albida*), Porbeagle Shark (*Lamna nasus*), and Shortfin Mako Shark (*Isurus oxyrinchus*).

Swordfish and Bluefin Tuna are seasonally present and may forage within and migrate through the AOI (Figure 6). Distinct oceanographic processes, including upwelling at the mouth of the Fundian Channel, internal waves generated within the Channel, and local gyres, in conjunction with dynamic features associated with the Gulf Stream, concentrate plankton and forage species such as squid and Atlantic Herring, attracting large pelagic fishes to the AOI and continental slope. Other tunas and large pelagic species, such as Mahi Mahi (*Coryphaena hippurus*) and Blue Marlin, are occasional visitors to the AOI.

The AOI may also function as seasonal migratory habitat for large pelagic fishes, including sharks. Nine of 12 Basking Sharks (*Cetorhinus maximus*) tagged with pop-up satellite tags in the Bay of Fundy between 2011 and 2015 swam through the Fundian Channel as they headed for the shelf break. Three sharks that had longer deployments were also tracked through this

region as they returned to the Bay of Fundy[2]. Although this is a small sample size, these data revealed that Basking Sharks migrate through the Fundian Channel while entering and leaving the Bay of Fundy.

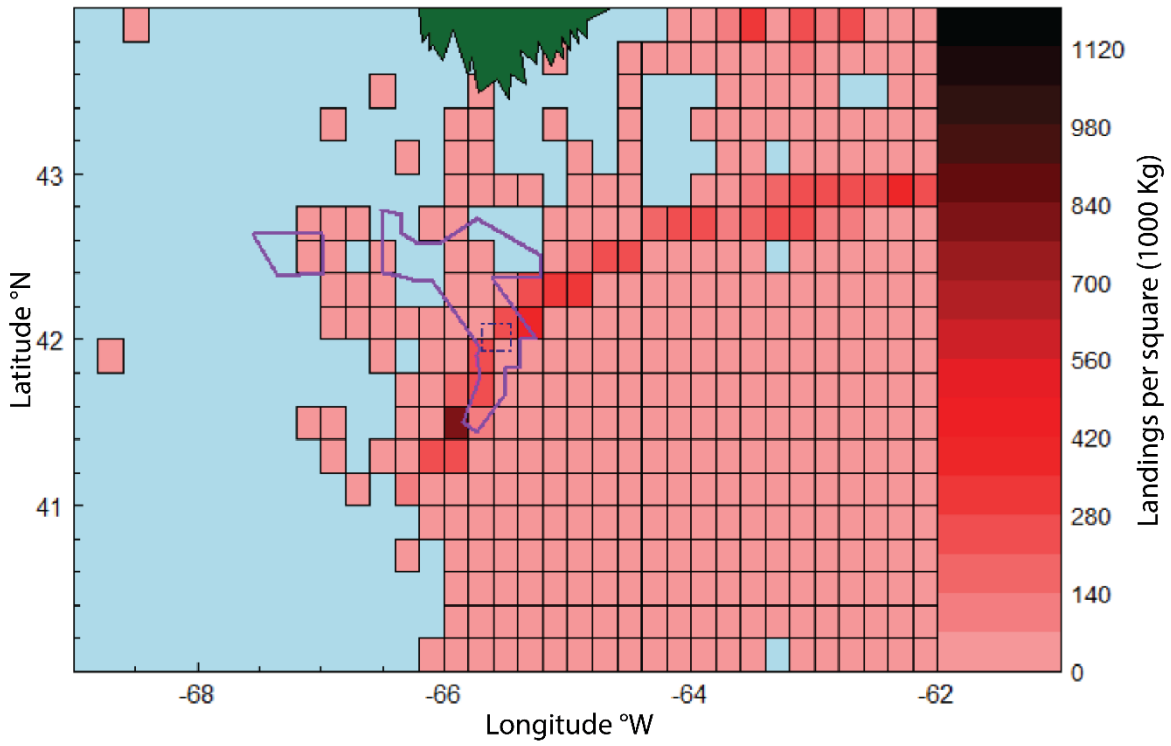

Figure 6. Distribution of Swordfish (Xiphias gladius) landings from the Atlantic Canadian Swordfish/Other Tuna Pelagic Longline Fishery for 2004–2018 for the area around the AOI (outlined in purple) using 0.2 degree x 0.2 degree cells.

Marine Mammals

At least 22 species of cetaceans are known to occur in the waters of Atlantic Canada (Gomez-Salazar and Moors-Murphy 2014). Many of these species have been observed off the southwestern coast of Nova Scotia; however, no comprehensive systematic surveys on the occurrence or distribution of cetaceans in the AOI have been conducted, and the abundance of cetaceans has not been estimated for this area. Most of the sightings that do exist for this area are opportunistic in nature. A comprehensive analysis of any associated observational effort for these data is necessary to fully characterize cetacean distribution in the area over temporal and spatial scales. Baleen whales identified within the study area include Blue Whale (*Balaenoptera musculus*), Fin Whale (*Balaenoptera physalus*), Sei Whale (*Balaenoptera borealis*), Minke Whale (*Balaenoptera acutorostrata*), Humpback Whale (*Megaptera novaeangliae*), and North Atlantic Right Whale (*Eubalaena glacialis*). Large odontocetes identified within the study area include Cuvier's Beaked Whale (*Ziphius cavirostris*), Killer Whale (*Orcinus orca*), Long-finned

[2]Andrew Westgate (University of North Carolina Wilmington) – unpublished data

Pilot Whale (*Globicephala melas*), Northern Bottlenose Whale (*Hyperoodon ampullatus*), Sowerby's Beaked Whale (*Mesoplodon bidens*), and Sperm Whale (*Physeter macrocephalus*). Small odontocetes identified within the study area include Common Bottlenose Dolphin (*Tursiops truncates*), Atlantic White-sided Dolphin (*Lagenorhynchus acutus*), Common Dolphin (*Delphinus delphis*), Harbour Porpoise (*Phocoena phocoena*), Risso's Dolphin (*Grampus griseus*), Striped Dolphin (*Stenella coeruleoalba*), and White-beaked Dolphin (*Lagenorhynchus albirostris*).

The continental shelf edge has been identified as an important foraging area for Blue Whale (*Balaenoptera musculus*; Endangered – SARA), including a portion of the AOI (Lesage et al. 2018). This foraging habitat was identified using information on Blue Whale distribution in combination with areas of krill aggregation (observed or predicted) (Gomez et al. 2017, Moors-Murphy et al. 2019). There are estimated to be fewer than 250 mature individuals that occur in Canada and there are indications of low recruitment and calving rates (COSEWIC 2002, Gomez-Salazar and Moors-Murphy 2014).

Sowerby's Beaked Whale (*Mesoplodon bidens*; Special Concern – COSEWIC) and Northern Bottlenose Whale (*Hyperoodon ampullatus*; Endangered – SARA) are distributed along the Scotian Shelf slope near the Fundian Channel, and in submarine canyons on the eastern Scotian Shelf (DFO 2016b, 2017a). These species are present within the AOI and their presence is supported by recent acoustic and visual detections from NOAA and the Whitehead lab at Dalhousie University. Sowerby's and Northern Bottlenose whales, like all beaked whales, are vulnerable species that are particularly sensitive to noise resulting from human activities (Gomez-Salazar and Moors-Murphy 2014).

Sea Turtles

Leatherback Sea Turtles (*Dermochelys coriacea*; Endangered – SARA) undergo annual migrations from southern nesting grounds to the Gulf of St. Lawrence to feed. Three primary areas of important habitat were previously identified from 70 satellite-tagged Leatherback Sea Turtles; for animals that have been tagged, it seems that there is a relatively higher probability of residency in and near the Fundian Channel (DFO 2012). These areas were identified as important foraging habitat for Leatherbacks; however, additional turtles have been tagged since the identification of this habitat and there is a plan to update this information by 2020 (Mike James, personal communication). Leatherbacks are entangled in a variety of fishing gears as bycatch, including gear used by fisheries in the AOI.

The estimated range of **Loggerhead Sea Turtles** (*Caretta caretta*; Endangered – SARA) in Atlantic Canadian waters extends from Georges Bank, along the edge of the Scotian Shelf and Grand Banks, to the limits of the Exclusive Economic Zone, with occasional forays into waters on the shelf. Atlantic Canadian Loggerhead Sea Turtle habitat seems to be partially defined geographically and temporally by sea-surface temperature. Thermally dynamic waters along the shelf break and offshore are favoured, and Loggerheads are encountered in waters greater than 15°C, especially between 20–25°C. The primary use of habitat in Atlantic Canadian waters is thought to be for foraging. Given the information that is currently available, the identification of important habitat for the Loggerhead Sea Turtle is not possible at this time. The only documented source of human-induced harm or mortality of Loggerhead Sea Turtles in Canadian waters was associated with the tuna and swordfish longline fishery (Paul et al. 2010).

Marine Birds

Although most species known to occur in significant numbers within the AOI area do so outside of their breeding season, some species shown to be relatively abundant are not known to breed in the Northern Hemisphere (e.g., Great Shearwater (*Puffinus gravis*), Sooty Shearwater (*Ardenna grisea*), and Wilson's Storm-petrel (*Oceanites oceanicus*)). Given an approximate distance of 75 km from the AOI to the nearest breeding habitat, and based on best available information on mean maximum foraging range, only Leach's Storm-petrel (*Oceanodroma leucorhoa*) has a foraging range enabling the species to reach both AOI components during the breeding season (Pollet et al. 2014), with evidence of use by individuals from two large colonies in the bioregion (Hedd et al. 2018). Historically, Northern Gannet (*Morus bassanus*) also could have accessed the AOI during the breeding season, as colonies of this species existed on nearby coastal islands. However, this species remains locally extirpated as a breeder.

The AOI and Georges Bank are characterized by a variety of well-known enduring habitat features known to host substantial seabird diversity. Specifically, offshore habitats of the AOI area include offshore bank, deep water channel and basin habitats, and oceanographic features linked to elevated primary productivity (e.g., upwelling and gyres). The abundance and diversity of marine birds in the vicinity of the AOI is reflective of an abundant and varied prey base. The AOI has supported top decile (i.e., top 10th percentile) concentrations of most marine bird functional guilds at various annual and decadal timescales based on bird observer data from the 1960s onward. The avifaunal community includes species that access prey on the near-surface, such as storm-petrels, phalaropes, gulls, terns, skuas, and jaegers; plunge divers, such as Northern Gannet; shallow divers, such as shearwaters; and deep divers such as auks that can reach nearly 200 m in depth. The prey base of seabirds ranges from zooplankton to squid and fish. This broad prey base and association with productive, prey abundant areas, makes certain marine birds a useful indicator of biodiversity, ecosystem productivity, and overall ecosystem health.

Species at Risk

A variety of marine fish, mammals, turtles, and birds that have been observed in the AOI are assessed as at risk by COSEWIC and/or listed under SARA and the International Union for the Conservation of Nature (IUCN). Some of these species may be considered as conservation priorities depending on their prevalence, representative habitat, and relative occurrence within the AOI. In addition to those mentioned previously, Roundnose Grenadier (*Coryphaenoides rupestris*) are assessed as Endangered by COSEWIC; Roseate Tern (*Sterna dougallii*) and White Shark (*Carcharodon carcharias*) are listed as Endangered under SARA; and American Plaice (*Hippoglossoides platessoides*), Northern Wolffish (*Anarhichas denticulatus*), and Spotted Wolffish (*Anarhichas minor*) are assessed as Threatened by COSEWIC.

The Black-capped Petrel (*Pterodroma hasitata*) and the Bermuda Petrel (*Pterodroma cahow*) are assessed as Endangered by the IUCN, but they have not been assessed by COSEWIC. These species are known to forage within the AOI boundaries.

Knowledge Gaps

The information summarized in the ecological overview of the AOI was based on data from the DFO Multispecies Summer RV Survey, Atlantic Zone Monitoring Program (AZMP), DFO-Industry Halibut Longline Survey, Continuous Plankton Recorder, NOAA seasonal surveys, DFO's Whale Sightings Database, fisheries-dependent landings and catch per unit effort

(CPUE) data for tunas and Swordfish, tagging data (unpublished), and academic research, providing a comprehensive understanding of the communities within the AOI.

Data documenting the full distribution of corals and sponges within the AOI, knowledge of the infaunal community composition, and population genetic information for most fish and invertebrate populations is not currently available. While this information could assist boundary delimitation and zoning within a potential MPA, its absence does not preclude the development of conservation priorities.

The Summer RV Survey provided the majority of the groundfish and invertebrate diversity information used in this ecological overview. Therefore, seasonal migrations, variations in abundance, and changes in groundfish and invertebrate community composition within the AOI remain largely unknown.

Observations of faunal composition in deep water slope habitat are limited to adjacent strata in the Summer RV Survey. There have been no Summer RV Survey sets conducted deeper than 400 m within the AOI. The community composition of these deep water sets adjacent to the AOI are summarized in Clark and Emberley (2011).

Finally, the movements and seasonal distributions of large pelagic fishes, sharks, cetaceans, and sea turtles in the vicinity of the AOI remain largely uncharacterized. Many species occur in the summer months and are presumed to be feeding based on the productivity and oceanographic features of the AOI; however, no direct observations of feeding in association with the features of the AOI have been recorded.

Sources of Uncertainty

Key data uncertainties include species catchability for specific survey gears, use of opportunistic sightings in the absence of systematic surveys for some species, and limited seasonal or temporal coverage of surveys and sampling.

Most of the sightings of cetaceans for this area are opportunistic in nature. Therefore, we expect the data used for cetacean sightings reflect presence of species at specific time periods. Data do not reflect abundances or diversity of cetacean species in the area.

The trawl gear used in the DFO Summer RV survey has known catchability issues (Harley et al. 2001) for some pelagic and benthic fish species that burrow or hide in crevices, including Cusk, Atlantic Wolffish, and Atlantic Halibut. For these fishes, the Halibut Industry Survey was used to supplement patterns of distribution, which includes other catchability issues (e.g., bait; Cox et al. 2018).

Some data collections, like tagging and passive acoustics, have a shorter time series on which to characterize the usage of the AOI as habitat. Approaches to integrating these data sources with traditional sampling methods are under development.

Climate Change Considerations

There is some uncertainty about how key biological and physical attributes of the AOI have been responding, or will respond, to the impacts of a changing marine climate. Specifically, we acknowledge the uncertainty regarding the impacts of:

- the observed shift in zooplankton communities within and in the vicinity of the AOI on productivity and distribution of predators, and overall use of the area by pelagic species;

- ocean acidification and warming on corals and sponges, which are noted as conservation priorities;
- climate change and associated warming temperatures on the distribution, biomass, and resilience of groundfish and invertebrate communities within the AOI; and
- changing fish and invertebrate community composition associated with the increased prevalence of warm-water species and loss of habitat for some colder adapted species, especially in the Western Scotian Shelf.

Stortini et al. (2015) assessed the vulnerability of 33 fish and invertebrate species to projected warming on the Scotian Shelf under mild (+0.7°C) and severe (+3.0°C) scenarios. Vulnerability was defined as the degree to which a system is susceptible to adverse effects of climate change, or is unable to cope with these adverse effects according to the Intergovernmental Panel on Climate Change. Populations of fish in the southwest portion of the Scotian Shelf were found to be more vulnerable than those in the northeast, and 45% of populations examined in the study may be vulnerable under the severe warming scenario. One species, the Moustache Sculpin (*Triglops murrayi*), was the only species with a relatively high vulnerability score under the mild warming scenario. Under the severe warming scenario, 18 species or populations, including Western Scotian Shelf Cusk, Smooth Skate, Winter Skate, Little Skate, Western Scotian Shelf Pollock, Western Scotian Shelf Cod, and Atlantic Wolffish, are considered vulnerable.

CONCLUSIONS AND ADVICE

The Fundian Channel – Browns Bank is a large, offshore AOI covering a wide range of bathymetries and substrate types, creating habitat complexity that facilitates a diverse assemblage of benthic and pelagic marine fauna. Based on WWF Canada (2009), the AOI consists of four main habitat classifications: Outer Gulf of Maine (basin and channel), Scotian Slope – fan, Outer Scotian Shelf – saddle, and Outer Scotian Shelf – bank.

Based on clustering analyses, the AOI can broadly be divided into two communities – the shallower community on Browns Bank, and the deeper community within the Fundian Channel, Georges Basin, and the continental slope. Trawl sets from the DFO Summer RV Survey since the 1970s show the Browns Bank and Georges Basin to be the most species rich regions within the AOI, with up to 20 species of fish and invertebrates captured per individual trawl. The Browns Bank portion of the AOI is also a persistent hotspot for juvenile Atlantic Halibut, and the majority of Atlantic Cod, Haddock, Silver Hake, Pollock, American Plaice, flounder, Atlantic Lobster, and Sea Scallop captured in the Summer RV Survey on the Western Scotian Shelf are caught on Browns Bank.

The Fundian Channel portion of the AOI is considerably deeper than Browns Bank (>200 m), and is known to contain some of the densest aggregations of deep-water corals in Atlantic Canada. These corals have relatively low recruitment and very slow growth, suggesting that some of the larger individuals may be hundreds of years old. Corals provide important biogenic habitat for invertebrates and fish, such as redfish and juvenile Cod. Sea pens and sponges also inhabit the Fundian Channel, including the Russian Hat Sponge (*V. pourtalesi*), which is a vulnerable marine ecosystem indicator species. The Fundian Channel is also highly suitable habitat for Cusk, a species assessed as Endangered by COSEWIC.

The Georges Basin portion of the AOI spans one of the deepest areas of the continental Scotian Shelf, with depths reaching approximately 350 m. This area is primarily characterized by mud

substrate with sporadic boulder and cobble glacial relicts. It is relatively species-rich, with records of sea pens and some large gorgonian corals. White Hake, Cusk, Smooth Skate, Thorny Skate, and Atlantic Hagfish are more abundant within Georges Basin relative to other components of the AOI.

A diverse and abundant prey base within the AOI, including pelagic zooplankton, squid, and fish such as Mackerel and Atlantic Herring, supports a high diversity of marine birds, including most functional guilds. The avifaunal community includes species that access prey on the surface, such as storm-petrels and phalaropes; those that can access waters to about 1 m, including gulls, terns, skuas and jaegers; plunge divers, such as Northern Gannet; shallow divers, such as shearwaters; and deep divers such as auks that can reach nearly 200 m in depth. Oceanographic features, including upwelling and high concentrations of chlorophyll-a, attract larger predators such as tunas, Swordfish, sea turtles, Blue Whales, and other cetaceans.

Potential threats to the AOI include anthropogenic activities and climate change. Notably the AOI is situated at the northern limit of the Gulf of Maine, which has been noted as a global hotspot for ocean warming. Bottom and surface temperatures have been warming consistently over the past decade on the Scotian Shelf and Gulf of Maine, with a record warm year in 2012. The AZMP report for 2016 notes above normal winter sea-surface and bottom temperatures on the Scotian Shelf and Bay of Fundy (DFO 2017b), and in April 2018 water column temperatures in the Northeast Channel reached a record-breaking 14°C. Under a severe climate warming scenario, Stortini et al. (2015) modeled that 18 species or specific populations of fish on the Scotian Shelf have a high vulnerability to warming ocean temperatures. The majority of these are skates and Western Scotian Shelf populations of groundfish such as Cod and Cusk, including those that are found within the AOI. There is evidence that a regime shift may be underway in the Gulf of Maine, as shown by a general decline in large copepods and their replacement with smaller-bodied, warm-water species; these copepods form the basis of the marine food web. A lack of recovery in Atlantic Cod in NAFO Divisions 4X5Y may also be the result of a regime shift in their prey abundance or from climate change, as commercial fishing for Cod has remained very low in this region.

The resiliency of the AOI to natural or anthropogenic disturbance and climate change remains unknown; if corals or sponges are physically damaged, they may take decades to recover. Bottom-contact fishing, in particular, may damage or destroy Gorgonian corals that have low recruitment rates and very slow growth, and while the densest aggregations of these corals are protected by the NECCCA, this small fisheries closure does not protect all of the corals in the area. The magnitude of the influence of ocean acidification, associated with climate change, on the growth and recruitment of coral and shellfish species is unknown.

Sounds (noise) generated by human activities such as hydrocarbon exploration, shipping, and military-exercises, are causing large-scale changes in the marine acoustic environment. Noise can have a broad variety of effects on marine mammals, sea turtles, fish, and zooplankton. Effects of noise on marine mammals can include loss of hearing sensitivity, deafness, behavioural changes, displacement, and induce stress responses. Further, noise from human activities can interfere with an individuals' ability to detect, recognize and discriminate sounds used for foraging, conspecific communications, navigation, and predator/hazard avoidance.

Systematic DFO surveys, particularly the Summer RV Survey, AZMP surveys, and research by other DFO and academic scientists will be important for monitoring this large system over time. The Summer RV Survey represents an important time-series set describing the faunal composition and relative trends in abundance for the AOI. Maintenance of this dataset will be

essential for any long-term monitoring program. However, the current extent of the survey is limited to Browns Bank, Georges Basin, and sets in the shallow component of the Fundian Channel in areas devoid of sensitive biogenic habitat (i.e., gorgonian corals). Non-invasive approaches such as camera surveys are important for evaluating marine communities in association with these sensitive habitats.

Chemical and physical oceanography data collected by AZMP on the Browns Bank and Portsmouth lines will be useful to continue to understand how factors such as temperature, salinity, nutrients, and dissolved oxygen structure the animal communities within and beyond the AOI. The DFO-Industry Halibut Longline Survey may also help inform the status of fishes that are not well-sampled by the RV Survey, such as Cusk, Halibut, Atlantic Wolffish, and Hagfish. Current seabed characterization by multibeam and sediment samples over the offshore banks (Browns and Georges) covers a significant portion of the AOI. However, large contiguous gaps in this coverage exist, in particular northern George's Basin and the Scotian Shelf Slope. Multibeam data collected over these unsurveyed areas is required to complete the evaluation of seabed characteristics in the area and provide an important baseline for habitat characterization in the AOI.

Conservation Priorities

Potential conservation priorities for the AOI were identified prior to the CSAS Science Peer-Review process by the Oceans Management Program. These conservation priorities were assessed through this CSAS review and were either recommended to be retained, modified, or rejected based on the strength of available scientific evidence. Features were assessed against the Ecologically and Biologically Significant Area (EBSA) criteria of aggregation, uniqueness, and fitness consequences (DFO 2004), or the species-based vulnerability, conservation status, and Ecologically Significant Species criteria.

While consensus was reached on the majority of proposed conservation priorities, based on whether sufficient evidence existed for their inclusion, a minority view was expressed on the inclusion of persistent juvenile Atlantic Halibut as a conservation priority. This conservation priority was proposed based on analysis that indicates there has been a hotspot for juvenile Halibut on southern Browns Bank that has persisted over the past three decades. While there was agreement that this hotspot is a feature of the AOI, that it is persistent, and that the hotspot is currently expanding, a minority view was presented that the mature Halibut stock is currently healthy and existing management measures prevent/reduce juvenile Halibut fishing mortality, and, therefore, this feature should not be considered as a conservation priority for the AOI.

Additionally, the following features were discussed but not supported as Conservation Priorities for the AOI based on the information that was available for review:

- Habitat for Smooth Skate: Did not meet decline or aggregation criteria.
- Habitat for redfish: Did not meet decline or aggregation criteria.
- Habitat for Spiny Dogfish: Did not meet aggregation criteria and stock status was uncertain (did not meet decline criteria).
- Habitat for Roundnose Grenadier: Did not meet aggregation criteria.
- Benthic invertebrate diversity hotspots: Not supported as a conservation priority on its own, but is captured under the conservation priority related to the diverse representation of habitats types.

- Fish diversity hotspots: Not supported as a conservation priority on its own, but captured under the conservation priority related to the diverse representation of habitats types.
- Migratory habitat between southern and temperate waters and on/off shelf movements: Considered a feature of the AOI but did not meet aggregation criteria.
- Significant concentrations of sea pens: Did not meet aggregation criteria, but would be expected to receive ancillary benefit.
- Feeding area for sea turtles: Did not meet aggregation criteria.

Should adjustments to the AOI boundary be made, new information becomes available, or shifts in distribution occur, these could be reassessed as conservation priorities through a review process.

The following features (Table 1) were supported as conservation priorities by the majority of participants, based on the information that was available for review:

Habitat

- Diverse representation of habitat types, including basin, bank, deep water slope and channel habitats, and their associated fish and invertebrate communities
- Persistent habitat for juvenile Atlantic Halibut
- Concentrations of large mature female lobster
- Suitable habitat for Sowerby's Beaked Whale and Northern Bottlenose Whale

Biodiversity

- Deep-water corals
- Significant concentrations of sponges
- Representative habitat for Atlantic Cod, Atlantic Wolffish, Winter Skate, Thorny Skate, and White Hake
- Highly suitable habitat for Cusk

Productivity

- The collection of oceanographic features, such as internal waves, areas of upwelling, and occasional presence of Gulf current and warm-core rings, at the mouth of the Fundian Channel that make it a highly productive area that is associated with the presence of large pelagic fishes, sea turtles, and cetaceans
- Blue Whale foraging area
- Foraging ground for most functional guilds of marine birds, particularly Leach's Storm Petrel (*Oceanodroma leucorhoa*)

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SOURCES OF INFORMATION

This Science Advisory Report is from the Regional Peer Review Process of the Biophysical and Ecological Overview of the Fundian Channel – Browns Bank Area of Interest held November 27–29, 2018, with follow up meetings on December 19th, 2018, and February 26, 2019. Additional publications from this meeting will be posted on the *Fisheries and Oceans Canada (DFO) Science Advisory Schedule* as they become available.

Beazley, L., Kenchington, E., and Lirette, C. 2017. Species Distribution Modelling and Kernel Density Analysis of Benthic Ecologically and Biologically Significant Areas (EBSAs) and Other Benthic Fauna in the Maritimes Region. Fisheries and Oceans Canada= Pêches et océans Canada.

Boudreau, S.A., Shackell, N.L., Carson, S., and den Heyer, C.E. 2017. Connectivity, persistence, and loss of high abundance areas of a recovering marine fish population in the Northwest Atlantic Ocean. Ecology and evolution 7(22): 9739–9749.

Bryan, T.L., and Metaxas, A. 2007. Predicting suitable habitat for deep-water gorgonian corals on the Atlantic and Pacific Continental Margins of North America. Marine Ecology Progress Series 330: 113–126.

Buhl-Mortensen, L., and Buhl-Mortensen, P. 2018. Cold Temperate Coral Habitats. *In* Corals in a Changing World. InTech.

Buhl-Mortensen, L., and Mortensen, P.B. 2005. Distribution and diversity of species associated with deep-sea gorgonian corals off Atlantic Canada. *In* Cold-water corals and ecosystems. Springer. pp. 849–879.

Clark, D.S., and Emberley, J. 2011. Update of the 2010 summer Scotian Shelf and Bay of Fundy Research Vessel Survey. Can. Data Rep. Fish. Aquat. Sci. 1238.

COSEWIC. 2002. COSEWIC assessment and update status report on the Blue Whale *Balaenoptera musculus* in Canada. Committee on the Status of Endangered Wildlife in Canada Ottawa: vi + 32 pp.

COSEWIC. 2010a. COSEWIC assessment and status report on the Atlantic Cod *Gadus morhua* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa: xiii + 105 p.

COSEWIC. 2010b. COSEWIC assessment and status report on the Deepwater Redfish/Acadian Redfish complex *Sebastes mentella* and *Sebastes fasciatus,* in Canada. Committee on the Status of Endangered Wildlife in Canada: Ottawa. x + 80.

COSEWIC. 2012a. COSEWIC Assessment and Status Report on the Cusk *Brosme Brosme* in Canada. Committee on the Status of Endangered Wildlife in Canada.

COSEWIC. 2012b. COSEWIC assessment and status report on the Smooth Skate *Malacoraja senta* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa: xix + 77 p.

COSEWIC. 2012c. COSEWIC assessment and status report on the Thorny Skate *Amblyraja radiata* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa: ix + 75 pp.

COSEWIC. 2013. COSEWIC assessment and status report on the White Hake *Urophycis tenuis* Southern Gulf of St. Lawrence population Atlantic and Northern Gulf of St. Lawrence population in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa: xiii + 45 p.

COSEWIC. 2015. COSEWIC assessment and status report on the Winter Skate Leucoraja ocellata, Gulf of St. Lawrence population, Eastern Scotian Shelf - Newfoundland population and Western Scotian Shelf - Georges Bank population in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xviii + 46 pp. .

Cox, S.P., Benson, A.J., and Doherty, B. 2018. Re-design of the joint industry-DFO Atlantic Halibut (*Hippoglossus hipoglossus*) survey off the Scotian Shelf and Grand Banks. DFO Can. Sci. Advis. Sec. Res. Doc. 2018/020: v + 50 p.

DFO. 2004. Identification of Ecologically and Biologically Significant Areas. DFO Can. Sci. Advis. Sec. Ecosystem Status Rep. 2004/006.

DFO. 2006. Identification of Ecologically Significant Species and Community Properties. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2006/041.

DFO. 2012. Using satellite tracking data to define important habitat for Leatherback Turtles in Atlantic Canada. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2012/036.

DFO. 2014. Update to the Recovery Potential for Cusk in Canadian Waters. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2014/048.

DFO. 2016a. Evaluation of hierarchical marine ecological classification systems for Pacific and Maritimes Regions. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2016/003.

DFO. 2016b. Recovery Strategy for the Northern Bottlenose Whale, (*Hyperoodan ampullatus*), Scotian Shelf population, in Atlantic Canadian Waters [Final]. . Species at Risk Act Recovery Strategy Series Fisheries and Oceans Canada, Ottawa: vii + 70 pp.

DFO. 2017a. Management Plan for the Sowerby's Beaked Whale (*Mesoplodon bidens*) in Canada. Species at Risk act Management Plan Series Fisheries and Oceans Canada, Ottawa: vii + 70 pp.

DFO. 2017b. Oceanographic conditions in the Atlantic Zone in 2016. DFO can. Sci. Advis. Sec. Sci. Advis. Rep. 2017/031.

DFO. 2018a. Harvest control rule update for Western Component Pollock (*Pollachius virens*) in NAFO divisions 4Xopqrs5. DFO Can. Sci. Advis. Sec. Sci. Resp. 2018/023.

DFO. 2018b. Stock status update of Atlantic Cod (*Gadus morhua*) in NAFO Divisions 4X5Yb. DFO Can. Sci. Advis. Sec. Sci. Resp. 2018/020.

DFO. 2018c. Stock status update of Atlantic Halibut (*Hippoglossus hippoglossus*) on the Scotian Shelf and Southern Grand Banks in NAFO Divisions 3NOPs4VWX5ZC. DFO Can. Sci. Advis. Sec. Sci. Resp. 2018/022.

DFO. 2019a. Stock Status Update of American Lobster (*Homarus americanus*) in Lobster Fishing Area 41 (4X + 5Zc). DFO Can. Sci. Advis. Sec. Sci. Resp. 2019/023.

DFO. 2019b. Stock Status Update of Unit 3 Redfish. DFO Can. Sci. Advis. Sec. Sci. Resp. 2019/014.

Gledhill, D.K., White, M.M., Salisbury, J., Thomas, H., Mlsna, I., Liebman, M., Mook, B., Grear, J., Candelmo, A.C., and Chambers, R.C. 2015. Ocean and coastal acidification off New England and Nova Scotia. Oceanography 28(2): 182–197.

Gomez-Salazar, C., and Moors-Murphy, H. 2014. Assessing Cetacean Distribution in the Scotian Shelf Bioregion using Habitat Suitability Models. Can. Tech. Rep. Fish. Aquat. Sci. 3088: iv + 49p.

Gomez, C., Lawson, J., Kouwenberg, A.-L., Moors-Murphy, H., Buren, A., Fuentes-Yaco, C., Marotte, E., Wiersma, Y.F., and Wimmer, T. 2017. Predicted distribution of whales at risk: identifying priority areas to enhance cetacean monitoring in the Northwest Atlantic Ocean. Endangered Species Research 32: 437–458.

Gordon Jr, D.C., and Kenchington, E.L. 2007. Deep-Water Corals in Atlantic-Canada: A Review of DFO Research (2001–2003). Proceedings of the Nova Scotian Institute of Science.

Harley, S., Myers, R., Barrowman, N., Bowen, K., and Amiro, R. 2001. Estimation of research trawl survey catchability for biomass reconstruction of the eastern Scotian Shelf. DFO. Can. Sci. Advis. Sec. Res. Doc. 2001/084: 54 p.

Harris, L., Greenlaw, M., McCurdy, D., and MacDonald, D. 2018. Information on the potential recovery of Cusk (*Brosme brosme*) in Canadian waters. DFO Can. Sci. Advis. Sec. Res. Doc. 2018/002: vi + 62 p.

Hedd, A., Pollet, I.L., Mauck, R.A., Burke, C.M., Mallory, M.L., Tranquilla, L.A.M., Montevecchi, W.A., Robertson, G.J., Ronconi, R.A., and Shutler, D. 2018. Foraging areas, offshore habitat use, and colony overlap by incubating Leach's storm-petrels *Oceanodroma leucorhoa* in the Northwest Atlantic. PloS one 13(5): e0194389.

Horsman, T., and Shackell, N. 2009. Atlas of important habitat for key fish species of the Scotian Shelf, Canada. Can. Tech. Rep. Fish. Aquat. Sci. 2835: viii + 82 p.

Jeffery, N.W., Heaslip, S., and Stanley, R. In prep. Biophysical and Ecological Overview of the Fundian Channel – Browns Bank Area of Interest (AOI). DFO Can. Sci. Advis. Sec. Res. Doc. 2019/nnn: xxiii + 299 p.

Kenchington, E., Beazley, L., Lirette, C., Murillo, F., Guijarro, J., Wareham, V., Gilkinson, K., Koen-Alonso, M., Benoît, H., and Bourdages, H. 2016a. Delineation of Coral and Sponge Significant Benthic Areas in Eastern Canada Using Kernel Density Analyses and Species Distribution Models. Canadian Science Advisory Secretariat.

Kenchington, E., Lirette, C., Murillo, F., Beazley, K., Guijarro, J., Wareham, V., Gilkinson, K., Koen Alonso, M., Benoit, H., Bourdages, H., Sainte-Marie, B., Treble, M., and Siferd, T. 2016b. Kernel density analyses of coral and sponge catches from Research Vessel Survey data for use in identification of Significant Benthic Areas. Can. Tech. Rep. Fish. Aquat. Sci. 3167: viii + 207 p.

Kostylev, V.E., and Hannah, C.G. 2007. Process-driven characterization and mapping of seabed habitats. Mapping the Seafloor for Habitat Characterization: Geological Association of Canada, Special Paper 47: 171–184.

Lacharité, M., and Metaxas, A. 2018. Environmental drivers of epibenthic megafauna on a deep temperate continental shelf: A multiscale approach. Progress in Oceanography 162: 171–186.

Lesage, V., Gosselin, J.-F., Lawson, J., McQuinn, I., Moors-Murphy, H., Plourde, S., Sears, R., and Simard, Y. 2018. Habitats important to blue whales (*Balaenoptera musculus*) in the western North Atlantic. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/080: iv + 50 p.

Moors-Murphy, H., Lawson, J.W., Rubin, B., Marotte, E., Renaud, G., and Fuentes-Yaco, C. 2019. Occurrence of Blue Whales (*Balaenoptera musculus*) off Nova Scotia, Newfoundland, and Labrador. DFO Can. Sci. Advis. Sec. Res. Doc. 2018/007: iv + 55 p.

Paul, S., Hanke, A., Smith, S., and Neilson, J. 2010. An examination of loggerhead sea turtle (Caretta caretta) encounters in the Canadian swordfish and tuna longline fishery, 2002–2008. Canadian Science Advisory Secretariat Research Document 88.

Pollet, I.L., Ronconi, R.A., Jonsen, I.D., Leonard, M.L., Taylor, P.D., and Shutler, D. 2014. Foraging movements of Leach's storm-petrels *Oceanodroma leucorhoa* during incubation. Journal of Avian Biology 45(4): 305–314.

Runnebaum, J., Guan, L., Cao, J., O'Brien, L., and Chen, Y. 2017. Habitat suitability modeling based on a spatiotemporal model: an example for cusk in the Gulf of Maine. Canadian Journal of Fisheries and Aquatic Sciences(999): 1–14.

Stone, H. 2012. Biomass Reference Points for Eastern Component Pollock (4VW+4Xmn). DFO Can. Sci. Advis. Sec. Res. Doc. 2012/027: ii + 11 p.

Stortini, C.H., Shackell, N.L., Tyedmers, P., and Beazley, K. 2015. Assessing marine species vulnerability to projected warming on the Scotian Shelf, Canada. ICES Journal of Marine Science 72(6): 1731–1743.

Ward-Paige, C.A., and Bundy, A. 2016. Mapping Biodiversity on the Scotian Shelf and in the Bay of Fundy. Fisheries and Oceans Canada, Ecosystems and Oceans Science.

WWF Canada. 2009. An ocean of diversity: the seabeds of the Canadian Scotian Shelf and Bay of Fundy. WWF Canada, Halifax, Canada. p. 24 pp.

APPENDIX

Table 1. Proposed conservation priorities (CP); representation, species-based (i.e., depleted or at-risk species), and EBSA criteria each priority meets; and levels of evidence (high=historical and recent records from within AOI, including imagery or physical samples; medium=historical evidence, modeled suitable habitat, or sparse records from within AOI; low=inferred from nearby survey sites or from literature with no physical samples or modeling). The recommendation for each conservation priority is given.

Proposed Conservation Priority	Representative Habitat within AOI	Species-based Criteria	EBSA Criteria	Evidence	Recommended as a Conservation Priority?
Biodiversity	-	-	-	-	-
Large gorgonian corals	Yes	Not assessed	Aggregation, Fitness, Uniqueness	High – DFO/academic camera studies in the NECCCA and Fundian Channel, kernel density estimates	Yes (modified to deep-water corals)
Significant concentrations of sponges	Yes	Not assessed	Aggregation, Fitness	High – DFO/academic camera studies, kernel density estimates, RV survey data	Yes
Sea pens	Yes	Not assessed	Aggregation	Medium – some records from within and adjacent to Georges Basin, only one “significant” catch within the AOI by Summer RV survey	No – did not meet aggregation criteria
Benthic invertebrate biodiversity	Yes	Not assessed	Aggregation	High – based on *in situ* camera studies, RV survey data	No – represented by CP on representation of habitat types

Proposed Conservation Priority	Representative Habitat within AOI	Species-based Criteria	EBSA Criteria	Evidence	Recommended as a Conservation Priority?
Fish diversity hotpots	Yes	NA	Aggregation, Fitness	High – based on hotspot and persistent habitat analyses by Ward-Paige and Bundy (2016) and Horsman and Shackell (2009), and RV survey data.	No – represented by CP on representation of habitat types
Representative habitat for Atlantic Cod	Yes	Depleted Species Assessed as Endangered and in the Critical Zone since 2011	Aggregation	High – some top quintile persistent habitat, spawning grounds, historical evidence of high larval concentrations	Yes
Habitat for redfish (*Sebastes* spp.)	Yes	Assessed as Threatened by COSEWIC but biomass has stabilised in the vicinity of the AOI	None	Low	No – did not meet decline criteria
Highly suitable habitat for Cusk	Yes	Depleted Species Assessed as Endangered and in the Cautious Zone since 2011	Fitness, Aggregation	High – modeled highly suitable habitat, distribution records from Halibut Industry Survey	Yes

Proposed Conservation Priority	Representative Habitat within AOI	Species-based Criteria	EBSA Criteria	Evidence	Recommended as a Conservation Priority?
Representative habitat for Atlantic Wolffish	Yes	Depleted Species Assessed as Special Concern (COSEWIC and SARA). Short-term biomass well below long-term biomass in Division 4X.	Fitness, Aggregation	High – top quintile persistent habitat on Browns Bank, distribution records from Summer RV and Halibut Industry surveys	Yes
Representative habitat for Spiny Dogfish	Yes (some)	Depleted Species Assessed as Special Concern (COSEWIC) but local 4X status is currently being re-assessed	Aggregation	Low – AOI not a top quintile persistent habitat, local status is currently being re-assessed	No – did not meet aggregation criteria
Representative habitat for Smooth Skate	Yes – most Smooth Skate caught between the AOI components	Depleted Species Assessed as Special Concern (COSEWIC) and 4X biomass trends remain low	Aggregation adjacent to proposed AOI boundaries	High – distribution records from Summer RV survey, knowledge of habitat preferences	No – did not meet aggregation criteria
Representative habitat for Winter Skate	Yes	Western Scotian Shelf Designatable	Aggregation	High – distribution records from Summer RV survey,	Yes

Proposed Conservation Priority	Representative Habitat within AOI	Species-based Criteria	EBSA Criteria	Evidence	Recommended as a Conservation Priority?
		Unit assessed as Not At Risk		knowledge of habitat preferences	
Representative habitat for Thorny Skate	Yes	Depleted Species Assessed as Special Concern (COSEWIC) and stock continues to decline despite reduced fishing mortality	Aggregation	Medium – distribution records from Summer RV survey, knowledge of habitat preferences	Yes
Representative habitat for White Hake	Yes	Depleted Species Assessed as Threatened and in the Critical Zone since	Aggregation	High – distribution records from Summer RV survey, knowledge of habitat preferences	Yes
Habitat for Roundnose Grenadier	Unknown	Assessed as Endangered (COSEWIC) but local status is unknown	None	Low – few records, no modeled suitable habitat	No
Habitat for deep sea fishes and invertebrates	Yes	NA	Aggregation, Fitness	Medium – inferred from adjacent deepwater Summer RV survey strata	No, but ensure deep sea representative habitat is included in a CP

Proposed Conservation Priority	Representative Habitat within AOI	Species-based Criteria	EBSA Criteria	Evidence	Recommended as a Conservation Priority?
Productivity					
Feeding area for large pelagic fish, such as tunas and Swordfish	Yes	NA	Aggregation, Fitness	Medium – fisheries-dependent data shows presence, but no direct link to foraging	No – but see CP on oceanographic features and an area of high productivity
Blue Whale foraging area	Yes	Endangered (COSEWIC and SARA)	Aggregation, Fitness	Medium – distribution and areas of krill aggregation (observed or predicted)	Yes
Suitable habitat for Sowerby's Beaked Whales and Northern Bottlenose Whales	Yes – modeled as suitable habitat, with observations to back it up	Assessed as Special Concern (Sowerby's) and Endangered (Northern Bottlenose)	Aggregation, Fitness	Medium - habitat suitability models, confirmed observations and acoustic detections within AOI	Yes – included as an element of the CP on oceanographic features and an area of high productivity
Feeding area for sea turtles	Some	Leatherback and Loggerhead are both designated Endangered by SARA	Fitness	Low – few observations, no direct links to foraging in the area	No – but AOI may provide ancillary benefits to sea turtles
Foraging grounds for most functional guilds of marine birds, including Leach's Storm Petrel	Yes	Species have variable designations under COSEWIC,	Aggregation, Fitness	High – five decades of observational data, migration studies	Yes

Proposed Conservation Priority	Representative Habitat within AOI	Species-based Criteria	EBSA Criteria	Evidence	Recommended as a Conservation Priority?
		SARA, and the IUCN			
Oceanographic features and an area of high productivity that attracts large pelagic fishes, cetaceans, sea turtles, and marine birds.	Yes	N/A	Aggregation, Fitness	Medium – known persistent and dynamic oceanographic features concentrate prey, high chlorophyll *a* concentrations, fisheries dependent and tagging data	Yes – the CP is not the species themselves, but the physical and oceanographic features of the AOI that attract these species
Habitat					
Habitat for juvenile Atlantic Halibut	Yes	Healthy Zone	Aggregation, Fitness Consequences, Uniqueness	High – Summer RV survey and Halibut-Industry survey records, Bayesian spatiotemporal modeling, juvenile habitat preferences knowledge, one of two juvenile hotspots in the Maritimes	Majority view that this is a feature of the AOI, that the feature is persistent, and currently expanding.
Concentration of large mature female lobster, as well as other life-history stages	Yes	Healthy Zone	Aggregation, Fitness Consequences.	Medium – Summer RV survey records from LFAs 40 and 41, not known what proportion contained within AOI. Low spatial resolution within LFA 40 and the AOI.	Yes

Proposed Conservation Priority	Representative Habitat within AOI	Species-based Criteria	EBSA Criteria	Evidence	Recommended as a Conservation Priority?
Representation of habitat types, including basin, bank, channel, and deep water slope habitat, and the associated representative fish and invertebrate communities	Yes	NA	Aggregation	High – seabed classification, geological studies, academic research using cameras, Summer RV survey, Halibut-Industry survey data	Yes
Migratory habitat between southern and temperate waters, and on/off shelf movements	Yes	NA	Fitness	Medium – tagging studies show lots of tracks through the area, but no strong evidence saying the AOI is a preferred migratory habitat	No – but see CP on oceanographic features and an area of high productivity

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