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Biophysical and Ecological Overview of a Study Area within the Labrador Inuit Settlement Area Zone

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Foreword

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

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We thank the Nunatsiavut Government and the Department of Fisheries and Oceans Canada for creating the partnership that led this process. Thank you also to the Canadian Wildlife Service, the Torngat Secretariat, the Province of Newfoundland and Labrador, Parks Canada, Memorial University, and Simon Fraser University for their participation and contributions. We want to thank everyone who provided input into this research document and participated in the science meeting. The time and feedback participants shared was invaluable and strengthened the meeting outputs.

ABSTRACT

The Government of Canada has committed to protect 10% of coastal and marine areas by 2020, which requires the creation of new protected areas throughout Canada's marine territory. The Labrador Inuit Land Claims Agreement (LILCA), signed in 2005, established the Labrador Inuit Settlement Area (LISA) which includes 72,520 km^2 of lands and 48,690 km^2 of coastal waters. In 2017, the Nunatsiavut Government signed a Statement of Intent with Environment and Climate Change Canada (ECCC) and Fisheries and Oceans Canada (DFO) to establish a marine plan for the Nunatsiavut Zone, including environmental protection. This report, and the associated Proceedings document, capture the results of a biophysical and ecological overview of the area, co-authored by the Nunatsiavut Government, Fisheries and Oceans Canada, and Environment and Climate Change Canada.

Available information (including Local Knowledge [LK], peer-reviewed literature, archived scientific data from government and academia, and ongoing research), sensitive habitats and species, data gaps, and research recommendations are presented here for 14 biophysical, ecological, and social components of the study area:

- Estuaries and coastal features;
- Seabed features;
- Sea ice;
- Physical oceanography;
- Biological oceanography;
- Macrophytes;
- Benthic communities;
- Corals, sponges, and bryozoans;
- Fish;
- Marine mammals;
- Marine birds;
- Ecologically and Biologically Significant Areas;
- Inuit use and other human activities; and
- Protected areas and other closures.

INTRODUCTION

The Government of Canada has committed to protect 10% of coastal and marine areas by 2020 to achieve international biodiversity conservation targets under the Convention on Biological Diversity. Pathway to Canada Target 1 outlines the Government of Canada's strategy to meet international (Aichi Target 11) and domestic (Canada Target 1) conservation goals. In particular, the Government of Canada will create a series of Marine Protected Areas (MPAs) throughout national waters of the Atlantic, Arctic, and Pacific Oceans that will be overseen by various federal departments and agencies. As part of the strategy to meet Canada's Marine Conservation Targets (MCTs), DFO's Five-Point Plan outlines a number of initiatives including the establishment new *Ocean's Act* MPAs and Other Effective Area-Based Conservation Measures.

Nunatsiavut was established with the signing of the LILCA in 2005. LILCA established the Labrador Inuit Settlement Area (LISA) which includes 72,520 km^2 of lands and 48,690 km^2 of tidal waters, referred to as the Marine Zone or, simply, the Zone. The Zone is used extensively by Labrador Inuit from the five Nunatsiavut communities and the Upper Lake Melville region. In 2017, the Nunatsiavut Government signed a Statement of Intent with ECCC and DFO to establish a marine plan for the Nunatsiavut Zone. *Imappivut* (Our Oceans) will be a comprehensive and adaptive marine plan to represent Labrador Inuit social-cultural and environmental interests in Nunatsiavut waters and contribute to Canada's MCTs.

A portion of the coastal and marine waters of the Nunatsiavut Zone (hereafter referred to as the "study area") is being investigated as a study area and potential candidate for an *Ocean's Act* Area of Interest (AOI). The study area extends from the Nunatsiavut coast to the edge of the Zone 12 nautical miles from the shore. The northern boundary of the study area extends to Cape Uivak (the headland just south of Saglek Bay), while the southern boundary is the LISA Zone boundary, excluding waters south of Rigolet (Figure 1). Scientific knowledge is limited for some features of the Labrador coastal and marine environment; however, ongoing and planned scientific studies will continue to deepen available knowledge. Labrador Inuit also hold extensive knowledge about many of these features, including observations of species distribution and temporal trends.

This document provides a biophysical and ecological overview of the study area and includes an integrated consideration of the social and cultural importance of the region and its resources for Labrador Inuit. Scientific and local knowledge studies are used to address available information and knowledge gaps for the following features: estuaries and coastal features, seabed features, sea ice, physical oceanography, biological oceanography, seaweeds and seagrasses, benthic invertebrate communities, corals and sponges, fish, marine mammals, marine birds, Ecologically and Biologically Significant Areas (EBSAs), Inuit use and other activities, and protected areas.

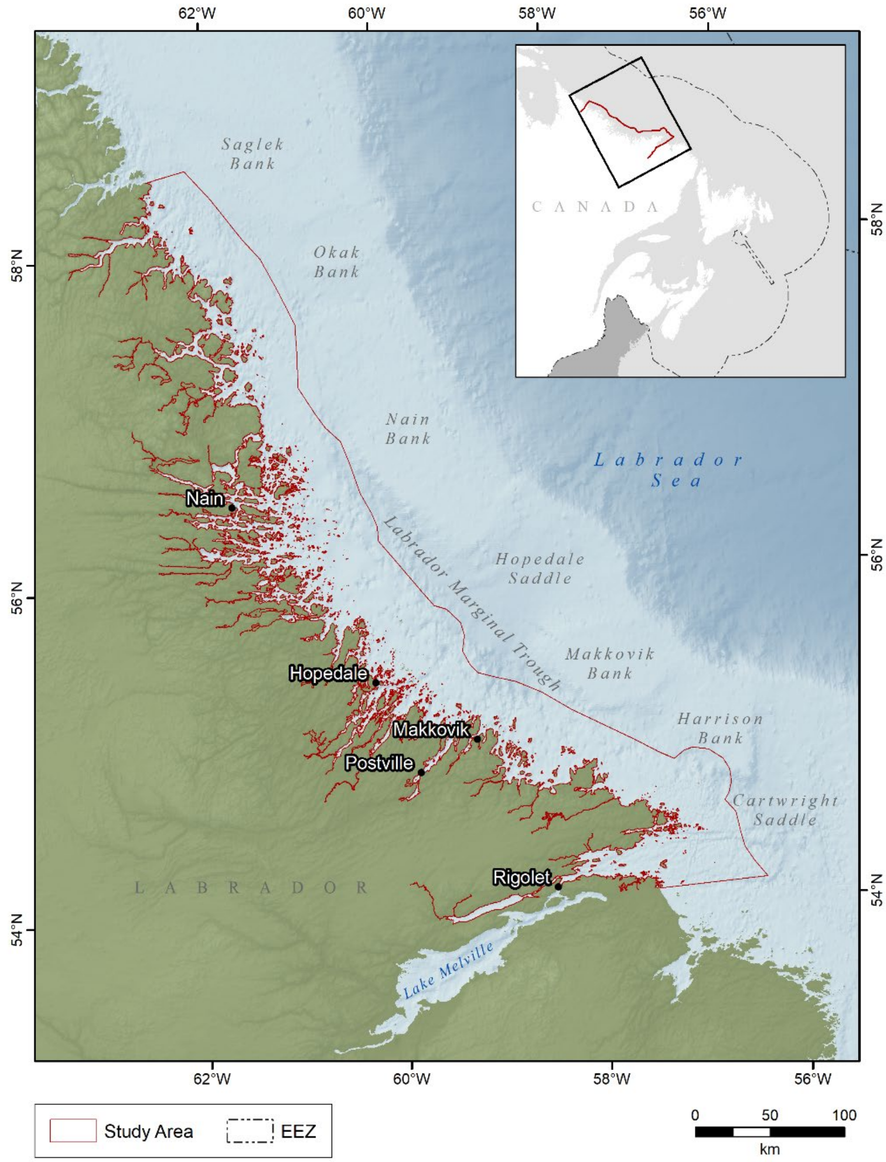


Figure 1.0: The coastal and marine waters of the study area which falls within the LISA Zone.

APPROACH AND METHODS

The study area falls entirely within the LISA Zone (Intergovernmental and Indigenous Affairs Secretariat 2005). The Nunatsiavut Government and DFO are full partners in activities and decisions pertaining to marine management and conservation within this jurisdiction. Further, the Final Report of the National Advisory Panel on Marine Protected Area Standards (DFO 2018a) identifies the need for Indigenous Knowledge to be "meaningfully integrated in all aspects of planning, design, management, and decision-making around MPAs" and for government to recognize Indigenous communities as partners and rights-holders in these processes. Consequently, the analysis and information presented in this report reflect a collaborative process between the Government of Canada and the Nunatsiavut Government. In addition to the biophysical and ecological overview, this document also recognizes and identifies the uses of coastal and marine resources by Labrador Inuit.

The data used to inform this document were generated through a variety of research programs and methods, and the summaries in each chapter represent a combination of available scientific data and Local Knowledge collected from throughout Nunatsiavut and Upper Lake Melville communities.

Ecological knowledge can come from a variety of sources and includes Local, Traditional, Indigenous, and fishers' knowledge (NOAA 2007). Decisions around terminology are made consciously and with consideration of the nuances of the various forms of knowledge held by Inuit communities. While recognizing the differences between the different terms, for consistency, we use Local Knowledge (LK) as a general term that includes and respects all ecological knowledge sources. Unless otherwise indicated, extensive LK data are derived from semi-structured interviews and participatory mapping methods that have been previously published (Brice-Bennet 1977; O'Brien et al. 1998; DFO 2007) or that have been collected to support development of the Imappivut marine plan (Nunatsiavut Government 2018). Imappivut data collection activities took place in Nain, Hopedale, Makkovik, Postville, Rigolet, Happy Valley-Goose Bay, and North West River and focused on the extent of Labrador Inuit use of the marine environment and were not limited to the current study area of the Zone. A similar approach was used for *Our Footprints are Everywhere* (OFAE) (Brice-Bennett 1977), where Labrador Inuit from Nain, Hopedale, Makkovik, Postville and Rigolet were interviewed to document and define the nature and extent of Inuit land use and occupancy in Labrador. Community Coastal Resource Inventory (CCRI) data were collected from the same five communities as those used in OFAE, but only a limited amount of data were collected north of Nain (DFO 2007). For the purposes of this document, all LK data presented here include only those that fall entirely, or in part, within the study area.

Imappivut interviews reveal that many human uses are interconnected and are based on ecological interchange between environmental features and therefore cannot be separated along clearly definable boundaries:

- There are no hard lines to show beginning or end points of various aspects of Inuit usage: water flows from rivers to the sea, animals travel from one place to another, birds migrate in and out, fish are constantly traveling, and seasonal sea ice joins and separates places.
- Inuit travel routes are interconnected throughout the study area and beyond.
- Community reliance on commercial and food fisheries are economically and traditionally intertwined.
- Cabins are scattered throughout traditional hunting, fishing, and gathering areas that hold personal value for food security, culture, and spirit.

Scientific data described or analyzed in this document are derived from standardized oceanographic, fisheries, seabird and marine mammal surveys, remote sensing as well as targeted, and usually smaller scale, scientific studies from academic literature or industry commissioned research.

Chapters were collaboratively written by NG, DFO, and ECCC staff (see Appendix A for a list of contributors for each chapter of the document). Insights from the various data sources are combined into overarching discussions in each chapter and should be understood as providing a cohesive and integrative summary of available knowledge and gaps, unless otherwise specified.

STUDY AREA FEATURES

1. Estuaries and Coastal Features

The coastline of the study area, including all islands, extends for 17,076 km (calculated in WGS 1984 UTM Zone 20N using the 1:50,000 CanVec land shapefile). There are 6,924 islands within the study area which make up approximately 47% (8,010 km) of the total coastline. The mainland coast (including rivers) measures 9,066 km. The coast of Labrador is highly complex due to glaciation, resistant bedrock geology and high coastal relief. Coastlines in Labrador have been shaped by glacial and coastal processes such as storm-waves and seasonal land fast ice that can cause scour and reposition sediment. Each of these zones provides a network of diverse habitats that are ecologically important to a variety of plants and animals, and which in turn provide important economic, cultural and food security benefits to nearby communities. Coastal zones are highly dynamic environment at the interface of terrestrial/freshwater and marine environments. As such they can be highly biodiverse and productive but can also be particularly sensitive to anthropogenic impacts (e.g., development, oil spills). This section focuses on the habitats and species communities found in subtidal, intertidal, estuarine, and above tide zones of the study area.

1.1. Available Information

The coast of Labrador is primarily made up of fjords, rocky shorelines, unconsolidated cliffs, beaches, intertidal boulder flats, deltas, estuaries, and marshes. These habitats have been described by two coastal surveys within the study area (McLaren 1981 and Woodward-Clyde Consultants 1980). McLaren's (1981) survey methods included beach profiling and nearshore SCUBA geological/biological sampling, as well as low level aerial photography to map coastal environments.

Coastal Labrador fjords are long, narrow, steep-sided embayments characterized by rocky coastlines, beaches, and boulder barricades (i.e., boulders that accumulate in the intertidal zone as a result of sea ice). These long embayments provide sheltered habitat as very little wave energy occurs here (Woodward-Clyde Consultants 1980). Three of the many fjords along the coast of the study area have been surveyed in detail. Hebron fjord is approximately 3 km wide and 29 km long with steep shorelines and is indented by four bays along the south and three on the north. In 1956, oceanographic data including temperature, salinity, oxygen, and inorganic phosphate were collected from various sites (Nutt and Coachman 1956). The other two fjords, Okak and Anaktalak, have been extensively characterized (Allard and Lemay 2012). Okak Bay, once the site of the largest Inuit population on the Labrador coast is characterized by an irregularly shaped, 50 km long inlet ranging from 45–50 m with low lying catchment and underwater features of flat bottom basins separated by low-relief sills. Anaktalak Bay, the site of a nickel-copper-cobalt mine and concentrator, forms a large basin between 100 and 120 m deep that rises to a sill at 85 m in the outer bay (Allard and Lemay 2012) with an average sediment load entering the basin ranging between 1,300 and 14,000 tonnes (t) per year (Kahlmeyer 2009). In 2010; Okak and Anaktalak fjords were sampled for dinoflagellate cyst assemblages and ultimately it was discovered that higher concentrations exist in southernmost fjords (Okak and Anaktalak) when compared to the more northern Nachvak and Saglek fjords. This was also true for inner versus outer fjord with the outer being more productive (Richerol et al. 2012). In this same study, two distinct dinocyst assemblages were found; Okak influenced by sea-surface salinity, temperature, and nutrient depletion and Anaktalak controlled by sea-surface salinity, temperature and water column irradiance. In 2017, researchers from DFO deployed baited cameras in Okak fjord in order to characterize species and habitats. Here, bottom sediments ranged from fine mud and sand to mixed rock substrates. High species richness is associated with fjord habitats, including Rock Cod (*Gadus ogac*), sculpin

(*Cotidae spp.*), Arctic Shanny (*Stichaeus punctatus*), Eelpout (*Lycodes sp.*), Toad Crab (*Hyas spp.),* sea urchins, clams, anemones, and ophiuroids.

The subtidal coastal zone of the study area is characterized primarily by high relief shelf, shelf valleys, basins, and glacial troughs (Harris et al. 2014). In the Nain area, the subtidal environment along exposed coastlines consists of gravel, cobble and boulders and abundant green and brown algae. In contrast, the subtidal environments along protected coastlines have an accumulation of sand and mud where marine invertebrates such as polychaetes, molluscs and echinoderms thrive. Two types of shallow subtidal biological assemblages have been identified in the Nain area;

1. a polychaete assemblage found in water depths of 0–15 m with bottom sediments consisting of gravel and muddy sands, and;
2. a mollusc-echinoderm assemblage from 15–45 m in depth with bottom sediments consisting of muddy sands (Gilbert et al. 1984).

Intertidal flats make up 34% of the coast of Labrador. These flats range from 50–1,000 m wide at low tide, and are characterized by fine grain sediments such as mud and sand, with occasional large boulders strewn along the surface (see Figure 1.1, Figure 1.2, and Figure 1.3). This particular zone provides important foraging habitats for many marine species. For example, Glaucous-Gulls (*Larus glaucescens)* migrate to breeding grounds on the Labrador coast and feed on intertidal species such as sea urchins, limpets, and sea snails (Wootton 1997). Many other marine bird species use coastal zones for foraging opportunities including a variety of gulls, ducks, and shorebirds (Hori and Noda 2008). The rocky intertidal habitats of the study area tend to have very little seaweed due to ice scouring; however, seaweed species including *Fucus vesiculosus* and *Ascophyllum nodosum* are common and provide a habitat for a variety of invertebrates and vertebrates (Ugarte and Sharp 2001).

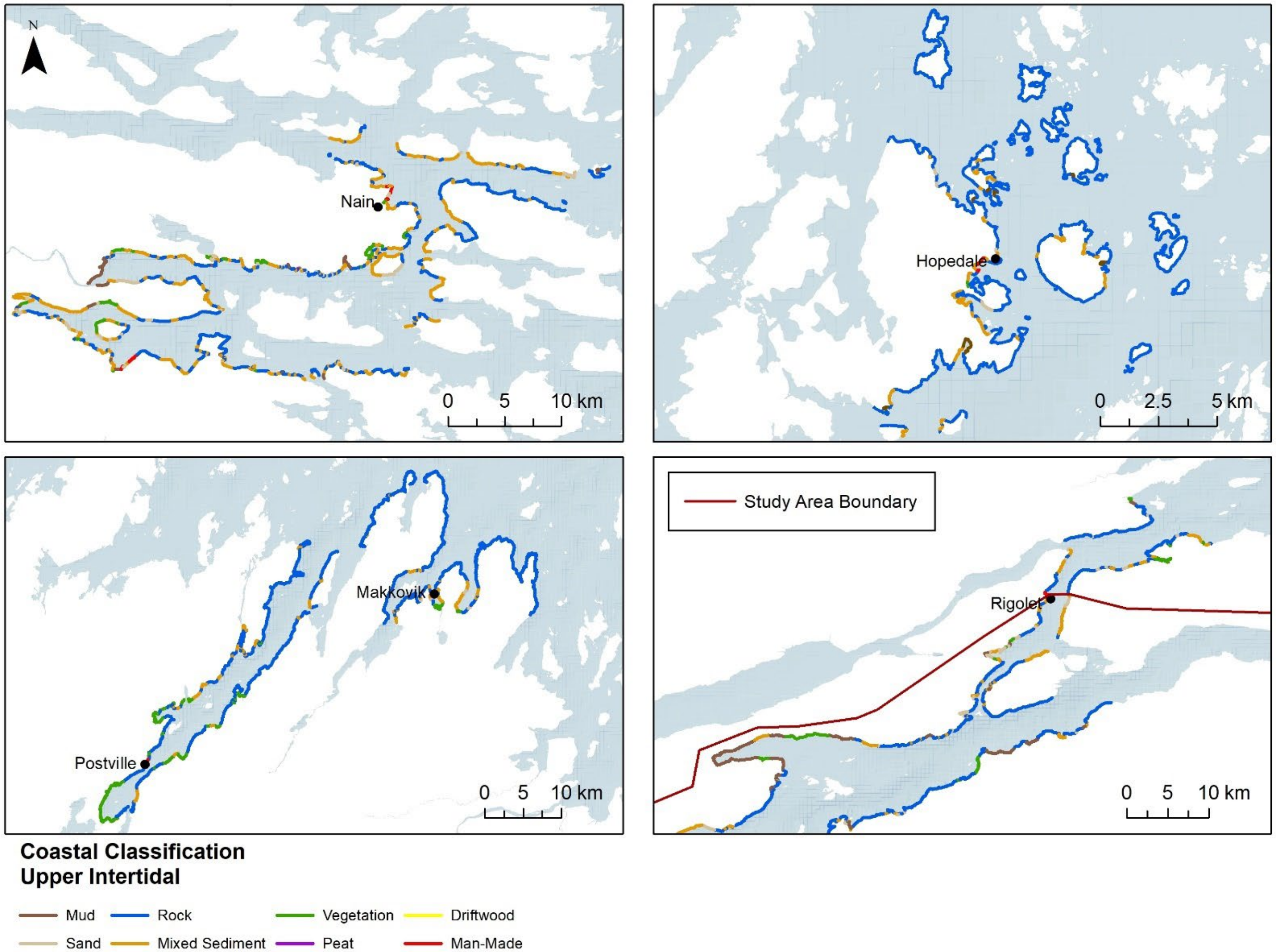


Figure 1.1: Coastal classification map showing the types of sediment found along the upper intertidal coastline of the study area.

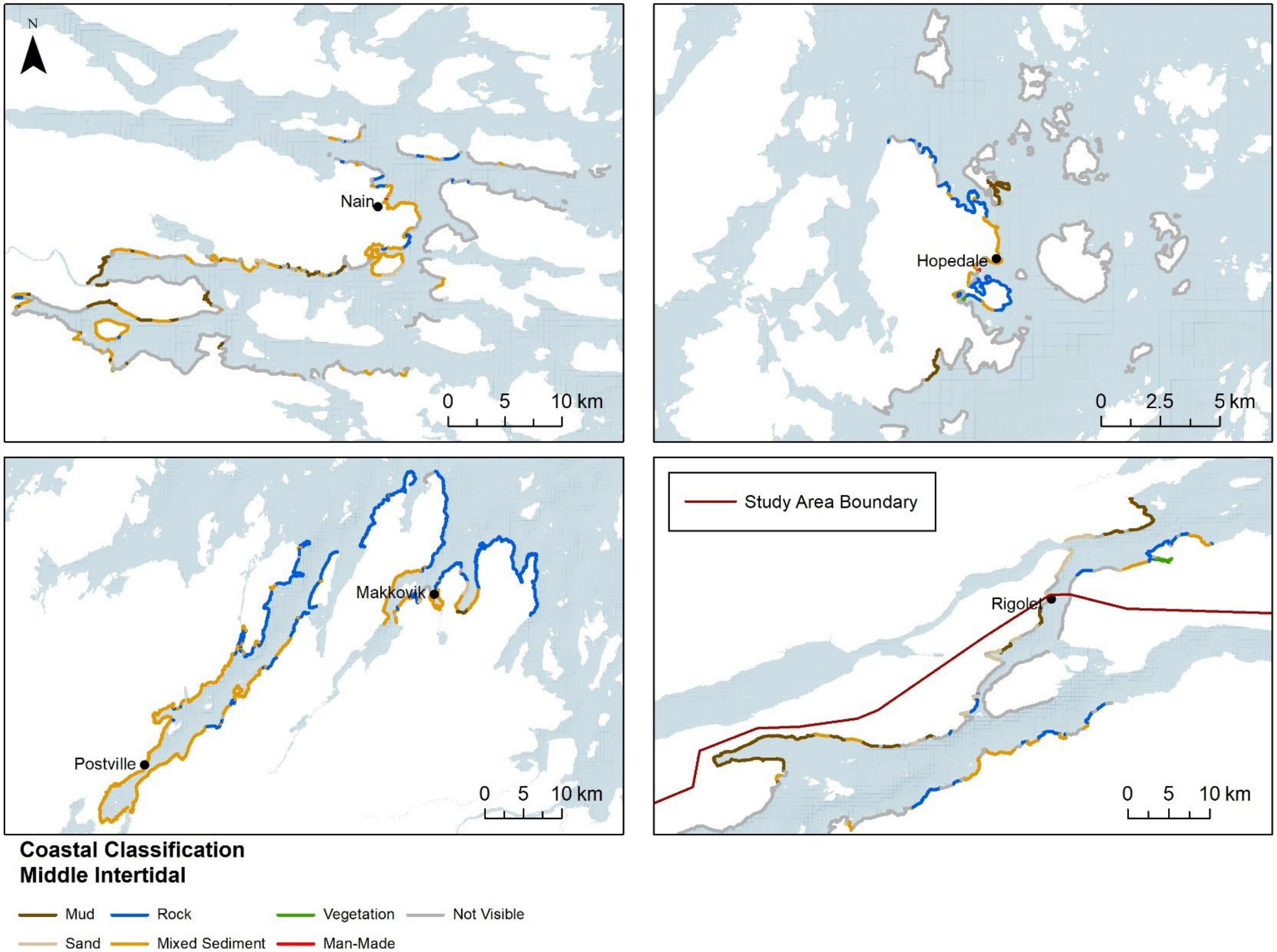


Figure 1.2: Coastal classification map showing the types of sediment found along the middle intertidal coastline of the study area.

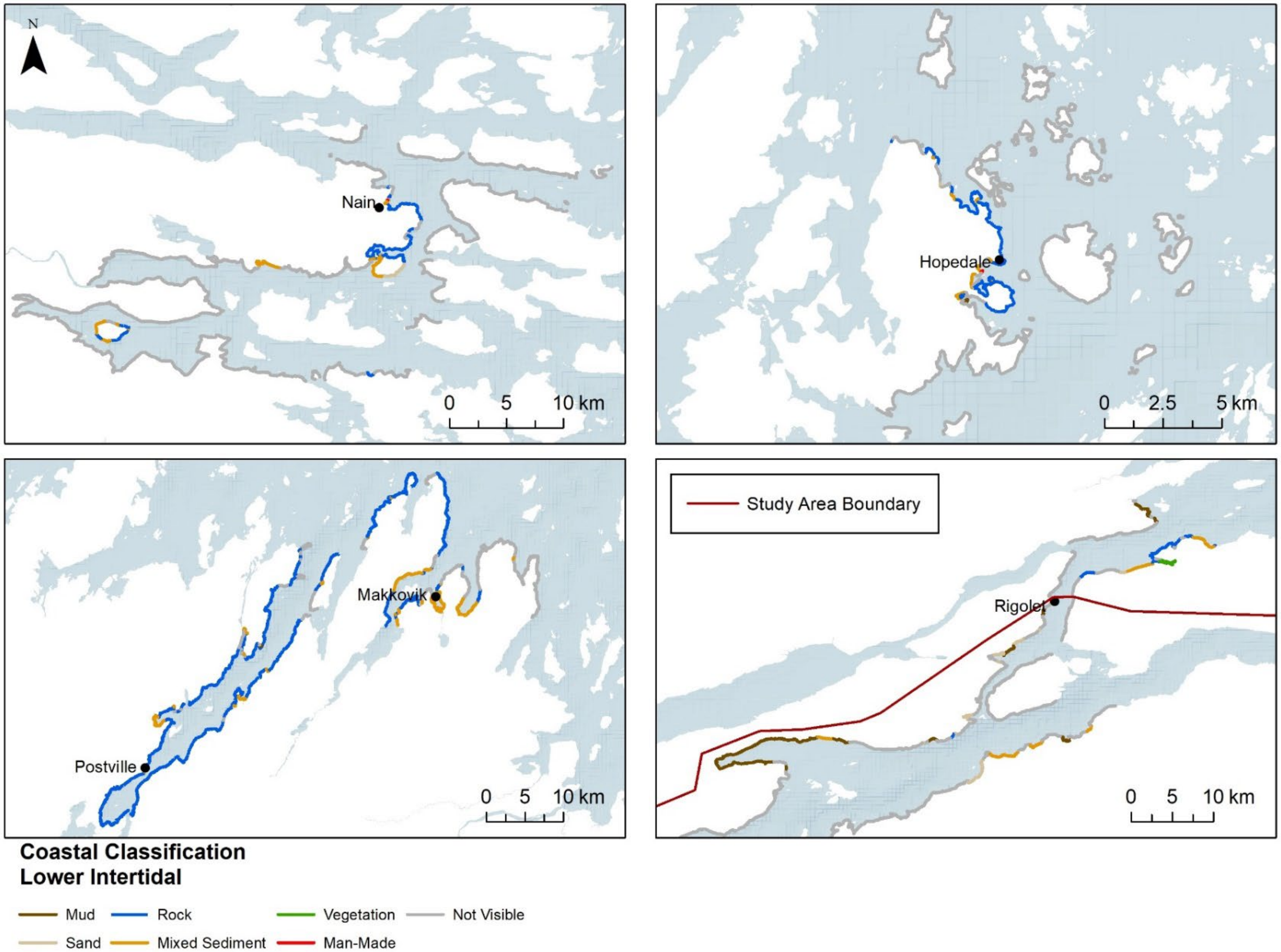


Figure 1.3: Coastal classification map showing the types of sediment found along the lower intertidal coastline of the study area.

Estuaries, considered among the most productive of marine ecosystems, are ecologically and economically important habitats (Underwood and Kromkamp 1999). In the study area, estuaries are of particular importance because they are used by Arctic Char (*Salvelinus alpinus*), an extremely important species for Labrador Inuit food security and culture. Arctic Char rely on estuarine waters to acclimate to the marine environment and estuaries are visited frequently by these fish during their marine phase (Spares et al. 2015). Several estuaries along the Labrador coast have been surveyed in detail; however only Groswater Bay of the Hamilton Inlet estuarine complex falls within the study area (Environment Canada 1990). This estuary is characterized by marsh and tidal mud flats, low rock shore platforms and narrow sandy beaches. The inner Groswater Bay area is a known staging area for marine birds such as eiders, geese and black ducks and is also a site for breeding Harlequin Ducks (*Histrionicus histrionicus*) (Environment Canada 1990).

Deltas, marshes, and rocky habitats are found at the upper extent of the tidal range. Deltas are rare features in Labrador due to high wave energies that prevent their formation. In the study area, deltas are typically small and limited by steep near-shore gradients; with the notable exception of the large (16 km^2) Kogaluk River delta near Nain (McLaren 1981). The upper sections of most fjords in Labrador are considered estuarine, however fluvial redistribution of sediments in some locations has led to the infilling of estuaries and the development of deltas in their place. Marshes in Labrador are associated with deltas and the landward margins of intertidal flats. In these northern marsh environments, McLaren noted that typical Atlantic coast vegetation such as Cordgrass (*Spartina sp.*) is replaced by Saltmarsh Sedge (*Carex salina*). Marshes provide important resources to estuarine environments through the process of outwelling of organic detritus and also provide refuge to fish and invertebrates from predators (Boesch and Turner 1984). Estuaries, marshes, and deltas are dominated with typical salt meadow vegetation; *Glyceria*, *Stellaria*, *Juncus* and *Carex* species.

Exposed coastal areas of the study area are characterized by steep cliffs or low-lying bedrock. These habitats can also be found on the many coastal islands and, in some cases, within sheltered bays. Most of these areas have very little sediment or vegetation due to the amount of wave action and ice scour (McLaren 1981). Unconsolidated cliffs are restricted in their extent but have been identified as being an important source of littoral sediments for beach development.

The Labrador coastline is approximately 30% beach, characterized as mixed sediments or boulder habitats depending on the extent of wave action. Low level wave action creates mixed sediment beaches whereas high level wave action washes away mixed sediments and leaves behind boulders.

1.2. Sensitive Species and Habitats

The coastal zone of the study area is a thin band that includes several unique and ecologically important habitats and is frequented by ecologically and culturally important species, some of which are species of conservation concern. Estuaries, for example, are among the most productive ecosystems in the world and many animals rely on them for food, places to breed and migration stopovers. Those found along the coast of the study area provide relatively warm, productive and brackish waters that are used for foraging and staging during migrations by a variety of marine and anadromous fish (e.g., Arctic Char and Atlantic Salmon [*Salmo salar*]; Spares et al. 2015). Some important estuaries located within the study area are the Hamilton Inlet estuarine complex comprised of Goose Bay, Lake Melville and Groswater Bay but most have yet to be characterized.

Many ecologically or biologically significant areas (EBSAs) have been identified along the coast of Labrador; however, only two of these fall within or are in close proximity to the study area’s coast; Nain Area and Hamilton Inlet. The Nain Area includes Webb Bay, Tikkoatokak Bay, Nain Bay, Anaktalik Bay and Voisey's Bay. Due to significant nutrient input from local rivers, this site has a high level of nearshore marine productivity which provides foraging opportunities for a number of marine species including but not limited to Arctic Char, Capelin (*Mallotus villosus*), and several species of marine birds. The Hamilton Inlet EBSA includes Hamilton Inlet, Sandwich Bay and extends south to Island of Ponds. This area is highly productive for Atlantic Salmon and includes some productive Capelin spawning beaches, mainly attributed to the large outflow of nutrients from Lake Melville. Other ecologically important areas include Groswater Bay and the Double Mer River, both of which part of Hamilton Inlet estuarine complex at the southern extent of the study area. These areas provide important habitat for migratory birds, breeding Harlequin Ducks, Arctic Char, Atlantic Salmon, and Pacific Cod (*Gadus macrocephalus)* (Environment Canada 1990). Additional details regarding EBSAs in the study area are provided in Section 12.

The coastal zone is very important to Labrador Inuit. Most of the major settlements are situated on the coast and the coastal zone includes some of their most important hunting grounds and travel routes. Marine food resources, such as Ringed Seals (*Pusa hispida*), are harvested along the coast year-round while other resources, like migratory birds, Harp Seals (*Pagophilus groenlandicus)*, Atlantic Salmon and Arctic Char, are harvested seasonally. Labrador Inuit also harvest other terrestrial species (e.g., caribou, [*Rangifer tarandus*]) and forage for berries and other edible plants in coastal environments (Figure 1.4). Since harvest areas are often located far from established towns, coastal travel routes during open water and during ice season are critical (Figure 1.5).

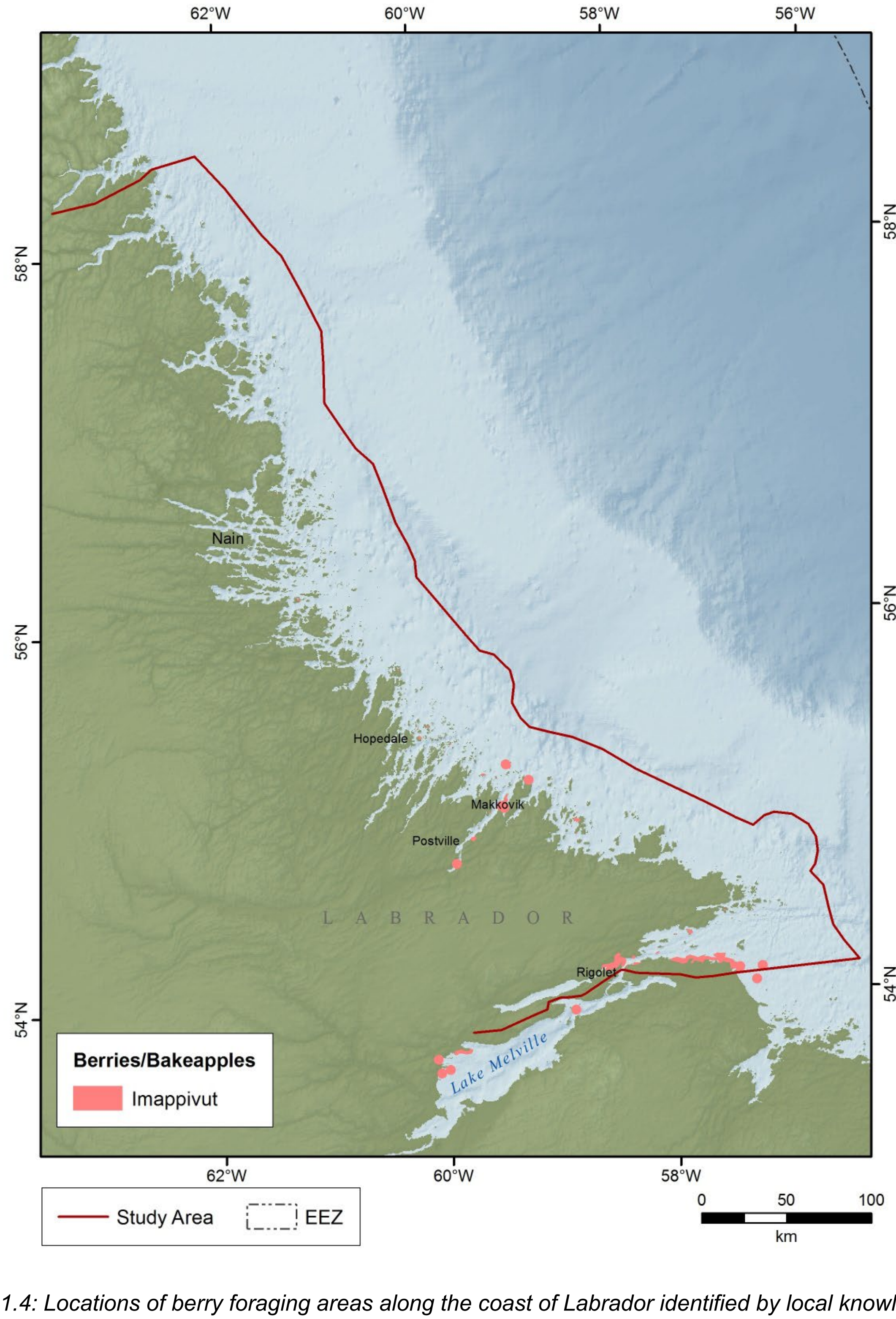


Figure 1.4: Locations of berry foraging areas along the coast of Labrador identified by local knowledge.

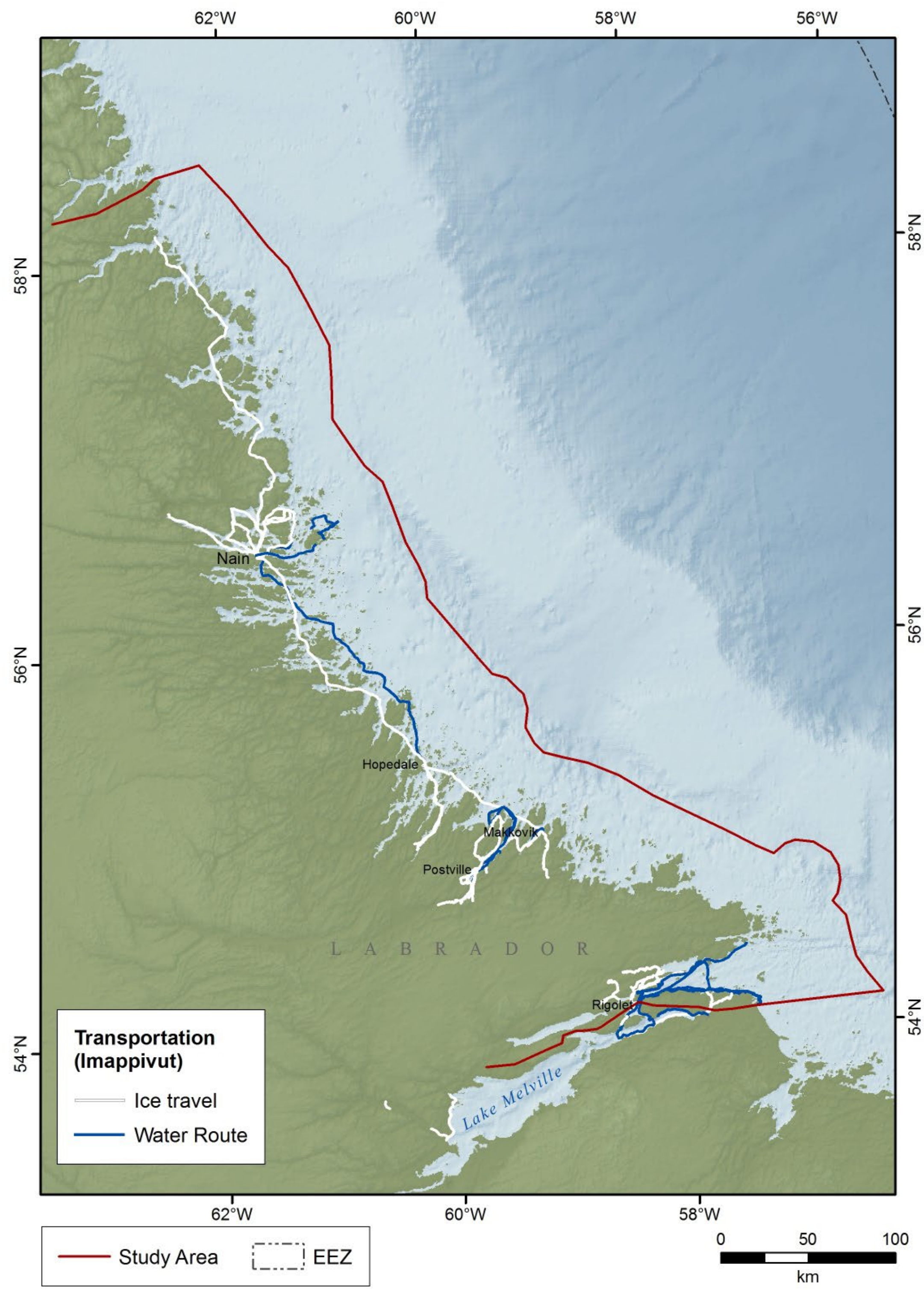


Figure 1.5: Locations of water and ice travel routes along the coast of Labrador identified by local knowledge.

1.3. Data Gaps and Recommendations

Despite the ecological and cultural importance of the coastal zone, there remain notable data gaps. With a few exceptions (e.g., Barrie 1979; Richerol et al. 2012; Gilbert et al. 1984), there has been little work done on characterizing intertidal and subtidal plant and animal communities and their associations with the available physical habitats in the study area. Such habitat-community associations would provide a means to predict the distribution and prevalence of biotic communities based on the distribution of physical habitat. While shoreline habitats are reasonably well documented in McLaren (1981) and Offshore Labrador Biological Studies (OLABS), there has been little multibeam mapping conducted in subtidal areas beyond Okak Bay (Allard and Lemay 2012). Such information, along with biotic community surveys, will be vital to address these knowledge gaps.

The oceanographic conditions (temperature, water chemistry, currents) in estuarine and nearshore zones not represented by programs like DFO's Atlantic Zone Monitoring Program (AZMP) that survey deeper, offshore water conditions (see Section 4). Unlike areas further offshore, the scale at which coastal oceanographic processes operate are much more localized and therefore it is difficult to infer results beyond the area being sampled. Nevertheless, sampling at representative index sites would be useful and could contribute data toward more accurate coastal oceanographic models.

Time series information is very important for understanding the natural variability in an ecosystem and for allowing the detection of directional shifts associated with natural or anthropogenic disturbance (climate change, invasive species, pollution etc.). Coastal zones may be particularly sensitive to stressors related to temperature change, development, and invasive species. The local knowledge provides important information on current and past coastal changes. Additional systematic and quantitative surveys are needed to support projections of how the coast of the study area will be affected by large-scale stressors such as climate change in the future.

Climate change has major implications for coastal ecosystems and the social and economic systems that depend upon them. Coastal ecosystems along the study area are most affected by sea level rise. In this particular area, the land is actually rising which will eventually require biota to shift, exposing different areas to erosion. This may have implications for cultural resources located along coastal areas. In addition to this, over shorter time frames, more severe storms could change erosion rates in coastal areas.

2. Seabed Features

Our understanding of seafloor habitats and species distribution is incomplete for most of the study area. In the absence of direct observational data, marine managers often rely on proxies of marine biodiversity to identify appropriate areas and effective strategies for conservation. The structures and processes that shape the seabed (i.e., geomorphology) provide powerful predictors of benthic biodiversity. A comprehensive understanding of the benthic environment and habitats is crucial to ecosystem management.

2.1. Available Information

Three sources of information on marine geomorphology are presented here: Seabed Features Mapped by Gordon Fader[1] (unpublished data), the Global Seafloor Features Map published by Harris et al. (2014), and Geomorphometric Analysis of the Canadian Hydrographic Service

[1] Gordon Fader, unpublished data, based on previous work for WWF in the Scotian Shelf.

Non-Navigational 100 m resolution bathymetry. Due to differences in the scale of analysis and methods (ranging from expert interpretation to quantitative analysis), these three sources of information are not directly comparable.

2.1.1. Seabeds of the Labrador Shelf

Marine geologist Gordon Fader (Atlantic Marine Geological Consulting Ltd.) delineated geological and structural features of the study area through a qualitative hierarchical classification designed for the Scotian Shelf (WWF-Canada 2009). The source data, classification rules, and spatial resolution of the classification were not available for this report. To place this seabed classification in context with other knowledge sources, it should be considered broad scale classification (i.e., identifying features >10 km^2). Three seabed feature types are identified within the study area by Fader (Figure 2.1): troughs (5,949 km^2), basins (105 km^2), and banks (114 km^2). The majority of the area (28,901 km^2) is classified as “continental shelf”, without further description.

Troughs formed by glacial erosion provide a range of habitat types which may include moraine ridges, steeply sloped flanks, and over deepened centres. Basins are generally characterized by deposition of fine sediments which provide habitat for small invertebrates (Edgar 2001) and their flatfish predators (McConnaughey and Smith 2000). Shallow banks are common features on Canada’s eastern continental shelf, characterized by sand, gravel, or glacial till, often deposited on bedrock (WWF-Canada 2009). Bank habitats may be colonized by seaweed and coralline algae in the photic zone, or sponge communities at greater depths (Buhl-Mortensen et al. 2012).

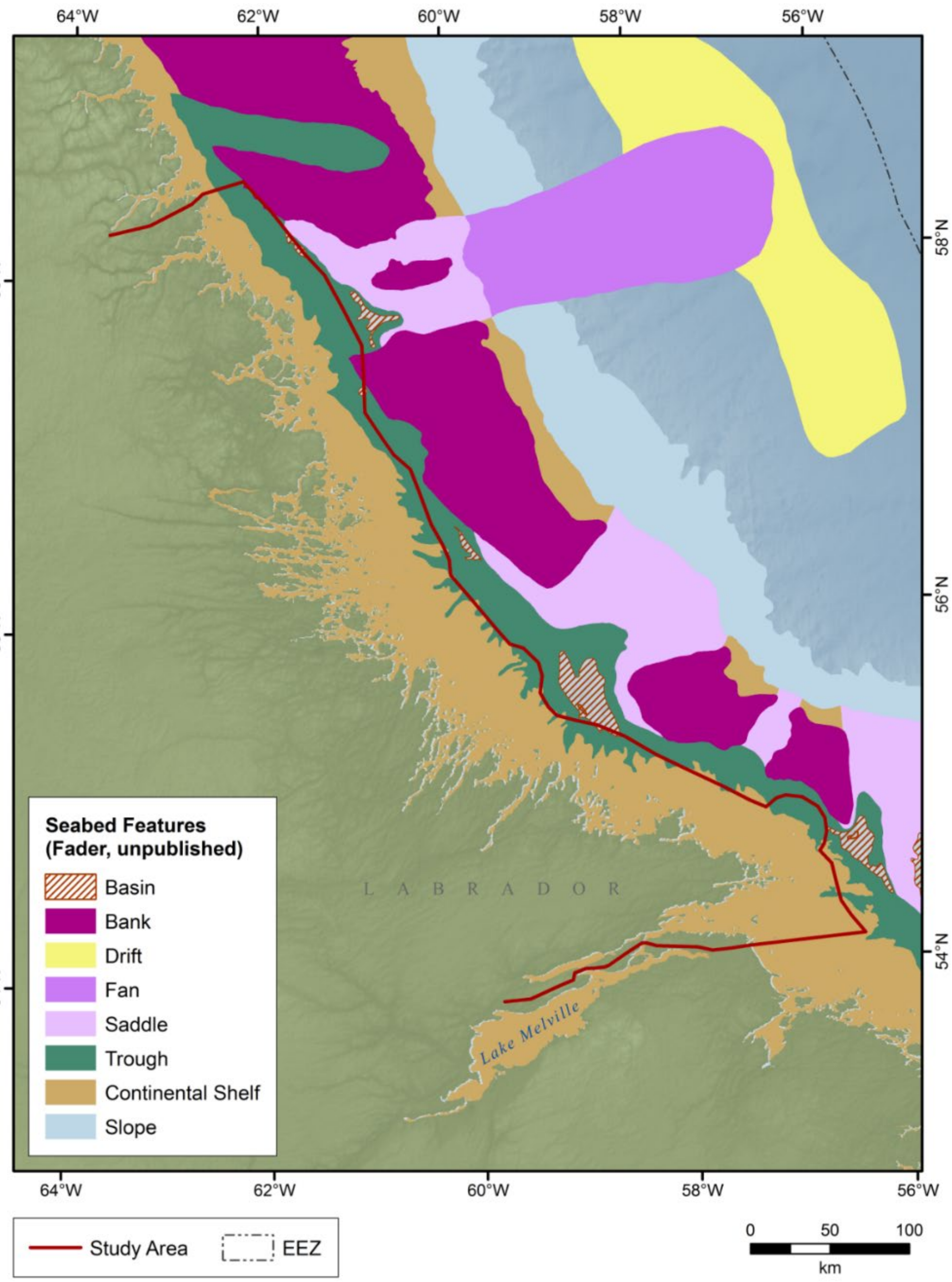


Figure 2.1: Broad scale seabed features identified by Gordon Fader[1] (unpublished).

2.1.2. Global Seafloor Features Map

The Global Seafloor Features Map (Harris et al. 2014) provides a broad scale classification of seafloor features, including shelf valleys, glacial troughs, and basins (Figure 2.2). Feature identification is based on expert interpretation and quantitative analysis of the SRTM30_Plus bathymetric dataset (30 Arc Second grid). Interpretation is limited to a 3x3 cell window of analysis; as a result, these maps identify features roughly 10 km^2 or larger.

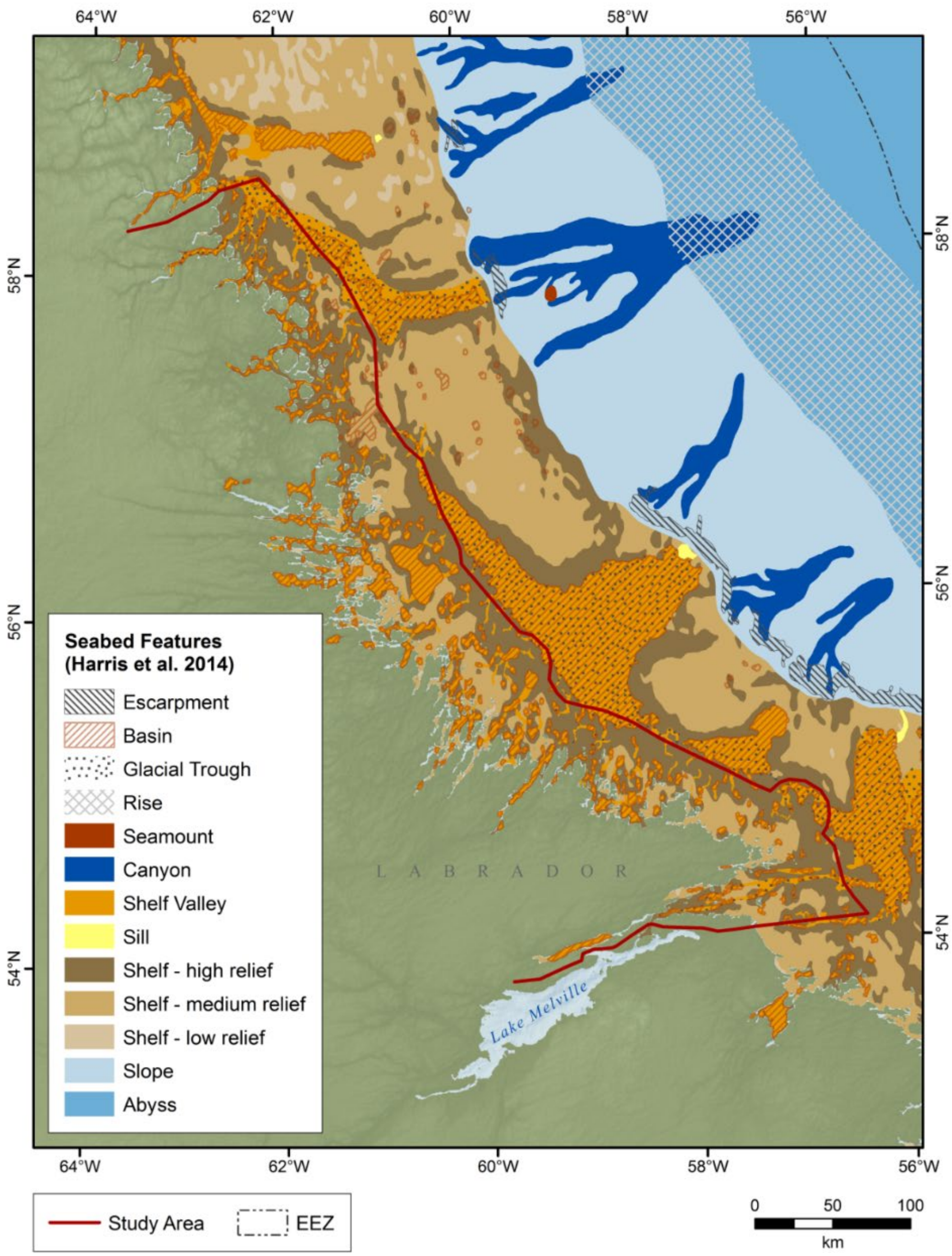


Figure 2.2: Seabed features classified by Harris et al. (2014) based on SRTM30_Plus bathymetry (30 Arc Second grid).

Harris et al. (2014) digitized basins, shelf valleys, and glacial troughs manually, based on expert interpretation of the 10 m bathymetric contours. Basins-identified by manual selection of the shoalest closed 10 m contour around a depression-are prevalent within the study area. Basins are distinguished from shelf valleys and glacial troughs by their shape; basins are roughly equidimensional in plan (Harris et al. 2014). Elongated shelf valleys were defined by Harris et al. (2014) as features of at least 10 km in length and >10 m depth (2014). Most of the shelf valleys in this area are small (<300 km^2); however, a few larger valleys were also identified (300–1,000 km^2). Glacial troughs are deeper than shelf basins (typically over 100 m) and, due to glacial movement, they reach greatest depth just inboard of the shelf break. Branched trough networks are present throughout the study area, with the largest features occurring at the north-east and south-east corners of the study area, reaching seaward. Beyond the boundaries of the study area, escarpments, sills, and canyons characterize the shelf break.

High seafloor roughness is associated with high biodiversity and high biomass per unit area. As a measure of seafloor roughness, Harris et al. (2014) classified the continental shelf into areas of low (<10 m), medium (10–50 m), and high (>50 m) relief. Within the study area, the majority of the area is classified as high relief (24,431 km^2), followed by medium relief (10,017 km^2) and low relief (94 km^2).

2.1.3. Canadian Hydrographic Service Non-Navigational 100 m Bathymetry (NONNA-100)

NONNA-100 is a non-navigational 100 m resolution bathymetric dataset, which incorporates all currently validated digital bathymetry sources acquired by the Canadian Hydrographic Service (CHS). These data were released by the CHS on October 11, 2018. The full dataset was downloaded from the Open Government data portal, and the digital bathymetry layers within and adjacent to the study area were selected for further analysis (Table B-1). NONNA-100 data cover 22% of the study area (8,471.15 km^2), with variable density (Figure 2.3A). In order to produce a more spatially continuous bathymetric surface for geomorphometric analysis, raster data were converted to points interpolated using the Empirical Bayesian Kriging (EBK) routine in ArcGIS 10.5. EBK was selected over other interpolation algorithms because it is able to handle moderate non-stationarity in the data, and because the use of iterative semivariograms (100 per local model) allows for more accurate estimation of standard error (Krivorouchko 2012).

CHS NONNA-100 data from at or above the water surface were excluded and a log-empirical transformation was applied to the remaining data (N=2 015 391 points) to prevent predictions above mean current sea level and a power semivariogram model was selected based on fit calculated in the ArcGIS 10.5 Geostatistical wizard and anticipated processing time. One hundred local models were run, with moderate local model overlap (overlap factor=3) to smooth the output surface. All predicted pixels with an estimated standard error >25 m were excluded. Major bathymetric artefacts were visually identified and removed. The final interpolated surface (Figure 2.3B) covers 70% of the study area (26,250.5 km^2).

Maximum estimated depth is 753 m; however, the majority of the interpolated area (76%) is less than 100 m. Benthic Terrain Modeler 2.0 was used to calculate seafloor slope, rugosity, and benthic position index. Slope is correlated to sediment stability and local acceleration of currents; factors that influence species ability to settle on or in the sediment and food availability for filter feeding species (Lecours et al. 2016). Slope within the study area ranges from 0–53 (Figure 2.4).

Benthic position index (BPI) identifies high and low terrain relative to surrounding pixels, providing a proxy for the level of shelter or exposure at the seafloor (Lecours et al. 2016). Shelf valleys and glacial troughs are prevalent in the study area and are well visualized by BPI. Many glacial troughs and shelf valleys are visible in the interpolated NONNA-100 data that do not appear in the broader scale seabed classifications (Figure 2.5).

Vector Ruggedness Measure (VRM) is an index of structural complexity (Figure 2.6), comparable to the Harris et al. (2014) classification of low, medium, and high relief continental slope described above. Habitats with high structural complexity provide shelter from predators and are linked to high biodiversity (Lecours et al. 2016). Areas of high complexity are concentrated in the centre of the study area; however, this may be an artefact of variable data availability.

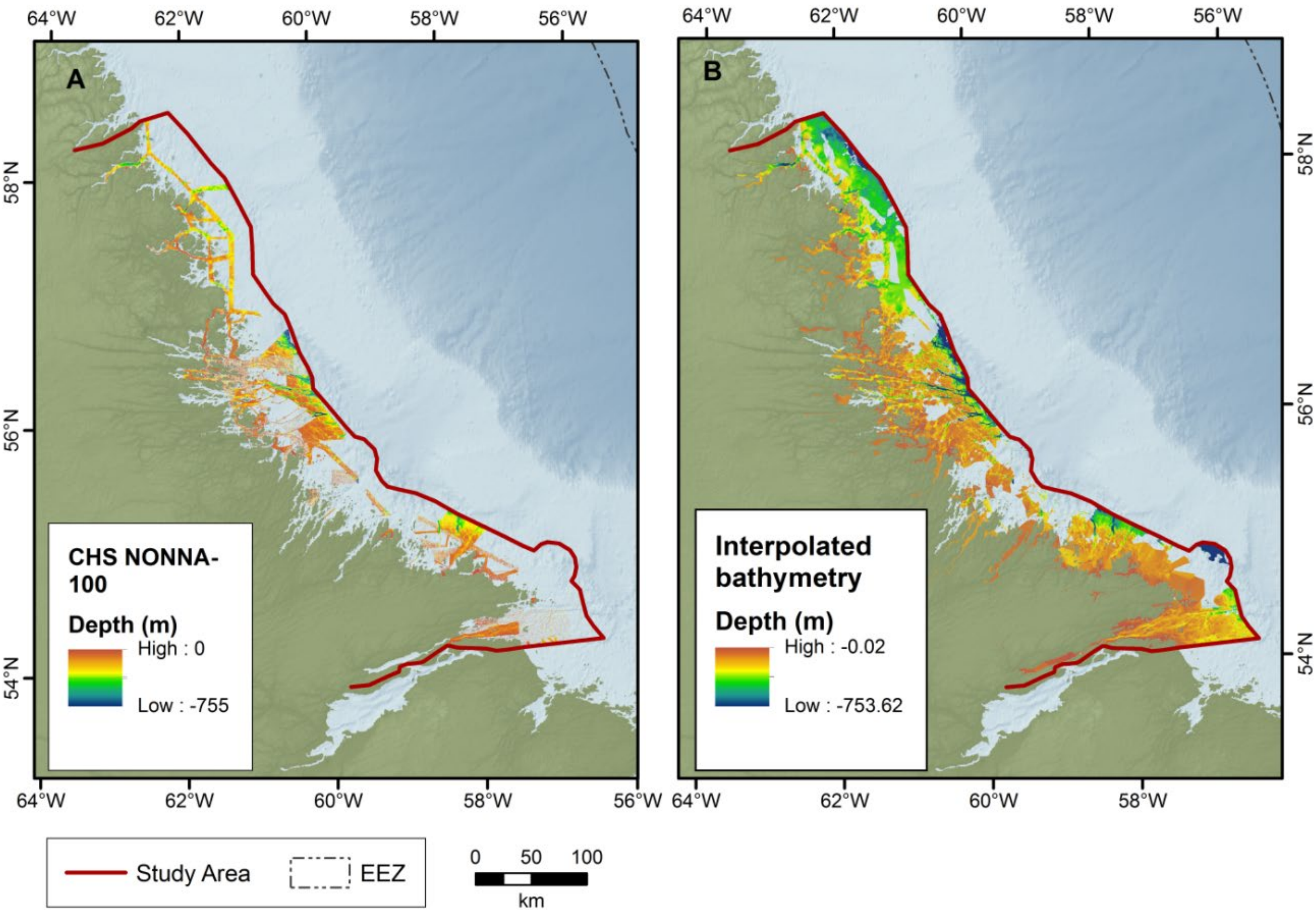


Figure 2.3: High resolution bathymetry for the study area: (A) provided by the Canadian Hydrographic Service Non-Navigational 100 m dataset and (B) after interpolation using empirical Bayesian kriging.

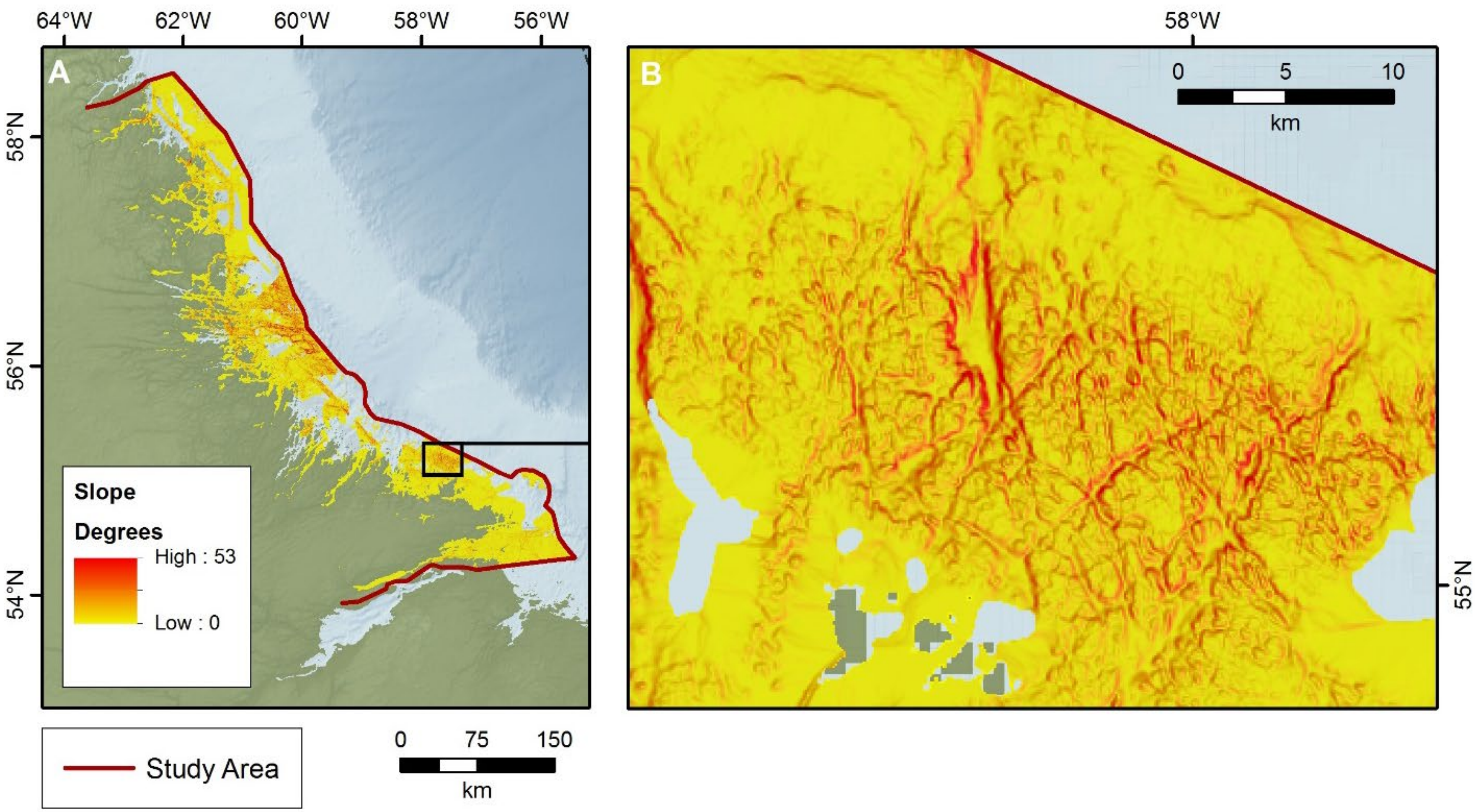


Figure 2.4: Slope derived from interpolated bathymetry within the study area; calculated for a 3x3 cell window.

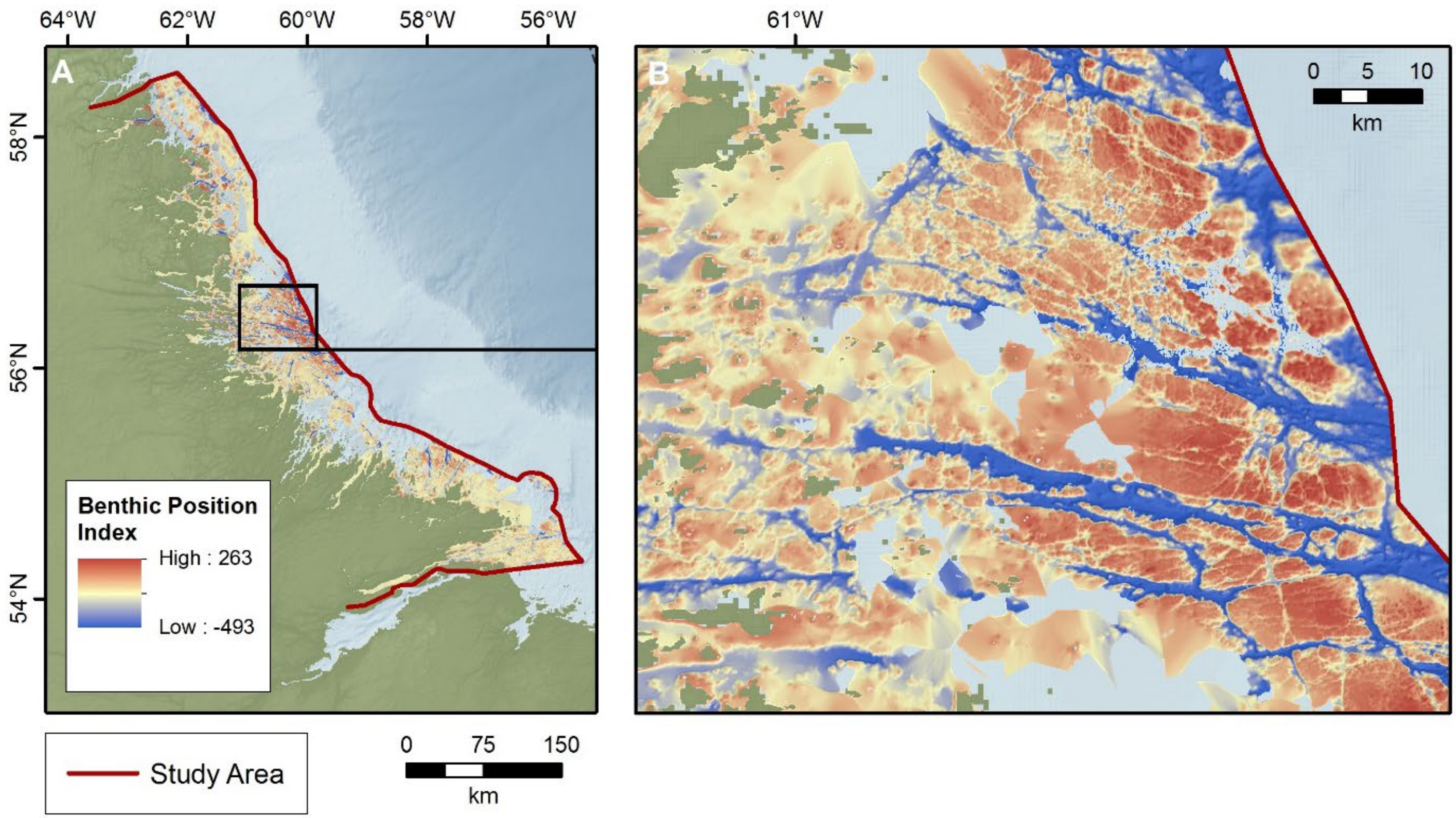


Figure 2.5: Benthic Position Index (BPI) derived from interpolated bathymetry within the study area; calculated based on a 25-cell inner window and a 100-cell outer window.

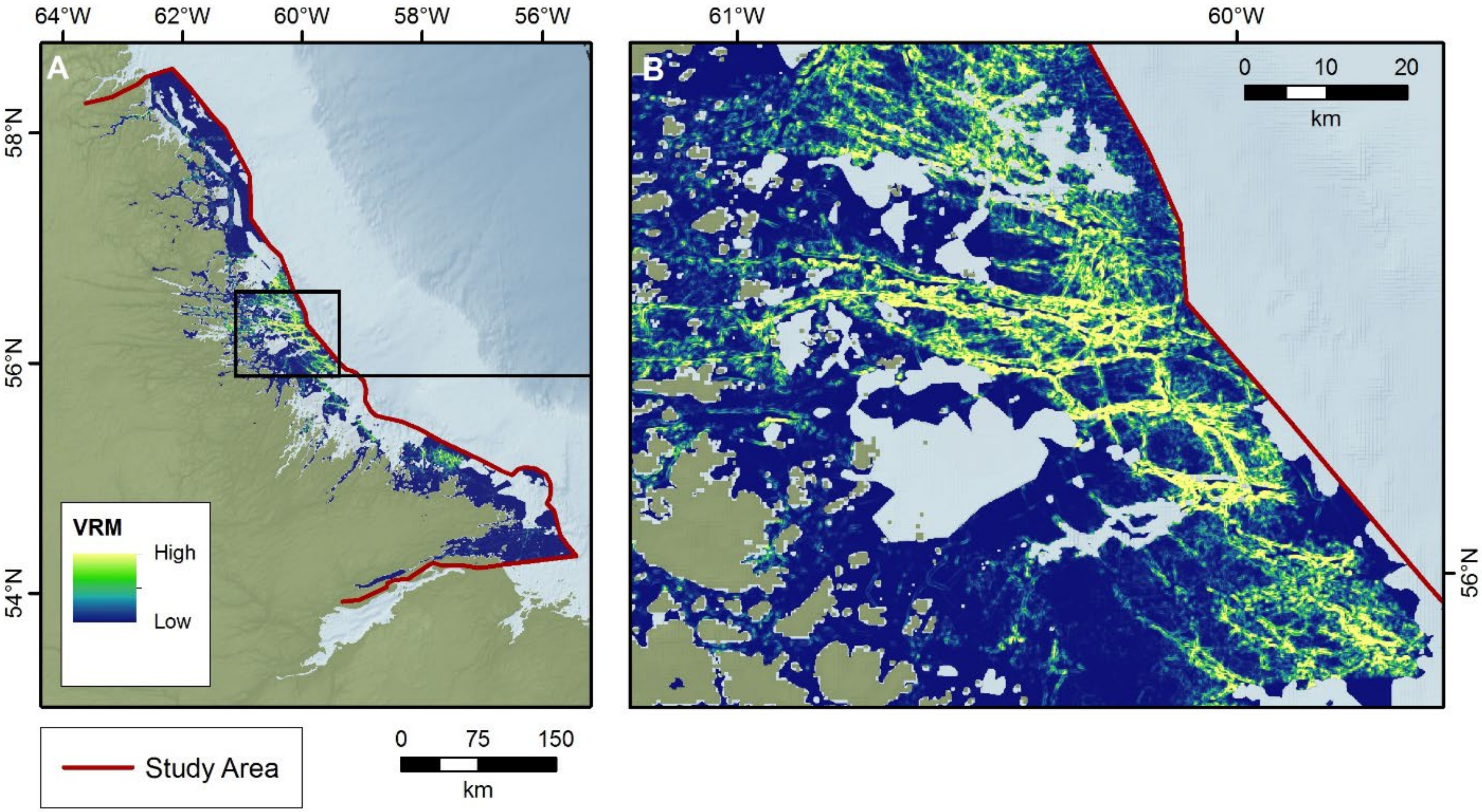


Figure 2.6: Vector Ruggedness Measure (VRM) calculated for a 9x9 cell neighbourhood.

2.2. Sensitive Habitats

2.2.1. *Shelf Valleys and Glacial Troughs*

High structural complexity, or roughness, is often used as a proxy of hard substrate, including reefs, rocky scarps at canyon heads and rock banks (Harris 2012). These features provide important habitat for corals and sponges that require holdfasts. In general, more complex benthic habitat is associated with high biodiversity and productivity (Baker at al. 2012). The centre of the study area is characterized by high structural complexity, associated with shelf valleys and glacial troughs, as indicated by the BPI (Figure 2.5). Large troughs can alter bottom currents which may provide important habitat for filter feeders. Mapping of glacial troughs in Norwegian waters has resulted in the discovery of coral colonies established at trough edges, with deep erosional scour shadows behind reef structures (Buhl-Mortensen et al. 2012). It is likely that there is more of this habitat type throughout the study area in unmapped or under-surveyed areas. In areas where the interpolation was informed by few depth values, the predicted surface may artificially smooth the seafloor, effectively hiding this type of habitat.

2.2.2. *Fjords and Fjards*

Seafloor relief and range of substrates is typically greater in fjords than on the continental shelf. These features also produce unique circulation patterns, and longitudinal gradients in temperature, salinity, and oxygenation (Syvitski et al. 1987). High resolution habitat mapping of seafloor habitats in Okak Bay identified seven distinct bottom types (bedrock and boulder, kelp, gravelly sand, gravelly mud, sand, sandy mud, and mud), occupied by five unique biological assemblages (Brown et al. 2012). Benthic habitat mapping in the Gilbert Bay MPA, in southern Labrador, identified fragile branched coralline algae beds, important fish nursery areas, and kelp beds (Copeland et al. 2013). The many fjords and fjards of the study area are expected to contain similar levels of diversity, and potentially important and/or sensitive species and habitats (ex. fish nurseries).

2.2.3. *Gravel and Mud Habitats*

Study of benthic disturbance impacts in the North Sea indicates that the taxa that occupy poorly sorted gravelly or muddy habitats are both the most productive in the area and the most sensitive to trawling (Bolam et al. 2014). These substrate types, and species with similar traits, are present on the shallow banks and in the basins of the study area.

2.3. Data Gaps and Recommendations

High resolution bathymetry is required to better understand the seafloor in the study area and to generate benthic habitat maps. The NONNA-100 bathymetry provides depth values for 22% of the study area. Un-surveyed areas should be prioritized for multi-beam echo-sounding. Other sources of data (ex. bathymetry associated with the Roxann dataset and/or crowd-sourced fisheries single-beam) may also be considered. The potential for benthic habitat mapping in this area, through analysis of the statistical relationship between distribution of biota and seafloor characteristics, should be explored.

3. Sea Ice

Sea ice is a dynamic ecosystem that provides critical ecological and social-cultural services within the study area. The sea ice ecosystem is defined by different types and forms of ice that play unique roles in ecological processes and these habitats are relied upon by many marine species throughout the food web. Sea ice in the study area is undergoing observed shifts in structure and function as climate change intensifies and impacts Arctic environments more broadly, with implications for predictability, safety, and reliability of ice. The study area hosts a wide diversity of marine species and many of these species, including seals and polar bears (*Ursus maritimus*), depend on the sea ice environment for key aspects of their ecology and life history. In addition, a number of terrestrial species make use of the sea ice for seasonal habitat and migration routes. Finally, sea ice forms critical infrastructure for Labrador Inuit in the study area who rely on ice as a travel and hunting platform.

3.1. Available Information

Information on sea ice in the study area is derived from LK collected from Labrador Inuit through interviews and mapping activities, the Nunatsiavut Government's Ice Monitoring Stations, the Voisey's Bay Mine and Mill Environmental Assessment Panel Report (Griffiths et al. 1999), the Strategic Environmental Assessment Labrador Shelf Offshore Area (Sikumiut Environmental Management Ltd. 2008), the SmartICE monitoring project (Bell et al. 2014; Safer 2016) and ice monitoring studies by the Canadian Ice Service.

The Nunatsiavut Zone is characterized by seasonal land fast ice that transitions to a shear ice zone and pack ice farther offshore. The shear zone is the contact zone between fast ice and pack ice where motion and pressure frequently result in an area of heavily ridged and rubbled ice. The extent, length, and timing of the ice season varies between the north and the south regions of the study area. Generally, freeze-up occurs in mid-November in the north to December in the south (Figure 3.1) and break-up occurs in mid-June to early-July (Figure 3.2), with thickness, timing, and extent varying between years.

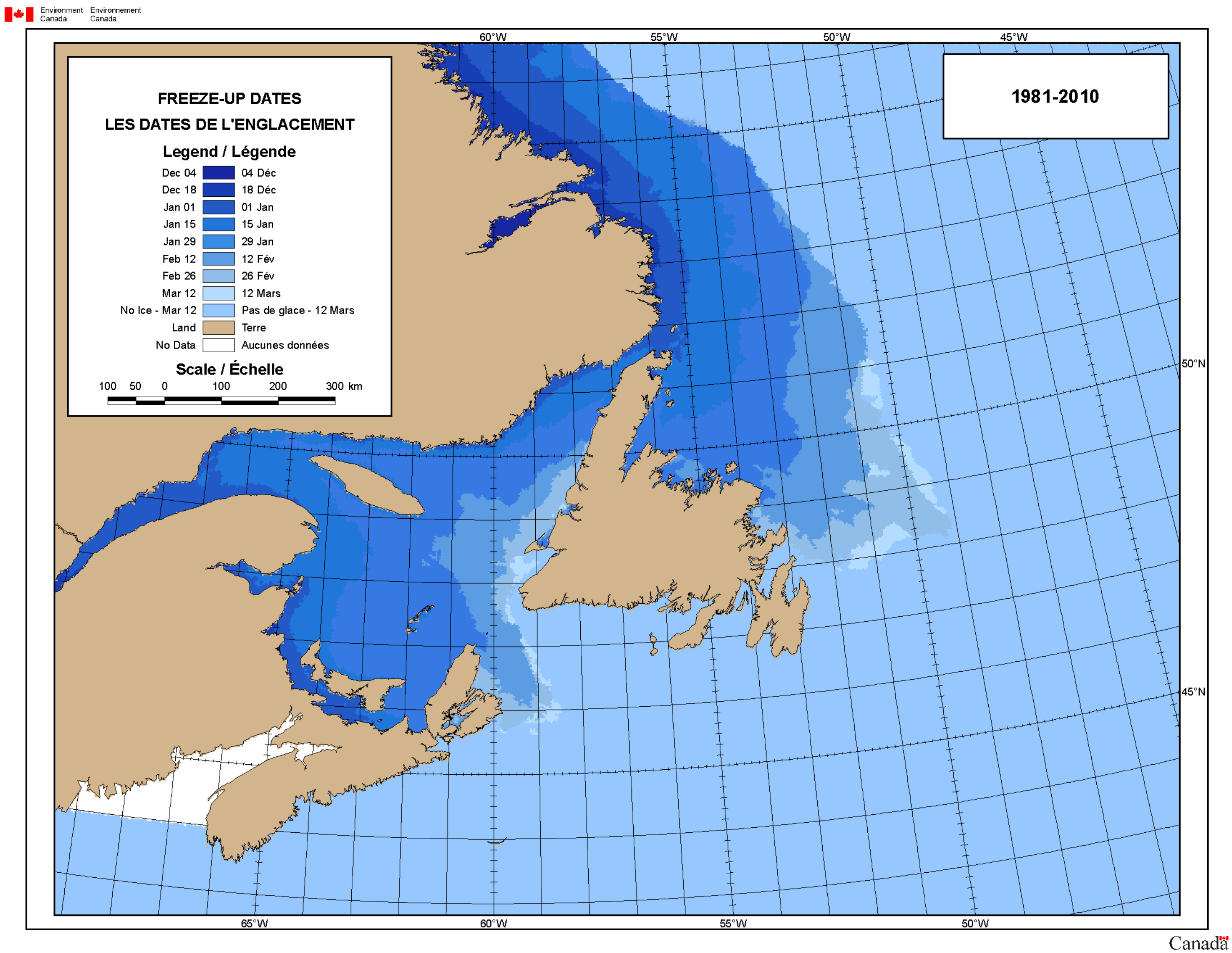


Figure 3.1: Mean sea ice freeze-up dates in the southern portion of the study area from 1981–2010. © Her Majesty the Queen in Right of Canada, as represented by the Minister of the Environment and Climate Change 2018.

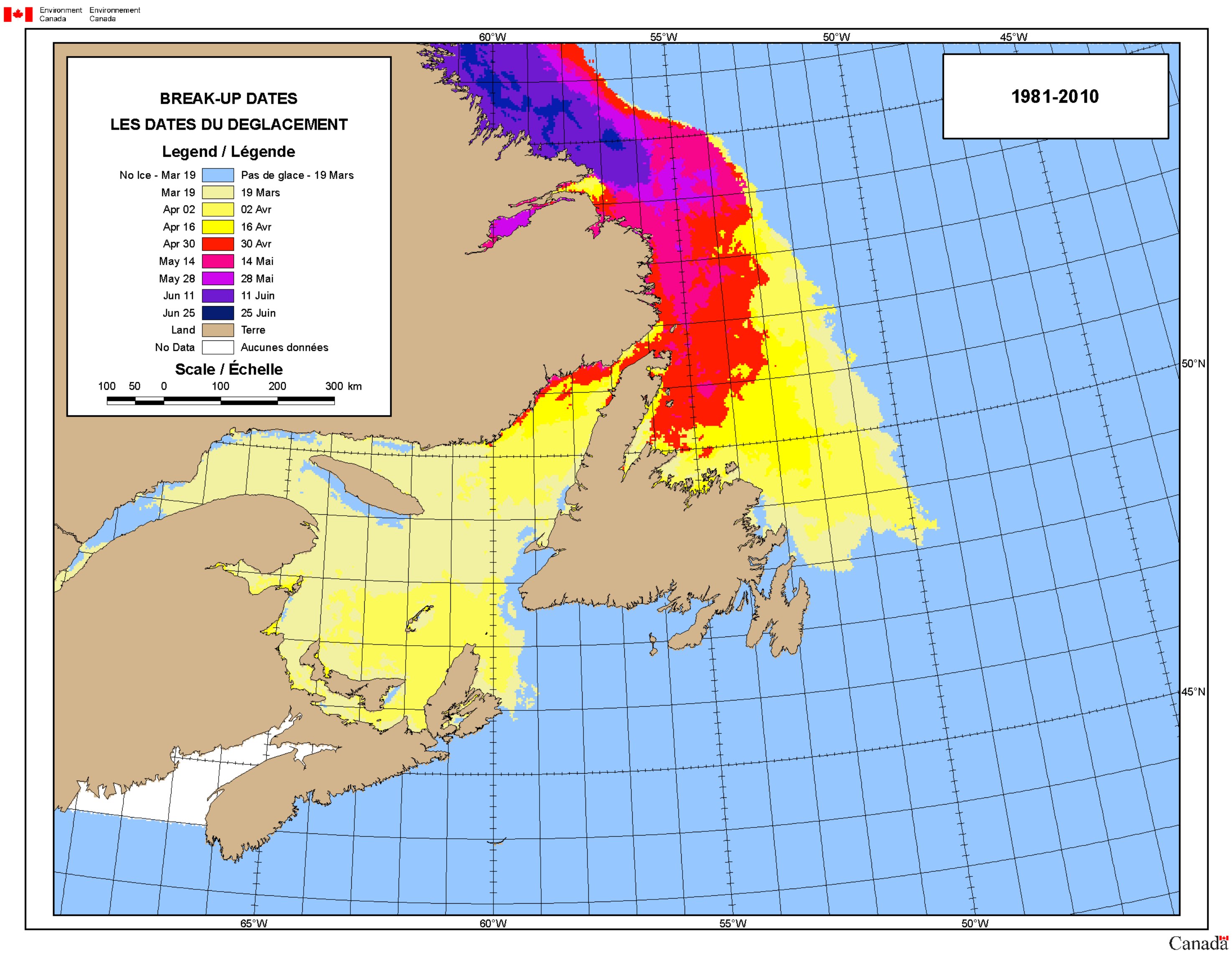


Figure 3.2: Mean sea ice break-up dates in the southern portion of the study area from 1981–2010. © Her Majesty the Queen in Right of Canada, as represented by the Minister of the Environment and Climate Change 2018.

The mean annual number of weeks of ice presence in the study area ranges from a maximum of 26 weeks in the northern range of the study area to 20 weeks in the southern range near the entrance to Rigolet (Sikumiut Environmental Management Ltd. 2008; Canadian Ice Service). Sea ice monitoring studies by the Canadian Ice Service from 1981–2010 reveal that during periods of ice presence, the dominant sea ice type in the study area transitions from a mix of new ice and grey ice in the inshore areas in December (Figure 3.3) to thick first-year ice throughout the extent of the study area by July (Figure 3.4). Over the 30-year monitoring period, the study area was dominated by a median ice concentration value of 9–10/10 from January (Figure 3.5) to June (Figure 3.6). Data from the Canadian Ice Service indicates that timing of ice coverage declined by an average of six weeks between 1971 and 2016; on average, break-up now occurs three weeks earlier and freeze-up occurs three weeks later, with sea ice coverage defined as 10/10 ice concentration within 30 nautical miles of Nain (Adrienne Tivy, Canada Ice Service, pers. comm.).

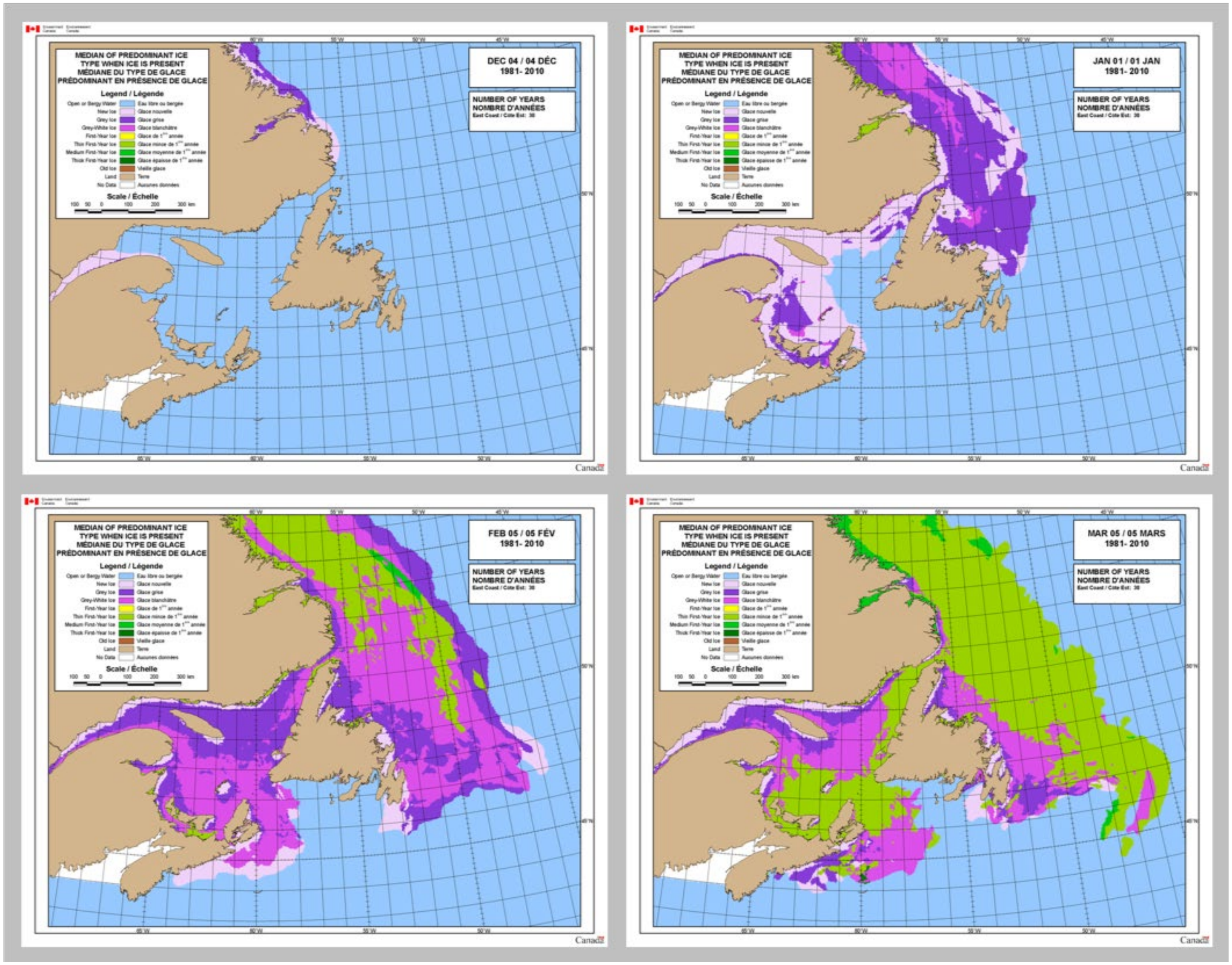


Figure 3.3: Median predominant ice type when present for December-March in the southern portion of the study area from Canadian Ice Service weekly ice monitoring data collected from 1981–2010. © Her Majesty the Queen in Right of Canada, as represented by the Minister of the Environment and Climate Change 2018.

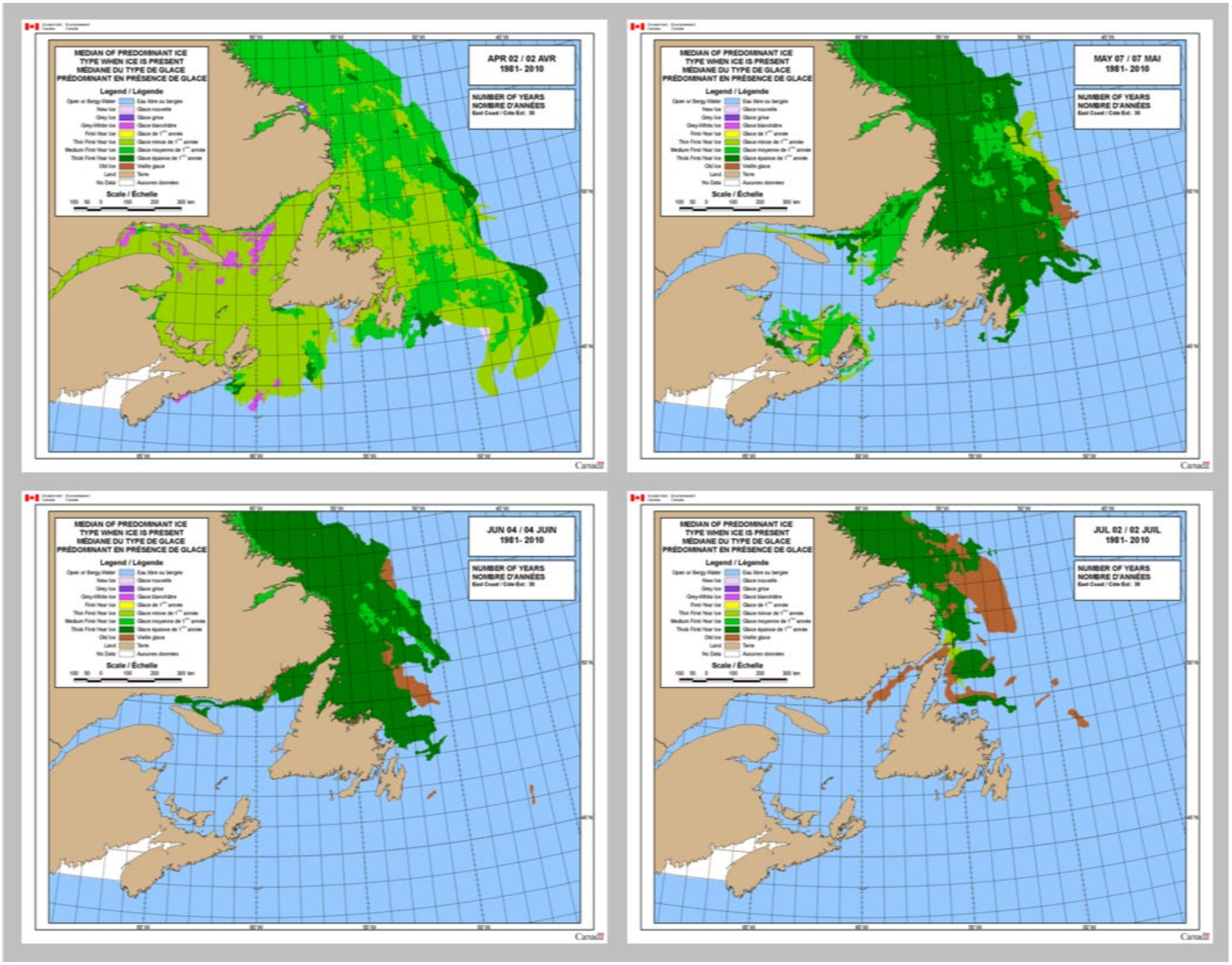


Figure 3.4: Median predominant ice type when present for April-July in the southern portion of the study area from Canadian Ice Service weekly ice monitoring data collected from 1981–2010. © Her Majesty the Queen in Right of Canada, as represented by the Minister of the Environment and Climate Change 2018.

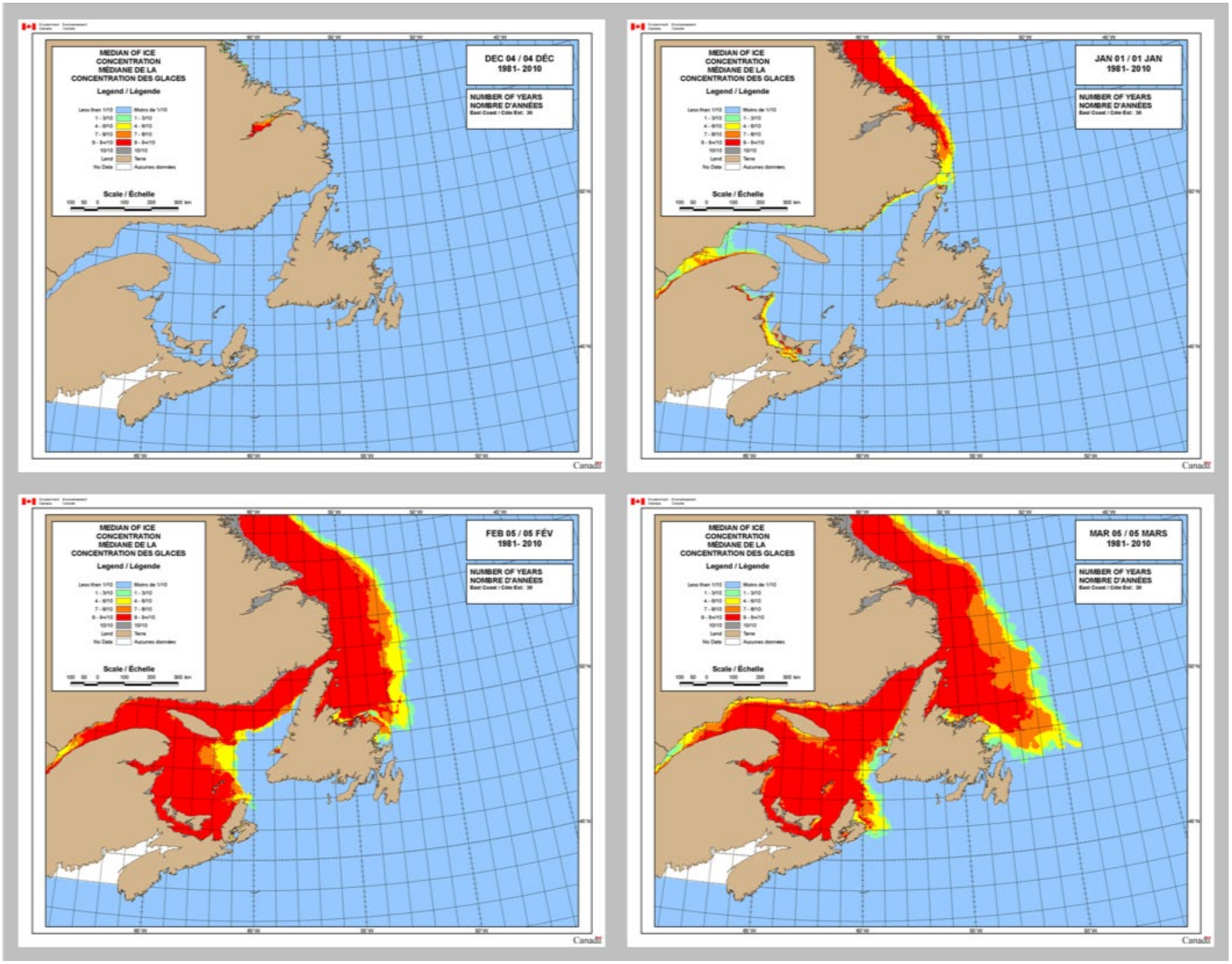


Figure 3.5: Median ice concentration when present for December-March in the southern portion of the study area from Canadian Ice Service weekly ice monitoring data collected from 1981–2010. © Her Majesty the Queen in Right of Canada, as represented by the Minister of the Environment and Climate Change 2018.

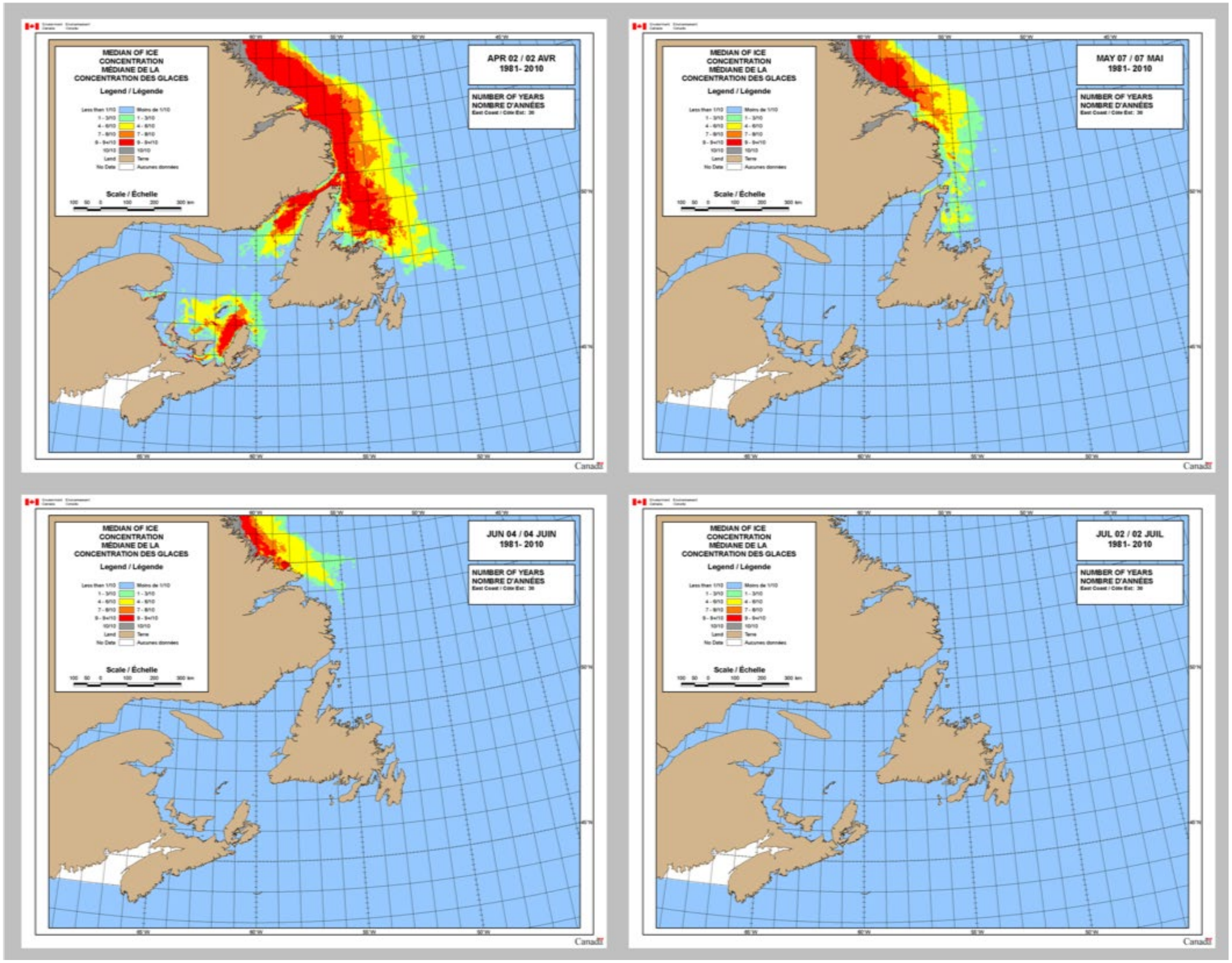


Figure 3.6: Median ice concentration when present April-July in the southern portion of the study area from Canadian Ice Service weekly ice monitoring data collected from 1981–2010. © Her Majesty the Queen in Right of Canada, as represented by the Minister of the Environment and Climate Change 2018.

Qualitative and spatial data was gathered by the Nunatsiavut Government as part of its Imappivut knowledge collection study through semi-structured interviews (n=45) (Bryman and Teevan 2005; Creswell and Poth 2018) and Direct to Digital Mapping methodologies (Olson et al. 2016). Aspects of the interviews related to sea ice focused on identifying unique ice features (polynyas, leads, floe edges), changes in ice conditions over time (locations of ice features, changes in winter travel safety, timing of ice formation and break-up), and the importance of ice for traditional uses (hunting, fishing) and wildlife (travel routes, crossing locations). Interview participants explained that they have noticed changes in ice conditions over time, including shortened ice seasons in some years and areas that have become less stable and predictable. One participant spoke about the floe edge and pack ice zone retreating and moving closer to shore over his life. Multiple participants noted that there was less ice in the winter of 2017–18 due to increased snowfall, especially early in the season. Changes in sea ice timing and predictability were summarized by one participant:

> *"It's the traditional skills that we were taught forever and for most years I guess there was a scattering years ago where you might get bad ice where it wasn't formed, but it was always so predictable you could always rely and trust that information and you can't now." (Nunatsiavut Government 2018).*

Regional sea ice data were downloaded from the Canadian Ice Service through December, January, and February from 1985–2012. Within the study area, sea ice data come from two separate regions: Hudson Bay and East Coast. Temporal coverage within the Hudson Bay region is poor in relation to the East Coast region, and historically contained just one week of sea ice data per month. In order to generate comparable datasets, each month of East Coast data was subsampled to include one week of data that was collected on a similar date as the Hudson Bay data for that month. Fast ice coverage was extracted from the data for each month and then summed by year to inform on the extent of sea ice coverage within each region for the winter. The summed datasets for the regions were then merged by year. For the purpose of this analysis, the weekly data was used as a proxy of sea ice coverage for the month.

Air temperature data from Nain was downloaded through the ECCC website and was used to identify cold, normal, and warm years within the study area. Anomalies were calculated by subtracting the monthly temperature value from the average monthly temperature from 1985–2012. The average anomaly for December, January, and February was then calculated and a 95% confidence interval was used to determine whether the temperature for each year was cold, normal, or warm. Over the 28-year monitoring period (1985–2012), there were nine warm, nine normal, and ten cold years (Figure 3.7). Eight of the nine warm years occurred since 1996, whereas only one cold year was measured in that period. The annual fast ice coverage was then averaged over the cold, normal, and warm years to determine the mean number of months during which fast ice was present. There were associated differences in fast ice extent during warm (Figure 3.8), normal (Figure 3.9) and cold years (Figure 3.10).

The Nunatsiavut Government has operated two ice monitoring stations since 2009 at Taktok and Satosoak near Nain in the northern range of the study area. Ice thickness is monitored weekly by Nunatsiavut Government staff. Analysis of these data is ongoing but preliminary results reveal annual variation in ice thickness over the study 1985–2012 period (Figure 3.11). Ice was thinnest in 2010 in both study locations, which is consistent with more broad Arctic Sea ice monitoring data that showed the 2010 minimum ice extent was the third-lowest recorded since 1979 (Beitler 2010).

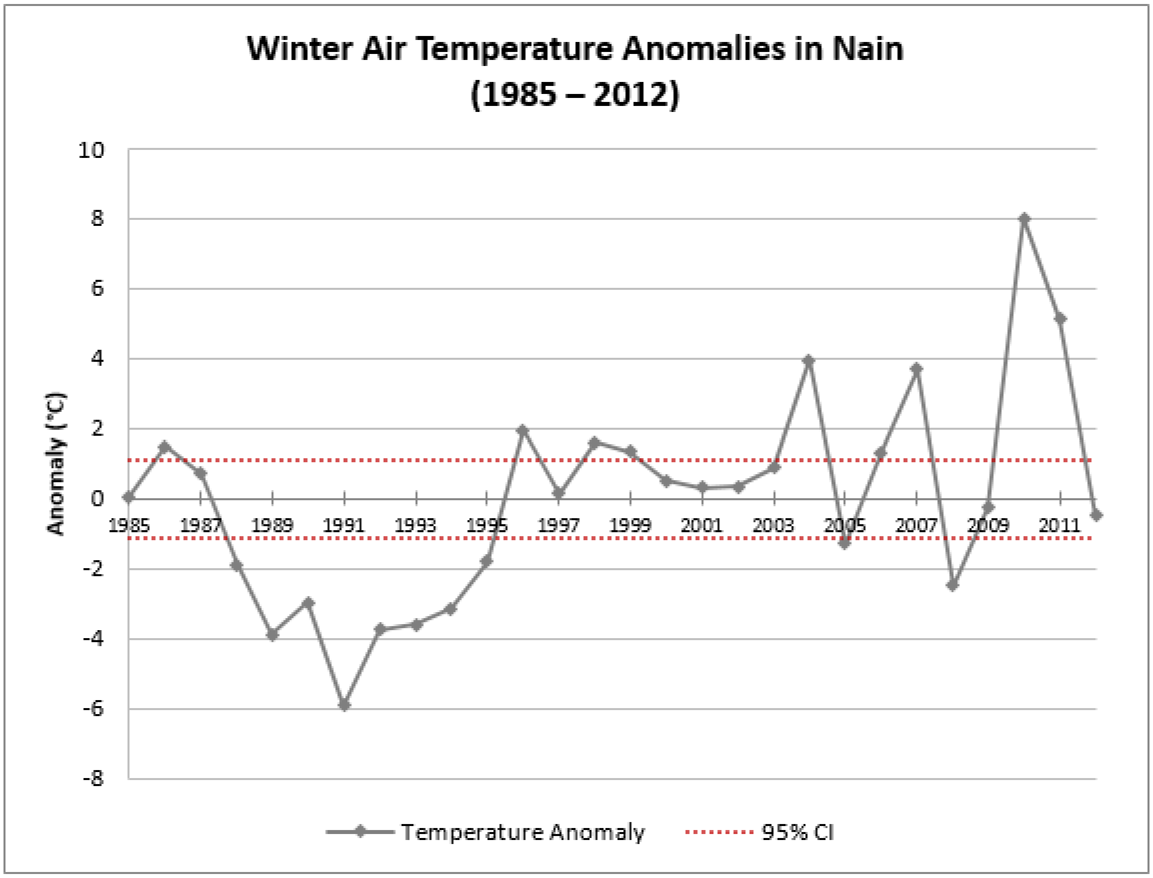


Figure 3.7: Characterization of temperature anomalies based on air temperature in Nain to identify warm, normal, and cold years. Dashed red lines represent the extent of the normal range as defined by 95% confidence intervals.

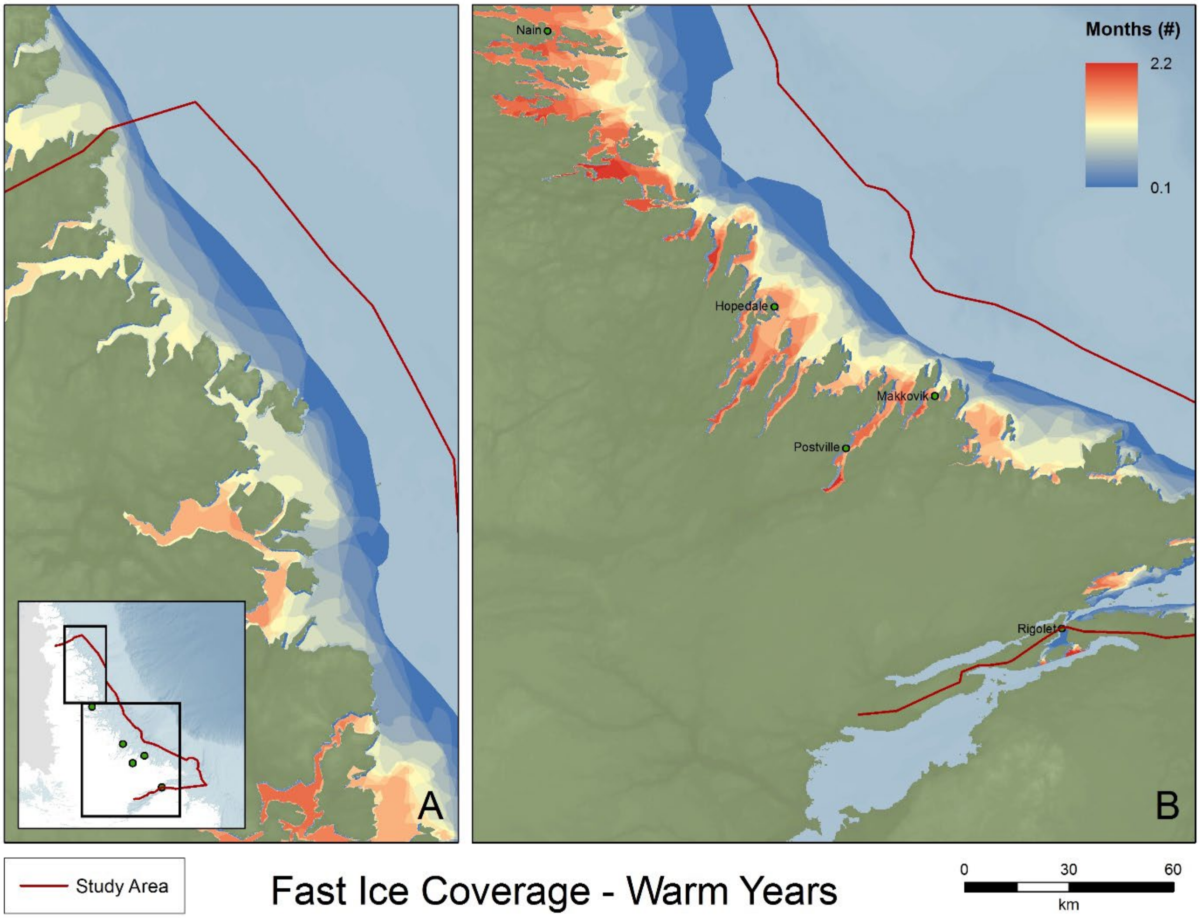


Figure 3.8: Differences in ice extent throughout the northern (A) and southern (B) portions of the study area during years classified as warm temperature anomaly years by Canadian Ice Service monitoring data (1982–2012).

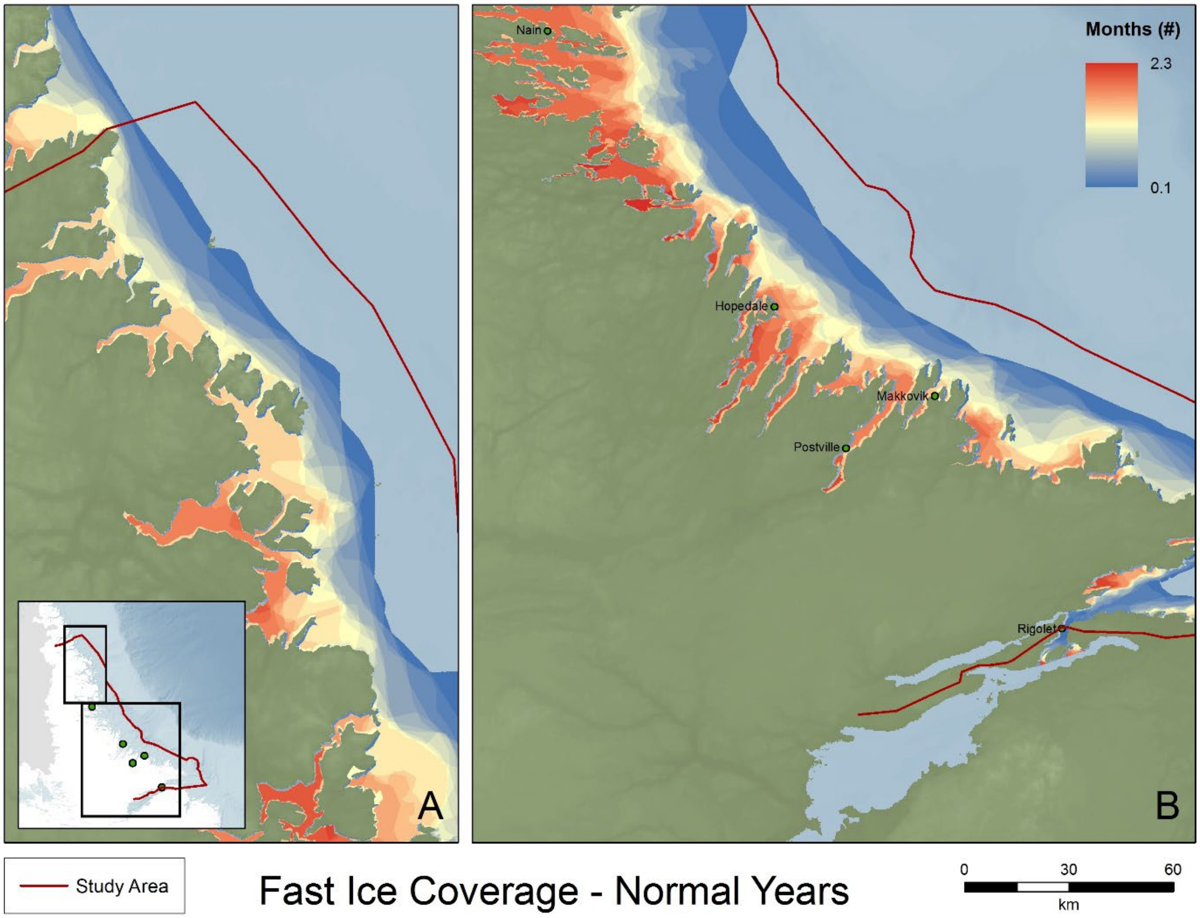


Figure 3.9: Differences in ice extent throughout the northern (A) and southern (B) portions of the study area during years classified as normal temperatures by Canadian Ice Service monitoring data (1982–2012).

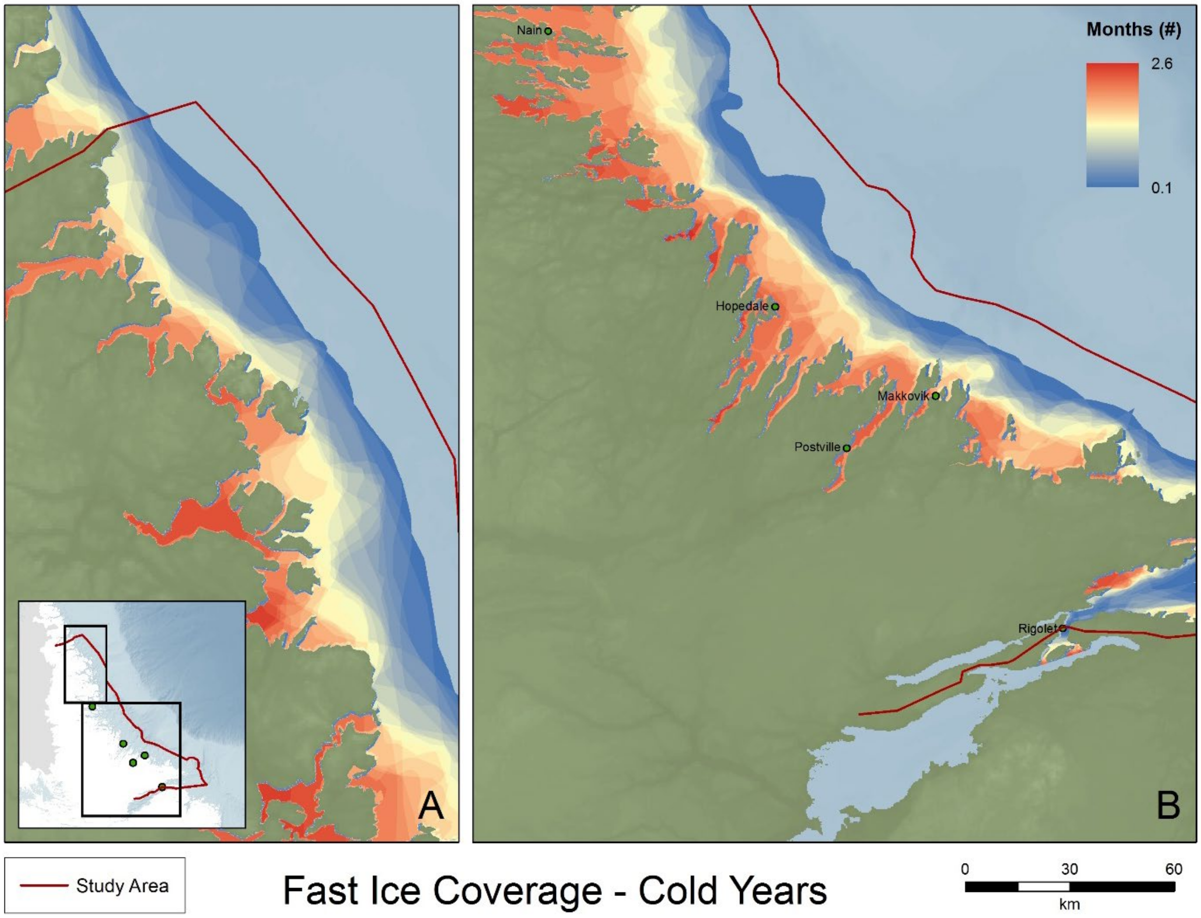


Figure 3.10: Differences in ice extent throughout the northern (A) and southern (B) portions of the study area during years classified as cold temperature anomaly years by Canadian Ice Service monitoring data (1982–2012).

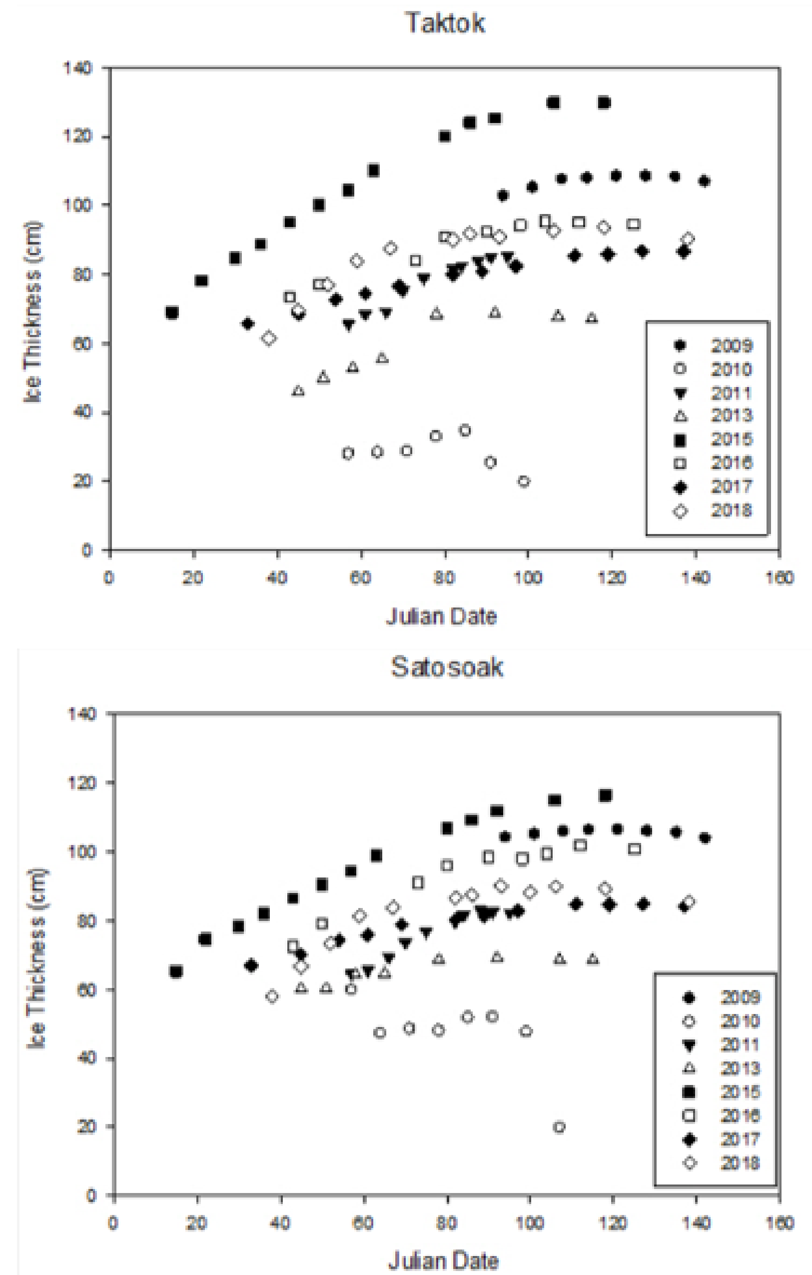


Figure 3.11: Nunatsiavut Government's ice thickness monitoring stations at Taktok and Satosoak near Nain for 2009–11, 2013, and 2016–18.

3.2. Sensitive Habitats

Sea ice has both ecological and social-cultural elements of importance in the study area related to its role as habitat for marine and terrestrial wildlife and its importance for Labrador Inuit.

The ecological importance of sea ice for marine wildlife is well documented (Griffiths et al. 1999). Sea ice plays a key role in primary productivity in Arctic ecosystems as a platform for ice algae and other ice-related organisms (Fernández-Méndez et al. 2015; Song et al. 2016). Climate-related changes in ice-dominated ecosystems could have implications for primary productivity in Arctic regions and have the potential to have cascading effects on Arctic marine food webs more broadly (Mäkelä et al. 2017a, 2017b). Sea ice provides critical feeding and breeding habitat for marine mammals such as Ringed Seals who maintain breathing holes through land fast ice throughout the winter and use ice platforms to construct birth lairs and as haul out locations in the spring (Furgal et al. 1996; Hamilton et al. 2018; Harwood et al. 2012). The importance of sea ice as a hunting platform for polar bears has also been well documented in multiple regions (Hamilton et al. 2017; Laidre et al. 2018; Pilfold et al. 2014, 2015). Many studies have documented the high biological productivity associated with polynyas (known locally in Nunatsiavut as rattles) and ice edges, such as floe edges (known locally as the sinâ) (e.g., Stirling 1997; Perrette et al. 2011). Accordingly, polynyas and ice edges are important gathering areas for seabirds and marine mammals such as Ringed Seals and Harbour Seals (*Phoca vitulina*) in the winter (Nunatsiavut Government 2018; Griffiths et al. 1999), which accounts for increased concentration and abundance of species such as marine mammals and seabirds in these environments. Accordingly, historical (Grønnow et al. 2011) and contemporary (Imappivut) sources have noted the importance of polynyas and ice edges as hunting locations for Inuit. Studies in other Arctic regions have documented the importance of polynyas as feeding and breeding habitat for seabird species such as Black Guillemots (*Cepphus grille*) and Northern Fulmars (*Fulmarus glacialis*) (Byers et al. 2010), Ivory Gulls (*Pagophila eburnea*) (Karnovsky et al. 2009), and Little Auks (*Alle alle*) (Mosbech et al. 2017). Currently, there is limited spatial data on the locations of polynyas in the study area, but some data was collected by Search and Rescue mapping activities and through Imappivut LK interviews and participatory mapping activities (Figure 3.12).

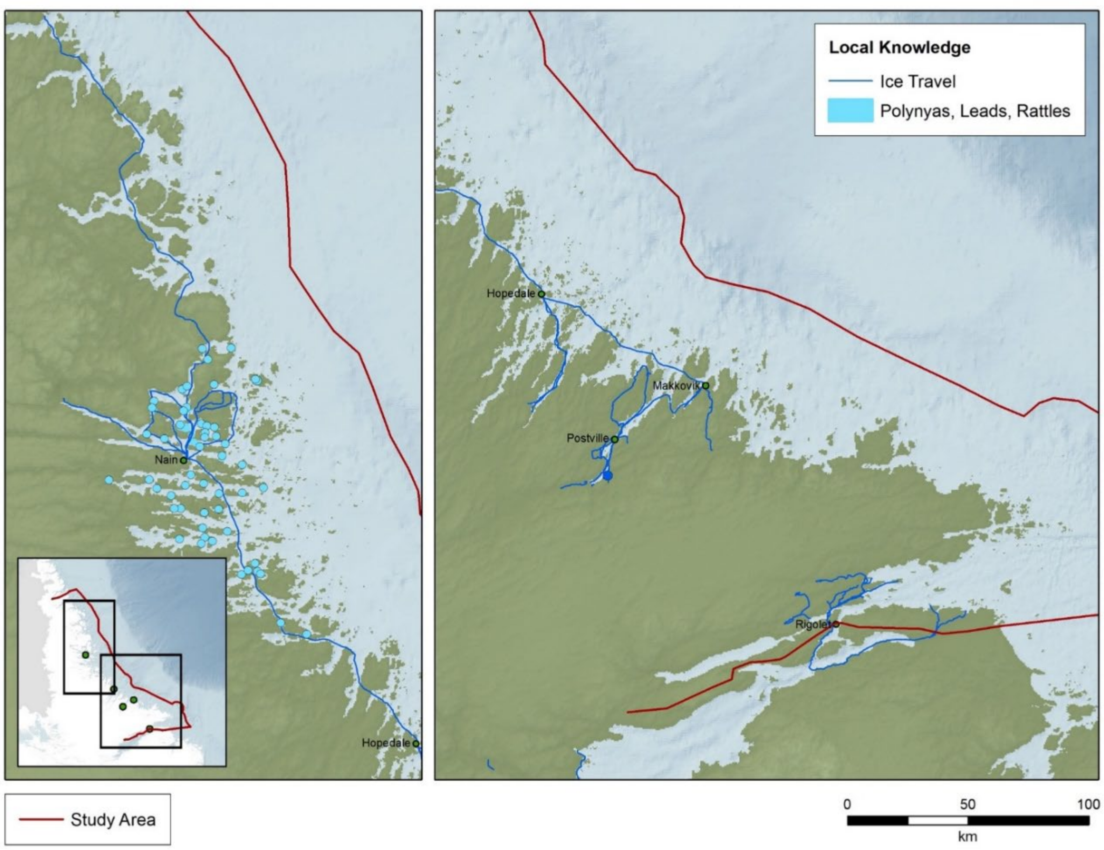


Figure 3.12: Locations of rattles (polynyas, leads) and sea ice travel routes documented by Labrador Inuit.

In addition to habitat for marine wildlife, sea ice also provides critical infrastructure as a platform for winter travel for terrestrial wildlife. Interview participants discussed the importance of sea ice as a winter travel platform for terrestrial species such as caribou, wolves (*Canis lupus*), Arctic Fox (*Vulpes lagopus*), and small mammals such as Arctic Hare (*Lepus arcticus*). The importance of sea ice as a travel platform for caribou has been noted in the study area and through studies in other regions (e.g. Jenkins et al. 2016; Joly 2012; Leblond et al. 2015; Poole et al. 2010).

Inuit communities in Nunatsiavut also rely on sea ice as a platform for travel routes to cabins, hunting and fishing areas, and as a highway between communities (Figure 3.12). All interview participants highlighted the importance of stable and reliable sea ice for harvesting activities and travel in the winter (Nunatsiavut Government 2018). Labrador Inuit continue to rely on sea ice to travel to freshwater Arctic Char fishing locations in the winter, to fish for Greenland Cod (also referred to locally as Rock Cod) through the sea ice throughout the winter, hunt Ringed Seals through breathing holes, at polynyas, and the floe edge, and hunt Polar Bears. Sea ice also offers community members the ability to travel to other land-based hunting locations to access species such as ptarmigan (*Lagopus* spp.), Moose (*Alces alces*), and caribou. Interview participants expressed that sea ice is equally important as open water for their continued ability to engage in activities in the marine environment.

3.3. Data Gaps and Recommendations

Spatial and temporal coverage of available sea ice information remain incomplete. Therefore, developing an understanding of sea ice that is proportionate to its importance to ecological and human communities in the study area requires longer-term and more comprehensive studies. Sea ice research and monitoring programs are ongoing throughout the Arctic and comparing observations and trends in other regions will help assess potential impacts of sea ice changes in the study area. In addition, it is important to consider standardized research and monitoring methods used elsewhere to maintain comparability with studies in other Arctic environments. Some key knowledge gaps and deficiencies could be addressed through further research.

It will be important to continue to deepen our understanding of the ecological role of sea ice in the study area. Sea ice comprises a range of habitats on different spatial scales and extents and the importance of different habitat features for wildlife species should be further characterized. Further, while the importance of documenting inter-annual changes in sea ice is well noted, sea ice as a habitat also changes intra-annually and it is important to study these habitat features and changes at finer scales. Sea ice features such as polynyas and leads are key areas of ecological productivity used by marine mammals and seabirds (Asselin et al. 2012; Black et al. 2012; Clayden et al. 2015; Galicia et al. 2015; Heide-Jørgensen et al. 2013; Mosbech et al. 2017; Stirling 1997). Interview participants indicated that sea ice conditions have changed over time with interannual fluctuations in the timing of ice formation and breakup, as well as variations in ice thickness and extent (Nunatsiavut Government 2018). It is important to understand how ice conditions are changing and are projected to continue changing over time to understand potential impacts on a variety of marine biota (e.g., Ringed Seals). With continued overall declines in sea ice, there are also changes in ice types that affect changes in the habitats and processes associated with sea ice. For instance, as sea ice dynamics alter, areas such as the shear zone may experience more destructive ice forces, which may impact species that rely on these areas for key habitat. These types of changes are poorly understood and therefore difficult to predict. Therefore, future studies should also focus on assessing the consequences of changing ice behaviours on ecosystems. Interview participants also expressed increased safety concerns related to travelling on sea ice as conditions continue to become less predictable between years. Increased understanding of trends in ice conditions can be developed through an expansion of the Nunatsiavut Government's ice monitoring activities and targeted interviews and mapping with Labrador Inuit to identify specific locations that have experienced changes in ice conditions over time. New studies by the Nunatsiavut Government will begin to address these data gaps in coming years.

Data on locations, seasonal variability, and other aspects of sea ice features such as polynyas is sparse and inconsistent and should be a focus of future research. Increased knowledge of polynyas and other ice features will contribute to a greater understanding of marine ecology in the study area and the effects of sea ice changes on biota as a result of climate and other environmental changes. Polynyas and other open water features also have safety implications for Inuit while traveling on the ice and it is therefore important to understand how these areas are predicted to change with climate. Expanding a spatial database of polynyas and leads will assist with monitoring these and other features over time, which will enhance understanding of the importance of sea ice for wildlife and human communities, including potential impacts of changing ice conditions over time. Since there is not a great deal of information specific to the study area, results from other regions indicate that further study on the relationship between polynyas and seabirds would be valuable. As sea ice continues to decline throughout the Arctic, there have been observed shifts from ice algal to phytoplankton contributions to primary production (e.g. Mäkelä et al. 2017a, 2017b). The impacts of these changes on the wider food web of the study area is a key data gap that should be addressed in the future. Further oceanographic modeling and sea ice monitoring are principal priorities for future study to better understand the impacts of climate change and more accurately predict the ecosystem effects of changes in sea ice.

4. Physical Oceanography

The physical oceanography of the Labrador Shelf, including the study area is of considerable interest and has far reaching downstream influences, affecting marine habitats from the Newfoundland Shelf, the Scotian Shelf and as far south as the Gulf of Maine and the Mid-Atlantic Bight. The dominant oceanographic feature is the Labrador Current which transports cold, relatively fresh, polar water southward along the Labrador coast to the northeast Newfoundland Shelf and the Grand Banks. A comprehensive understanding of the physical and biological dynamics of the Labrador Shelf and the study area is essential to ecosystem management.

4.1. Available Information

Knowledge of the study area is based on historical and current studies and observations collected along the coast of Labrador as early as the 1920s. The first such study took place in 1926 from the schooner Chance by Iselin (1932) who provided one of the first detailed descriptions of the Labrador Shelf waters from two oceanographic sections crossing the Labrador Shelf as well as observations within several fjords along the Labrador Coast. The first larger scale comprehensive physical oceanographic study of the Labrador Sea and adjacent shelf was conducted by Smith et al. (1937) using data collected during the Marion expedition in 1928 and the General Greene surveys of the early-1930s. These initial studies provided the foundations for much of the baseline knowledge of the oceanography of the Labrador Shelf and Sea.

Many other contributions to the oceanographic knowledge of the Northwest Atlantic including the Labrador Shelf from the late-1800s to early-1950s are chronologically summarized by Dunbar (1951). Of particular importance to this study are the voyages of the schooner Blue Dolphin from 1949–54 to several fjords along the coast of Labrador, including Hamilton Inlet and Lake Melville, Kaipokok Inlet, Nain Bay, Hebron, and Seven Islands Bay (Nutt 1951, 1953, 1963). The results from these surveys provided the first detailed oceanographic study of the coastal fjords of Labrador, including freshwater influx, temperature and salinity relationships, dissolved oxygen, sea ice dynamics and exchange mechanisms with the adjacent inshore Labrador Current waters (Nutt and Coachman, 1956). In addition, limited biological studies were also carried out during these surveys at several stations along the Labrador Coast (Grainger 1964).

In 1978, the Standing Committee on Research and Statistics of the International Commission for the Northwest Atlantic Fisheries (ICNAF) standardized a series of sections and stations throughout the Northwest Atlantic including the Labrador Shelf (ICNAF 1978). Several countries of ICNAF and its successor the Northwest Atlantic Fisheries Organization (NAFO) carried out oceanographic measurements along some of the standard sections as part of a larger Northwest Atlantic monitoring program in support of fisheries assessments.

An extensive physical and biological oceanographic study was carried out on the Labrador Shelf during 1979–80 by the Offshore Labrador Biological Studies (OLABS) program for the petroleum industry (Fissel and Lemon 1991). Colbourne and Foote, 1997 reviewed existing oceanographic and sea ice observations on Nain Bank (NB) and vicinity in support of the Voisey's Bay ecosystem characterization study.

More recently, in 1998 the AZMP of DFO (Therriault et al. 1998) began sampling standard sections on the southern and mid-Labrador Coast during the summer months. Additional oceanographic observations are also made during the fall Remote Vehicle (RV) multi-species surveys conducted by DFO. The physical oceanographic environment in the Newfoundland and Labrador (NL) Region based on these data are published annually as part of both the AZMP and the Fisheries Oceanography Committee of NAFO's Scientific Council (Colbourne et al. 2018 and Colbourne et al. 2017).

These data and other historical data from research surveys and ships of opportunity are available from archives at the Ocean Science Branch (OSB) of Fisheries and Oceans Canada in Ottawa and also maintained in regional data archives at the Northwest Atlantic Fisheries Centre (NAFC) in St. John's, NL. In this section, we review oceanographic data availability and examine the seasonal variability in baseline oceanographic properties and trends along the coast of Labrador, focusing on the current study area. To reduce spatial variability of oceanographic properties, in some cases we provided separate analysis in the northern and southern regions of the study area.

4.1.1. General Circulation and Water Mass Properties

The general circulation in the study area is dominated by the inshore coastal branch of the Labrador Current flowing south eastward along coast of Labrador. This current is part of the large-scale northwest Atlantic circulation consisting of the West Greenland Current that flows northward along the west coast of Greenland, a branch of which turns westward and crosses the Labrador Sea forming the northern section of the northwest Atlantic sub-polar gyre. Dunbar (1951) first described the properties of the source waters of the Labrador Current, including the outflows from Baffin Bay, Hudson Strait and the West Greenland Current. Near the northern tip of Labrador, outflow through Hudson Strait combines with the east Baffin Island Current and flows south eastward along the Labrador Coast (Chapman and Beardsley 1989; Lazier and Wright 1993). The current over the shelf regions is strongly influenced by the seabed topography, following the various cross shelf saddles and inshore troughs as it flows southward along the Labrador coast.

The surface circulation on the Labrador Shelf as depicted by a Global Ice Ocean Prediction model (Smith et al. 2016) shows a distinct coastal branch of the Labrador Current flowing through the study area as well as the general circulation in the northwest Atlantic (Figure 4.1).

Data from Acoustic Doppler Current Profiler (ADCP) measurements obtained from the summer AZMP surveys presented later in this section indicates that the volume transport through the study area however is only a fraction of the total transport of the Labrador Current, with most of the flow remaining offshore at the edge of the continental shelf. In this area the main branch of the Labrador Current forms a boundary that separates the cold and fresh shelf waters from the relatively warm and saline waters of the Labrador Sea.

Details of the near-surface circulation on the Labrador Shelf in relation to local bathymetric features are derived from the paths of satellite tracked drifters that were released north of the study area (Figure 4.2). In general, some drifters followed the inshore Labrador Current along the 200 m isobath and the offshore boundary of the study area while others followed the offshore Labrador Current along the shelf break seaward of the study area. Small scale eddy features are evident on the major banks (Saglek and NB) with time scales of several weeks, as well as areas with significant cross shelf exchange, particularly in the Hopedale Saddle area.

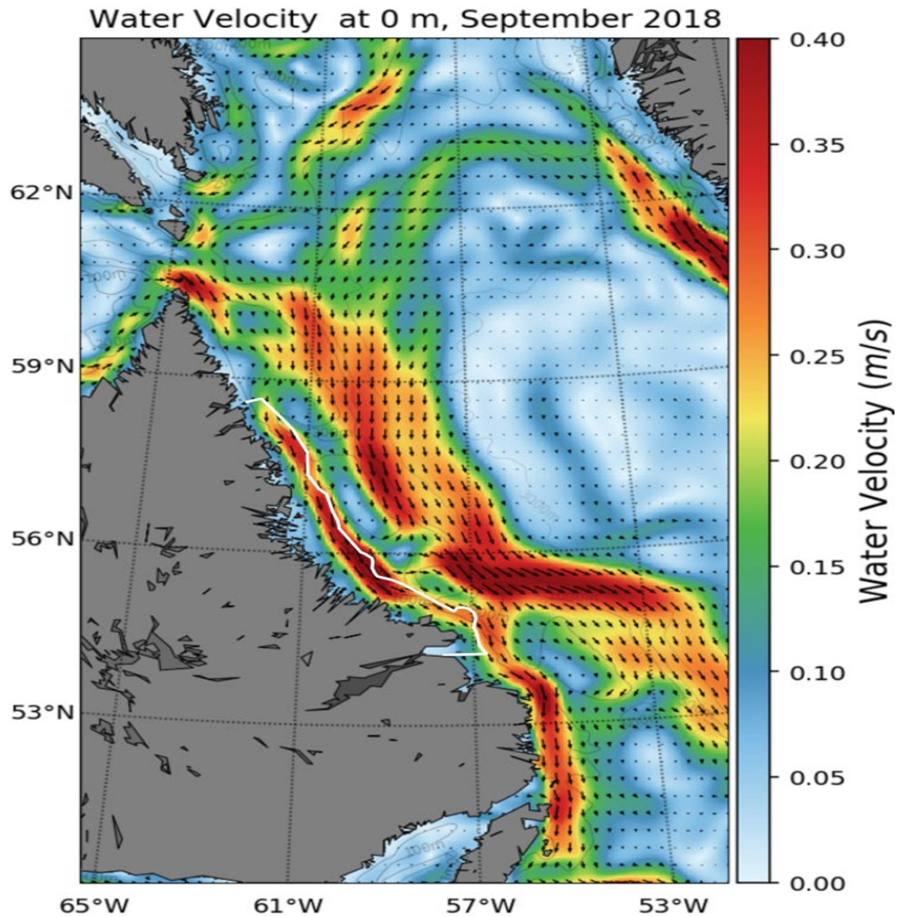


Figure 4.1: The ocean surface circulation in the Northwest Atlantic showing the inshore and offshore components of the Labrador Current for September 2018. From the Global Ice Ocean Prediction System of the Canadian Operational Network of Coupled Environmental PredicTion Systems (CONCEPTS) and provided by the [Ocean Navigator](). The approximate boundary of the study area is shown by the white line.

The water mass characteristics of the inshore branch on the Labrador Shelf are typical of subpolar waters with a temperature range of -1.5°C to 2°C and salinities of 32–33.5 practical salinity units (PSU). The seasonal cycle of air-sea heat flux and ice formation and melt produces warmer and fresher water in the near surface layer on the shelf with maximum temperatures reaching 6°C to 12°C during August and salinities decreasing to minimum values of <30 PSU during early-summer. Lazier (1982) undertook the first comprehensive study of the properties of Labrador Shelf water showing that the temperature and salinity fields were characterized by very small horizontal gradients, relative to waters at the shelf break, suggesting the presence of a single water mass of subpolar origin occupying the entire Labrador Shelf.

Sutcliffe et al. (1983) found evidence for nutrient enrichment of the waters of the northern Labrador Shelf and attributed it to the presence of intense tidal mixing at the mouth of Hudson Strait. In addition, Colbourne and Mertz (1998) showed evidence of a plume of well mixed water originating near Hudson Strait imparting a warmer than expected temperature anomaly on the northern Labrador Shelf that propagates southward during late summer and fall.

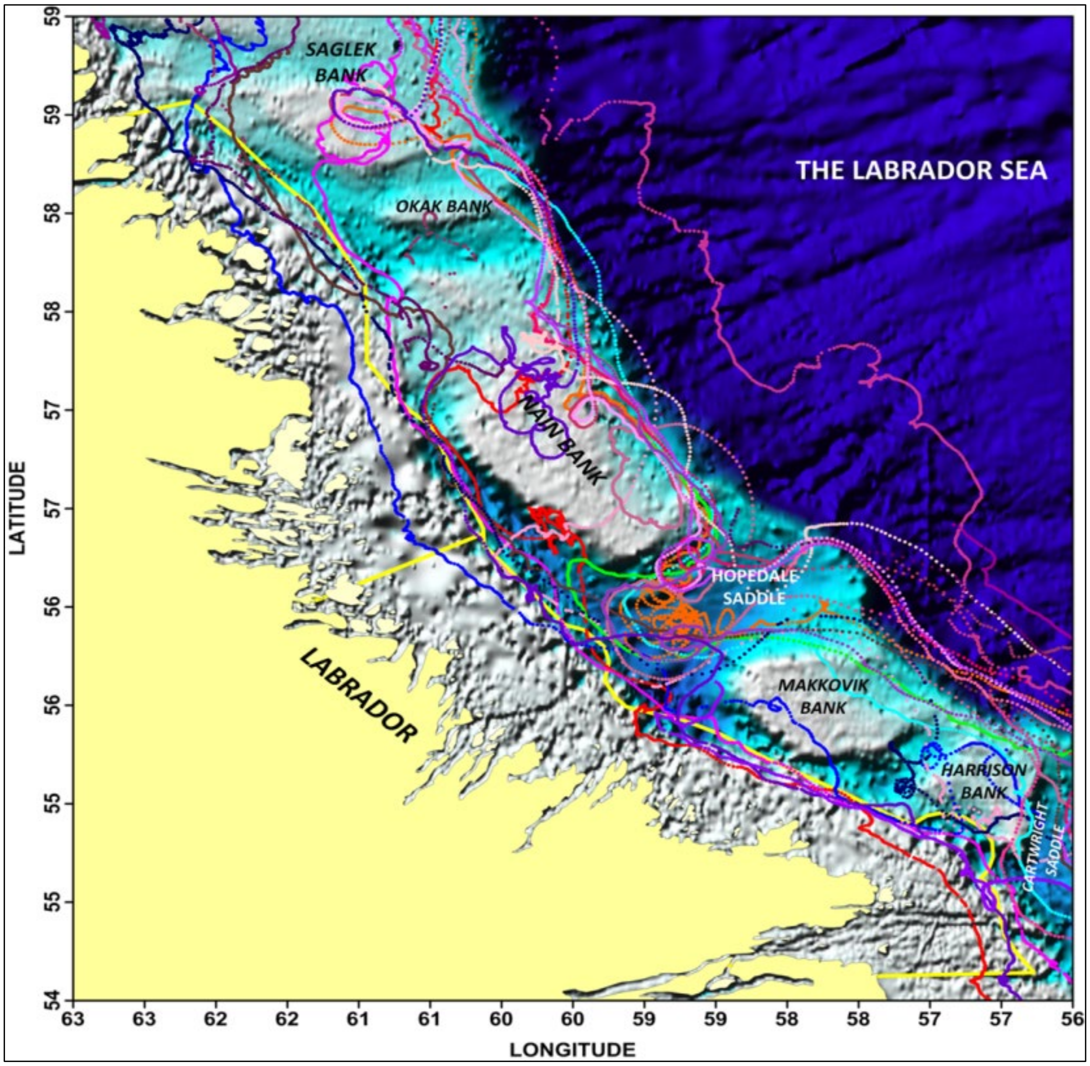


Figure 4.2: The surface circulation in relation to local bathymetric features on the Labrador Shelf based on a composite of 27 drifter tracks from 2016–18. Data courtesy of CONCEPTS and provided online by the Ocean Navigator. The boundary of the study area is shown by the yellow line.

The data from the Blue Dolphin surveys showed that the temperature and salinity of the basin waters within the fjords along the Labrador Coast remain nearly isothermal and isohaline throughout the year. In contrast, to the near surface layer of the water column which experiences a strong annual cycle resulting from seasonal solar heating, freshwater runoff, and ice melt.

4.1.2. Satellite Sea-Surface Temperatures

Sea Surface Temperature (SST) data based on infrared satellite imagery of the northwest Atlantic, including the Labrador Shelf study area are available as weekly or bi-weekly composites. The Pathfinder 5.2 SST data are available at a resolution of 4 km with seven-day composite averages from 1981–2012 (Casey et al. 2010). The National Oceanic and Atmospheric Administration (NOAA) Advanced Very High-Resolution Radiometer (AVHRR) SST data are available as bi-weekly composites from 1997–2018. These data sets have been used by the AZMP to construct SST time series throughout the Atlantic Zone, including the Labrador Sea and Shelf regions including the study area. These data are provided by the remote sensing group in the Marine Ecosystem Section at the Bedford Institute of Oceanography (BIO) (Figure 4.3, left panel).

In addition, the AVHRR SST data have been used to examine the frequency of occurrence and to identify locations of thermal sea surface fronts in Canadian waters, including the Labrador Shelf (Cyr and Larouche 2015; Belkin et al. 2009). In many areas of the ocean thermal fronts are often associated with enhanced biological production. On the Labrador Shelf, the high frontal frequencies are clearly associated with the stability of permanent oceanographic features, the inshore and offshore branches of the Labrador Current as well areas with enhanced cross shelf exchange such as the Hopedale Saddle area (Figure 4.3, right panel).

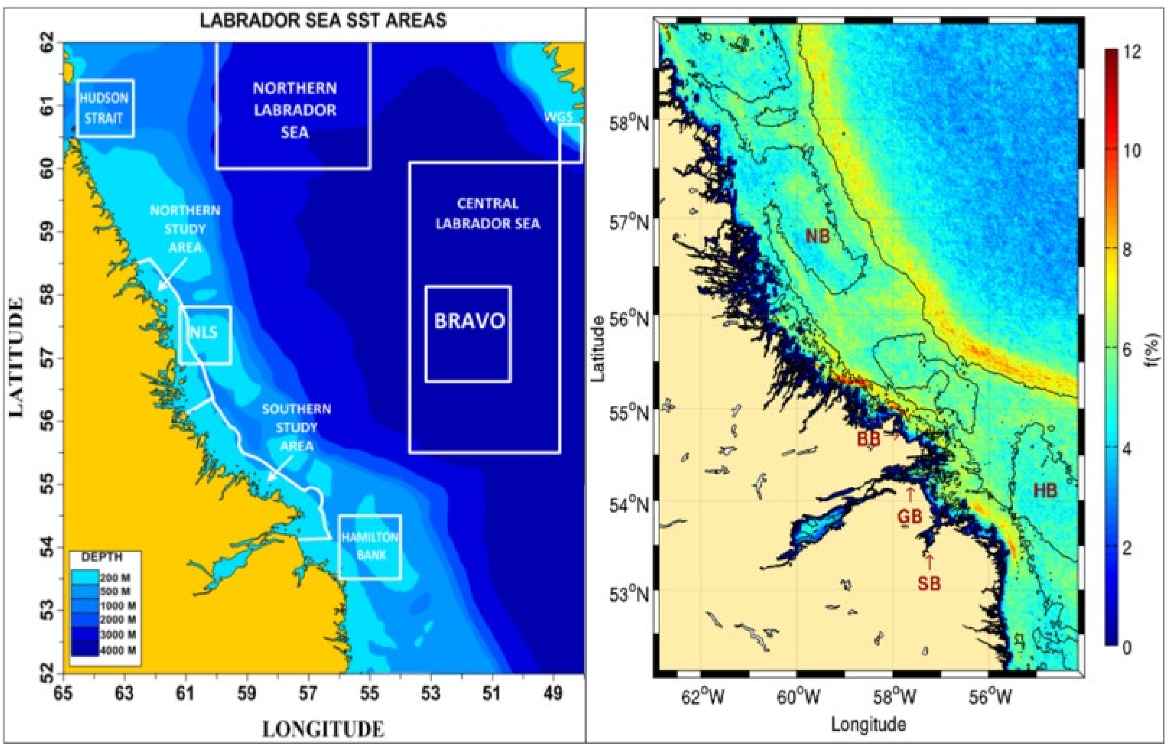


Figure 4.3: Map showing the subareas where SST time series were constructed for the Northwest Atlantic as part of the AZMP. SST data series were also constructed in the white polygons labeled as the northern and southern study area (left panel) and the mean frontal frequency (1986–2010) for the Labrador Shelf, adopted from Cyr and Larouche (2015) (right panel).

Bi-weekly maps of SST from NOAA's AVHRR during 2017, show the mid-Labrador Coast still partially covered with sea ice during the latter half of May with SST values in open water areas still <0°C. By the latter half of June sea ice have receded to Hudson Strait and open water areas have warmed to 0°C to 2°C. By August, SST have reached their maximum with values reaching

>10°C near the coast in core area 2, but generally around 5°C elsewhere (Figure 4.4). Contours of the SST climatology based on the bi-weekly AVHRR data from 1998–2010 are shown in Figure 4.5 for the ice-free months on the Labrador Shelf and the adjacent Labrador Sea.

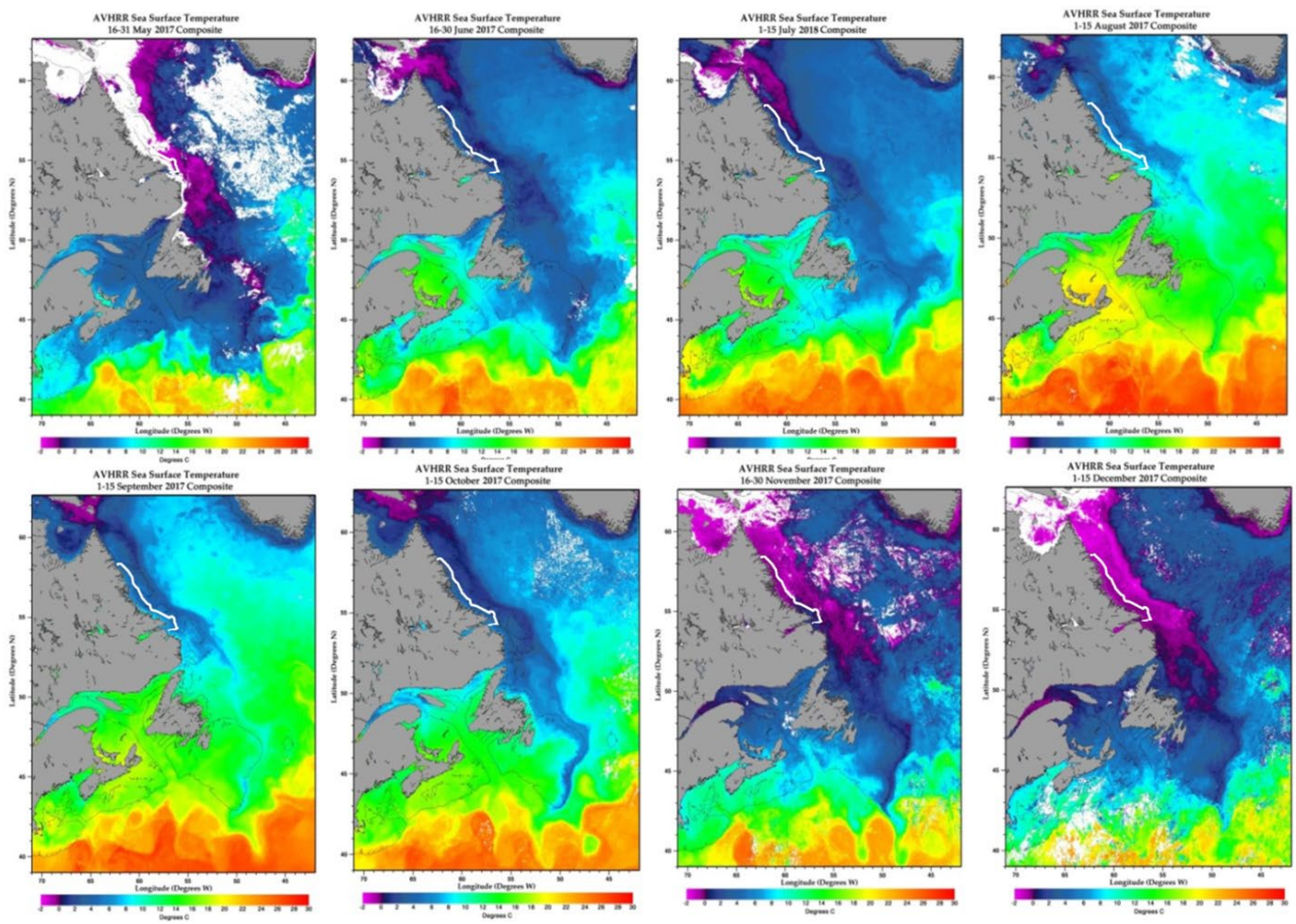


Figure 4.4: Maps of sea surface temperature (in °C) for May to December of 2017 based on NOAA bi-weekly AVHRR temperature data for the Atlantic Zone. SST maps courtesy of the Marine Ecosystem Section, Bedford Institute of Oceanography (BIO). The approximate boundary of the study area is shown by the white line on each panel.

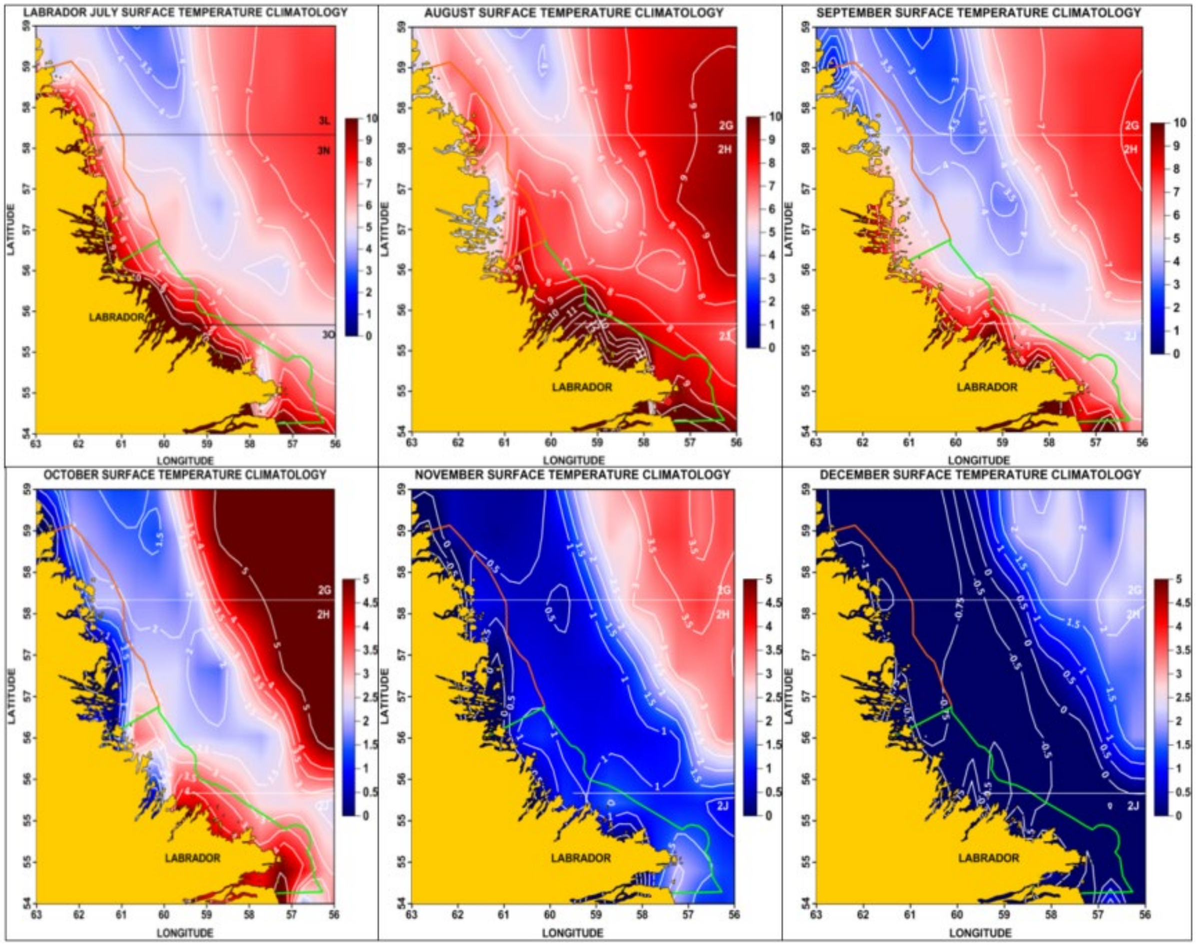


Figure 4.5: Maps of SST climatology (in °C) for July to December based on NOAA bi-weekly temperature data for the Atlantic Zone from 1998–2010. The study areas are outlined as the red (northern) and green (southern) polygons along the Labrador Coast. SST data courtesy of the Marine Ecosystem Section, Bedford Institute of Oceanography (BIO).

The annual cycle of SST within the northern portion of the study area displayed in Figure 4.6 show average April values of less than -1°C, warming to above 0°C by June and reaching a maximum of 5°C in August. Temperatures then decrease to about 0°C in November and to -1°C in December. A comparison of the average conditions in August to a typical warm year (2011) shows maximum values of about 7°C compared to <4°C during a cold year (1991) (Figure 4.6).

Annual SST anomalies in the northern portion of the study area show significant annual variability with below normal values from 1982–92, variable conditions from 1993–2002 and thereafter mostly above normal values (Figure 4.7). The time series shows an increasing trend of near 1°C from the low in 1984–2010. Since then, these series show a decreasing trend to close to normal in 2015 and remaining slightly above normal in 2016 and 2017.

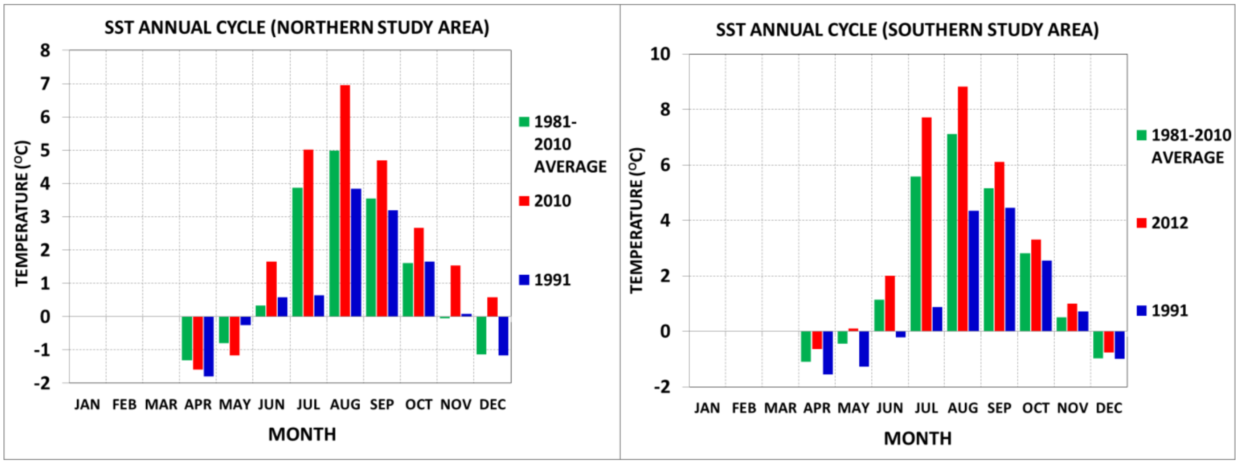


Figure 4.6: Monthly SST values for the northern and southern portions of the study area, comparing a cold year (1991) and warm years (2010, 2012) to the 1981–2010 climatology. SST data courtesy of the Marine Ecosystem Section, Bedford Institute of Oceanography (BIO).

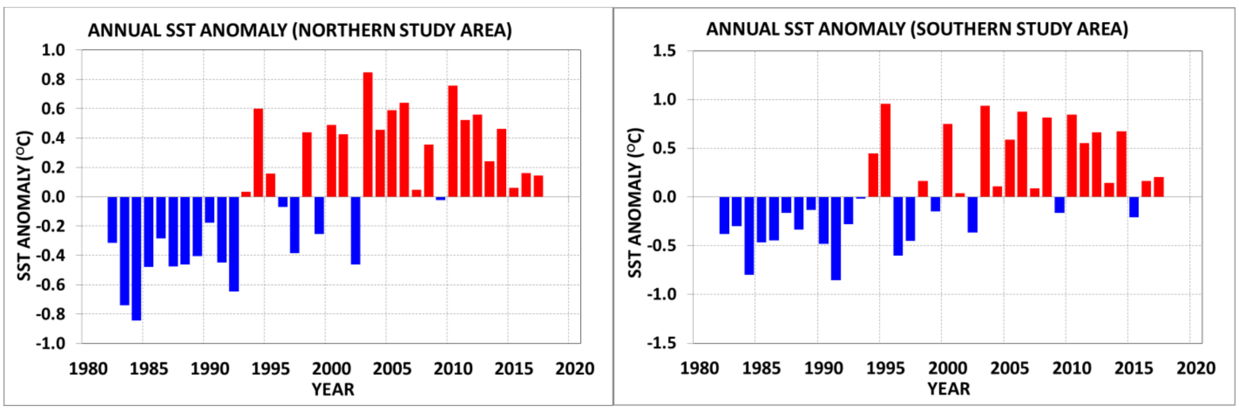


Figure 4.7: Time series of annual SST anomalies for northern and southern portions of the study area referenced to the 1981–2010 average. SST data courtesy of the Marine Ecosystem Section, Bedford Institute of Oceanography (BIO).

4.1.3. Historical Temperature and Salinity Observations

There is an extensive archive of temperature and salinity profile data available for the Northwest Atlantic (Figure 4.8). Until the1960s, profiles were collected at standard nominal depths using water-sampling bottles fitted with reversing thermometers. After the 1960s data were collected using mechanical and electronic bathythermographs supplemented with bottle data at specific depths and since the late-1970s conductivity-temperature-depth (CTD) recorders have become the primary instrument which records data at a much higher resolution and accuracy.

The spatial distribution of data collections shows the highest concentration of observations on the Labrador shelf and slope areas seaward of the study area but within the 1,000 m isobath. A significant portion of this data was collected by DFO’s ongoing multi-species assessment surveys. The seasonal distributions (Figure 4.8, right panels) show only a few observations in both northern and southern portions of the study area during winter and spring when most of the areas were covered by sea ice. During the summer, the study area was reasonably well sampled and during the fall most observations were made along the outer boundary of the study area, marking the inshore limit of the DFO’s fall multi-species surveys (Figure 4.8).

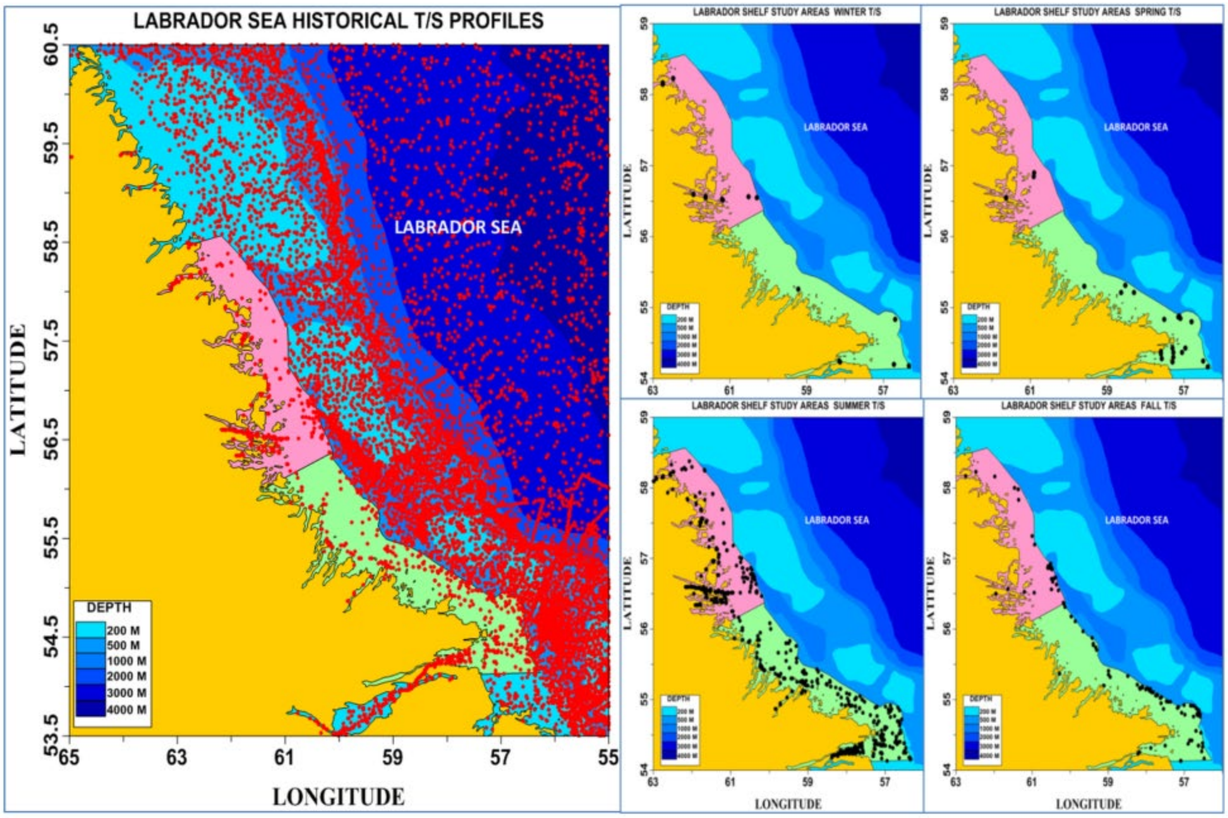


Figure 4.8: Maps showing the locations of historical temperature and salinity profiles in the Labrador Sea and shelf regions from 1928–2018 (left panel) and the seasonal (right panels) temperature and salinity profiles in the northern (pink polygon) and the southern (green polygon) portion of the study area from 1928–2018.

Temporally, the highest number of observations available in the northern portion of the study area occurred in July (134 profiles) and August (230 profiles) and no observations are reported during January, February and December (Figure 4.9). The high number in July and August are from directed studies that occurred in 1951 and 1954. The number of observations in other months ranged from two in June to 25 in October. Since the early-1950s most years had less than 10 sampling stations. For many years there are no observations available in the archive (Figure 4.9, right panel).

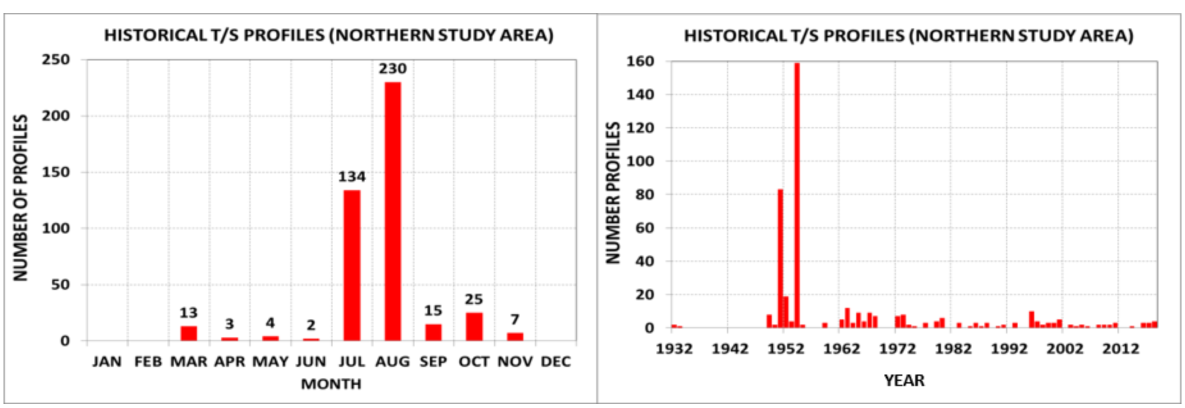


Figure 4.9: The number of historical temperature and salinity profiles in the northern portion of the study area by month (left panel) and by year (right panel).

Similarly, in the southern portion of the study area, most observations are available for July (234) and August (241) with none available during February, April, and May. In other months the number of profiles ranged from one in January to 40 in October. As in the northern area, the highest number of profiles was collected during the summer, in this case from 1949 to 1954. Other years had generally less than 10 profiles; with a couple of years (1962 and 1980) reporting more than 20 profiles (Figure 4.10, right panel).

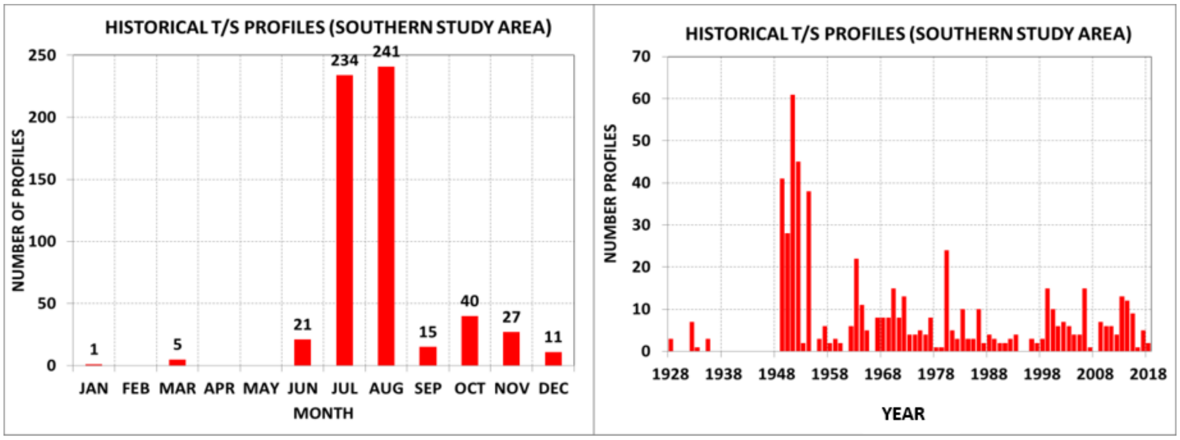


Figure 4.10: The number of historical temperature and salinity profiles in the southern portion of the study area by month (left panel) and by year (right panel).

The available data within the study area is insufficient to construct reliable time series of temperature and salinity trends over time at specific depths. However, a reasonable approximation of the annual cycle in temperature and salinity at various depths is possible with only a few missing months. The annual cycle in bottom temperature and salinity for both analysis areas from the available data is shown in Figure 4.11. Bottom temperatures show a weak annual cycle, with minimum observed values occurring in winter and spring of less than 0°C and maximum values of about 2°C occurring during late summer and the fall months.

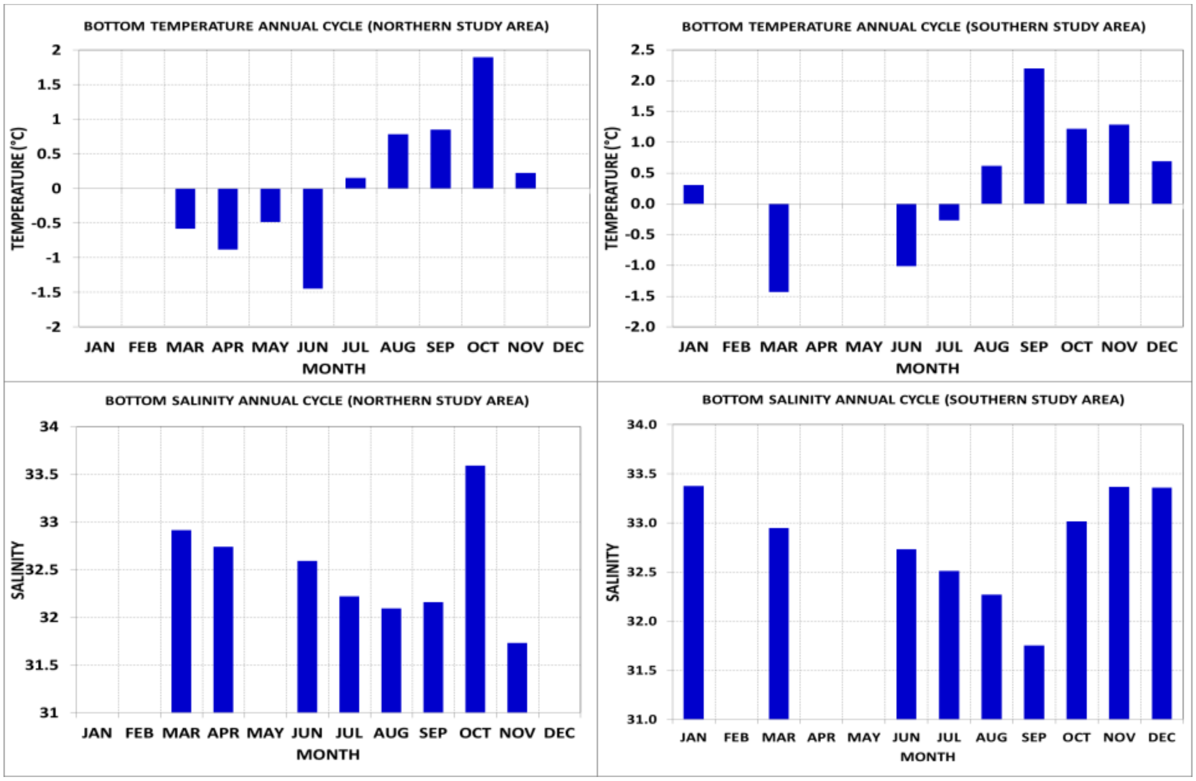


Figure 4.11: The monthly averaged bottom temperature and salinity in the northern (left panels) and southern (right panels) portions of the study area based on all historical data available in each zone.

Typical profiles of the temperature and salinity vertical structure for the winter and summer periods in the northern and southern portions of the study area are shown in Figure 4.12. During winter, the water column is essentially isothermal and isohaline over almost the entire water column with temperatures in northern area near -1.8°C and about -1.3°C in the southern area with a slight warming to above 0°C values near bottom.

Salinities are near constant during the winter at about 32.6 PSU increasing to about 33.7 PSU near bottom, where slightly warmer and more saline waters from further offshore floods in through the deeper cross-shelf channels. During the summer, as the water column becomes more stratified, upper layer temperatures increase to 5°C to 8°C, while salinities decrease to 29 to 30 PSU as a result of freshwater runoff and melting sea ice.

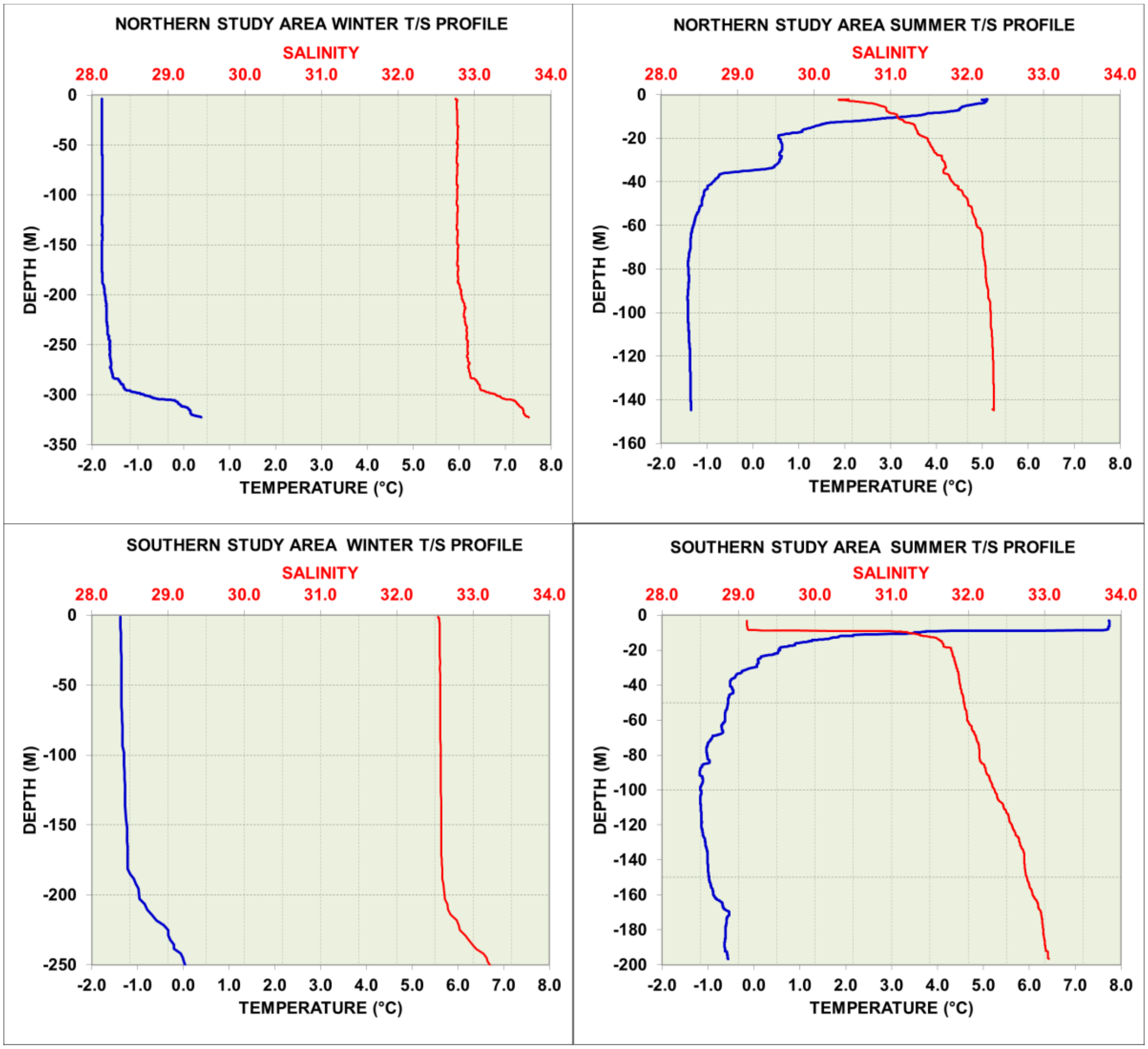


Figure 4.12: The vertical temperature (in °C) and salinity (in PSU) structure based on winter and summer profiles in the northern (top panels) and southern (bottom panels) portions of the study area.

4.1.4. Temperature and Salinity Along Standard Sections

Beginning in 1998 under the DFO's AZMP physical and biological observations along three standard sections crossing the Labrador Shelf were initiated. In addition to the standard sections, defined by ICNAF in 1976, namely the Seal Island (SI) and Beachy Island sections (BI), a third section on the mid-Labrador shelf crossing Makkovik Bank (MB) was selected for sampling during the annual summer survey.

The inshore portion of the BI section crosses the northern region of the study area while the inshore portion of the MB section crosses the southern portion of the study area (Figure 4.13). The SI section which crosses Hamilton Bank on the southern Labrador Shelf is not shown.

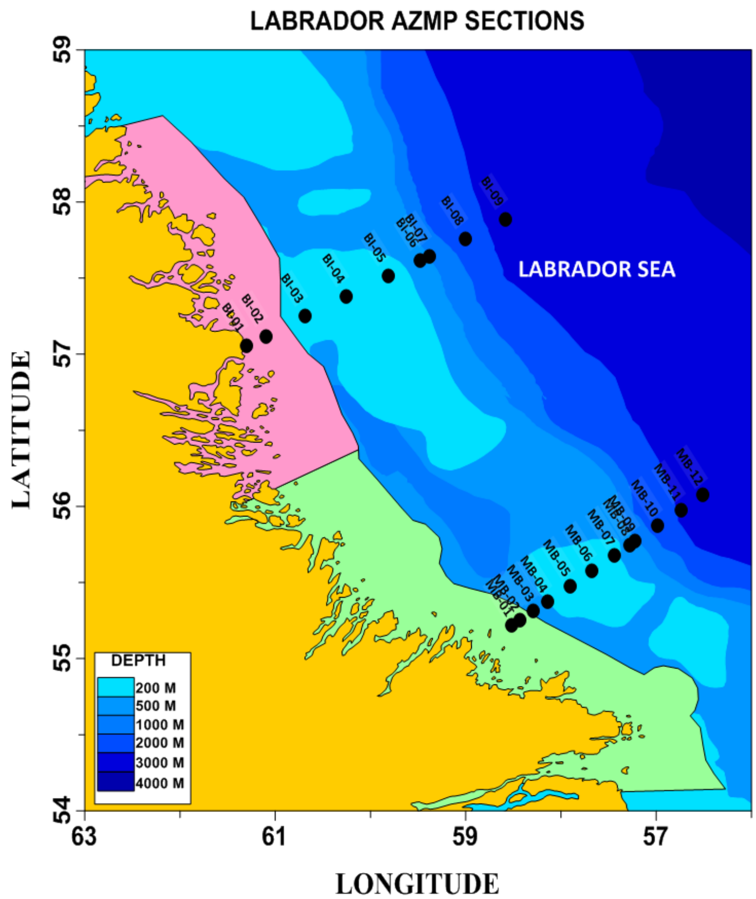


Figure 4.13: Map showing the standard AZMP stations along the Beachy Island (BI) and Makkovik Bank (MB) sections sampled during the mid-summer AZMP oceanographic surveys in relation to the northern and southern portions (colored polygons) of the study area.

Both the BI and MB sections have been sampled intermittently during the summer since 2000, with the most recent survey conducted during the summer of 2018. Summer cross sections (the 2000–18 average and for 2018) of the temperature and salinity structure are shown in Figure 4.14 and Figure 4.15.

The water mass characteristics observed show the sub-polar waters with sub-surface temperatures across the shelf ranging from less than -1°C to 2°C and salinities from 31.5 to 33.5 PSU. Labrador Slope water along the shelf edge is generally warmer and saltier than the sub-polar shelf waters with a temperature range of 3°C to 4°C and salinities in the range of 34 to 34.8 PSU. During the summer of 2018 sub-surface temperature and salinity values within the study area along the BI section ranged from less than -1°C to -0.5°C and 31.5 to 33 PSU with peak upper layer values reaching about 3.5°C and 31 PSU, respectively. In the northern portion of the study area water temperatures during the July surveys are less than 0°C throughout the water column, except for a very thin (less than 40 m) seasonally-heated surface layer. The summer salinity cross-sections along both the BI and MB sections show a relatively fresh upper layer of shelf water with salinities less than 31.5 PSU within the study area, resulting from arctic outflow and melting sea-ice along the Labrador Shelf (Figure 4.14 and Figure 4.15). The MB section within the study area crosses the Labrador Marginal Trough where water depths often exceed 250 m. As a consequence, near bottom temperatures increase to about 1.5°C with salinities up to 33.8 PSU where offshore slope waters floods the deep inshore troughs through the cross-shelf channels (Figure 4.15).

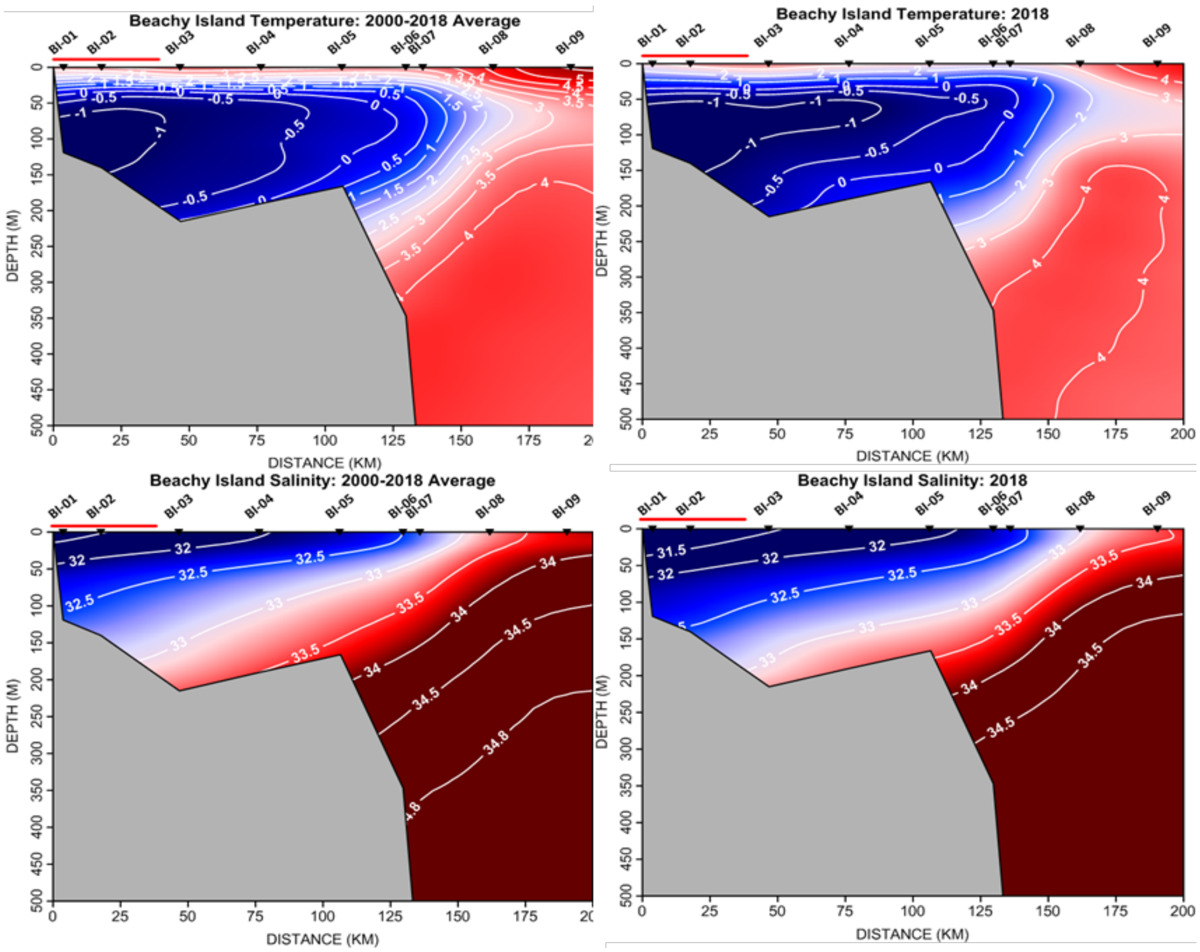


Figure 4.14: Contours of temperature (in °C) and salinity (in PSU) along the Beachy Island section (Figure 4.13) based on all data collected from 2000–18 (left panels) and for the summer of 2018 (right panels). Station locations along the section are indicated by the symbols on the top panels. The red bar at the top indicates the spatial extent of study area along the inshore portion of the section.

The most striking thermal feature along the sections is the mass of cold water overlying the shelf during the summer that is isolated from the warmer higher density water of the continental slope region. This winter chilled water mass was first observed along the Newfoundland and Labrador Shelf by Iselin (1932) and Nutt (1952) and is now commonly referred to as the cold-intermediate-layer (CIL) (Petrie et al. 1987). Its cross sectional area bounded by the 0°C isotherm is generally regarded as a robust index of ocean climate conditions on the eastern Canadian Continental Shelf. While the CIL water mass undergoes significant annual variability, the changes are highly coherent from the Labrador Shelf to the Grand Banks. The CIL remains present throughout the summer as the seasonal heating and freshening increase the stratification in the upper layers to a point where heat transfer to the lower layers is slowed. The CIL undergoes a gradual decay during the fall however, as increasing wind stress mixes the seasonally heated upper layers deeper into the water column (Colbourne et al. 2017).

Consistent with Lazier's (1982) study of the properties of the Labrador Shelf waters, the sub-surface water mass characteristics along the standard sections within the study areas are characterized by very weak horizontal and vertical temperature and salinity gradients compared to that offshore at the shelf break where strong frontal boundaries separate the shelf and slope water masses (Figure 4.14 and Figure 4.15).

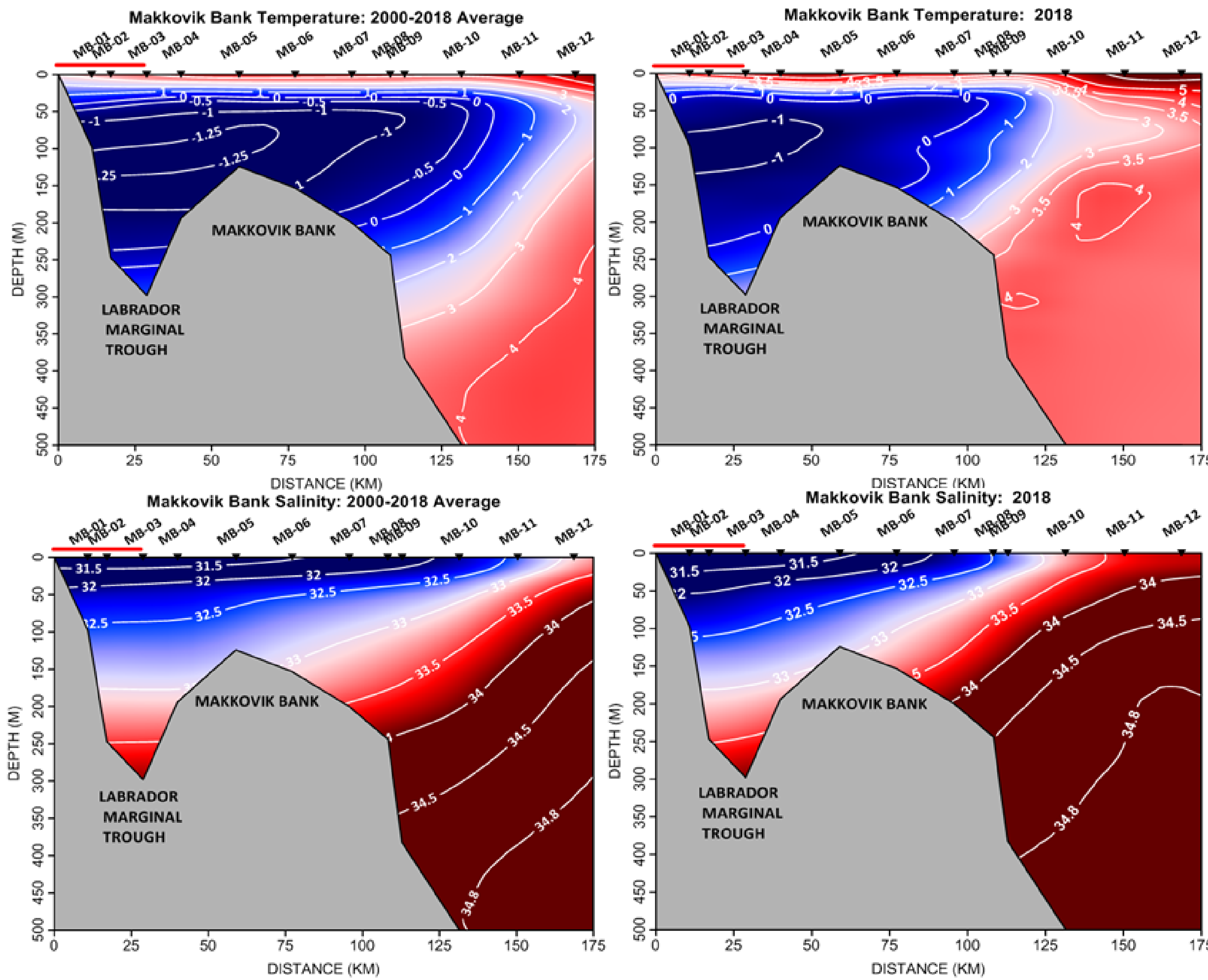


Figure 4.15: Contours of temperature (°C) and salinity (in PSU) along the Makkovik Bank section (Figure 4.13) based on all data collected from 2000–18 (left panels) and for the summer of 2018 (right panels). Station locations along the section are indicated by the symbols on the top panels. The red bar at the top indicates the spatial extent of the study area along the inshore portion of the section.

4.1.5. Labrador Current Variability

The vertical cross-shelf structure of the Labrador Current has been characterized using direct current measurements made during the summer AZMP surveys from vessel mounted 75 kHz ADCP. These instruments were operated at a resolution of 8 m vertically with an effective range of about 600 m producing a current profile every five minutes or about 1.5 km along the ship's track at a ship speed of 10 knots. Archived data were available along the BI section for the years 2009, 2010 and 2017 and for the years 2009, 2010, 2014, 2015 and 2017 for the MB section. Current velocities were adjusted for tidal currents using predictions obtained from a high-resolution numerical 2-dimensional tidal model. Offshore tidal currents were generally weak, less than 7 cm/s over the shelf areas.

The alongshore component (southeastward) of the Labrador Current through the BI and MB sections is shown in Figure 4.16. Currents are weak and highly variable over most of the Labrador Shelf regions with typically maximum speeds less than 20 cm/s within the study area along both sections. In some years, the inshore branch is not well defined but appears to progressively increase with offshore distance (BI section 2017). Over the central portions of the shelf a counter northwestward flowing current is evident in some years with currents greater than 10 cm/s, in 2009 over Makkovik Bank for example and in 2010 over the southern portions of NB along the BI section.

The main offshore branch of the Labrador Current starts at the edge of the Labrador Shelf approximately 100 km offshore where maximum current speeds often exceed 50 cm/s (greater than 1 knot). In some years, the offshore branch is relatively narrow less than 75 km wide (MB 2009) and in other years it extends seaward of the last station on the MB section (greater than 125 km wide).

Volume transport values were computed for the Labrador Current through the BI and MB sections during the summer AZMP surveys. Transport values along with average current speeds are presented across the extent of the study area (within 40 km offshore distance) along both sections and for comparison, along the shelf break (seaward of 100 km) in the offshore branch of the Labrador Current.

Transport and average current values for the northern portion of the study area along the Beachy Island section are shown in Figure 4.17. The transport along the BI section in 2017 was 2.7 million cubic metres per second at the shelf break and 0.5 million cubic metres per second within the study area. Average current speed in 2017 was about 28.6 cm/s (0.6 knots) in the offshore and 11.9 cm/s (0.23 knots) within the study area.

Transport and average current values for the southern portion of the study area long the MB section are shown in Figure 4.18. The transport along the MB section ranged from 1.6 million cubic metres per second in 2010 to over 12 million cubic metres per second in 2015 in the offshore Labrador Current and from 0.1–0.8 million cubic metres per second within the study area. Average current speed ranged from 17.4 cm/s in 2017 to 36.4 cm/s (0.7 knots) in 2017 in the offshore and from 4.7 cm/s in 2010 to 13.5 cm/s in 2017 within the study area.

In general, the transport through the MB section was stronger than that observed at the BI section. For example, in the offshore versus the study area of the sections the transport in 2017 was 2.7 versus 0.8 million cubic metres per second while at the MB section the transport was 6.4 versus 0.8 million cubic metres per second.

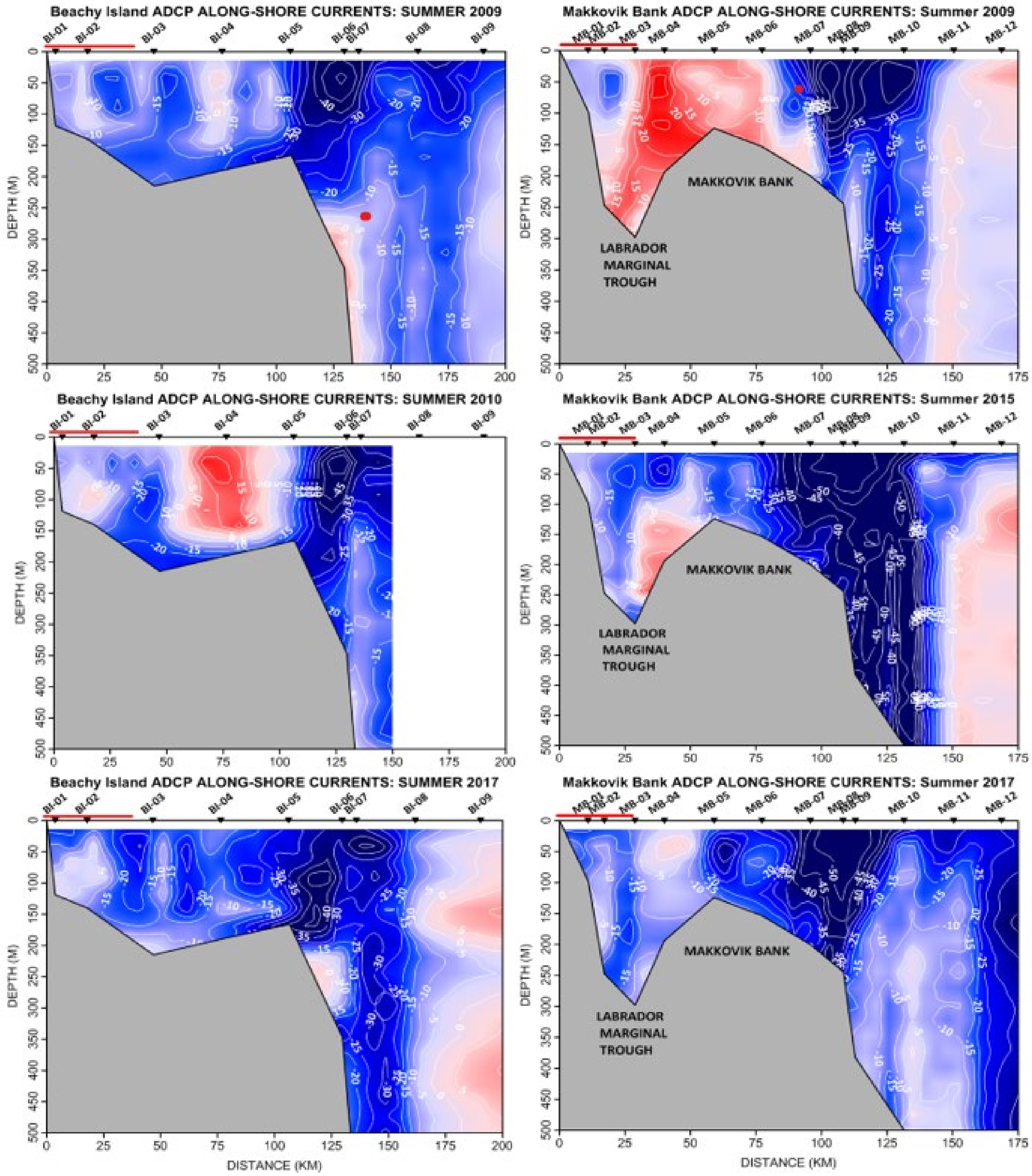


Figure 4.16: Contours of current speeds (in cm/s) along the Beachy Island section (left panels) for 2009, 2010 and 2017 and the Makkovik Bank section (right panels) for 2009, 2015 and 2017. Southeastward flowing water along the coast is colored blue and northward red. The symbols along the top of the panels are the standard AZMP stations. The red bar at the top indicates the spatial extent of the study area along the inshore portion of the section.

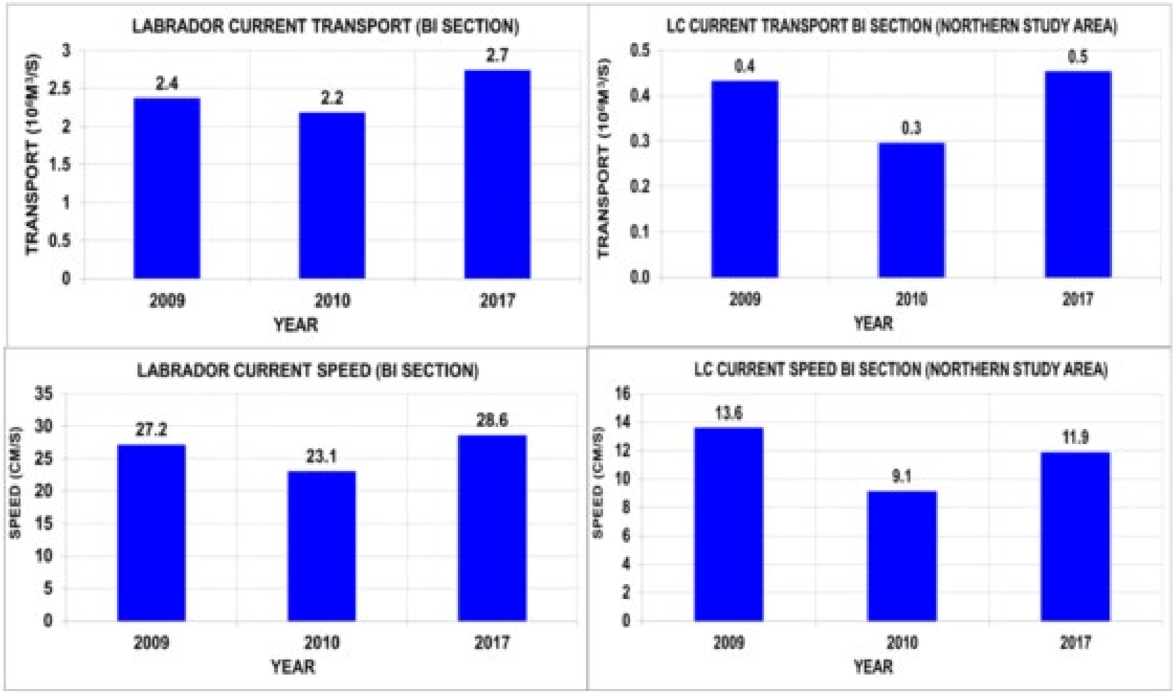


Figure 4.17: Labrador Current transport (top panels, in millions of cubic metres per second) and average current speed (bottom panels, in cm/s) along the shelf break portion of the Beachy Island section (left panels) and through the northern portion of the study area (right panels). Data from the summer AZMP surveys of the Labrador Shelf.

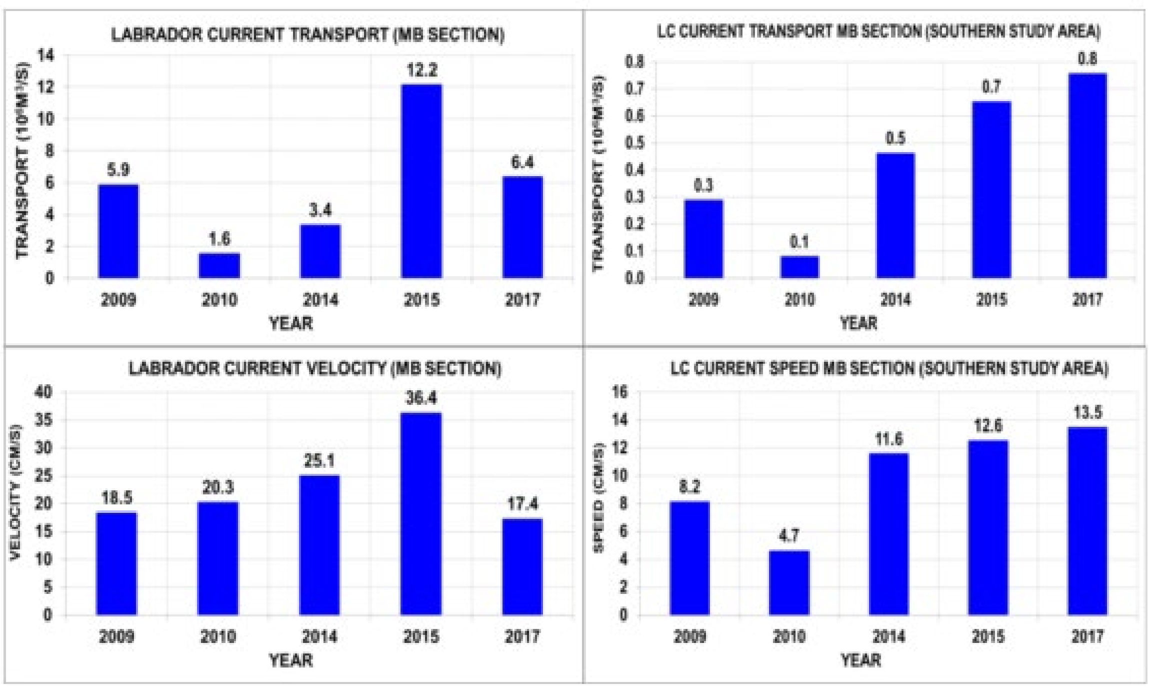


Figure 4.18: Labrador Current transport (top panels, in millions of cubic metres per second) and average current speed (bottom panels, in cm/s) along the shelf break portion of the Makkovik Bank section (left panels) and through the southern portion of the study area (right panels). Data from the summer AZMP surveys of the Labrador Shelf.

4.2. Sensitive Species and Habitats

The Labrador Current transports cold, relatively fresh polar water, sea ice, icebergs, nutrients, and planktonic organisms southward along the Labrador Coast to the northeast Newfoundland Shelf and further south. The study area represents a transition zone between subarctic and boreal marine conditions that affects primary and secondary production as well as other marine species that are at or near the limits of their thermal habitat. Under global climate warming the study area is expected to experience an increase in freshwater flux from melting arctic ice and subsequent changes in the water column stratification potentially leading to unknown impacts on the coastal marine ecosystem in this area. Sea surface temperatures within the study area, and indeed throughout much of the NW Atlantic, have already increased by roughly 1°C over the past three decades of observations.

4.3. Data Gaps and Recommendations

In spite of the significant amount of oceanographic information available for the study area, significant data gaps exist in the in-situ data coverage particularly during the winter and spring months and in fact, even during the summer and fall months insufficient data exist to reliably construct long-term trends in the most basic oceanographic properties including water temperature. In contrast, remotely sensed sea surface temperatures in both the northern and southern portions of the study area are now available at weekly or biweekly intervals and have shown a clear increasing trend in SST since observations began in late-1981. While more information on oceanographic conditions is being acquired through the summer data collection at standard stations along the sections sampled by the AZMP, oceanographic sampling in general within the study area remains limited. Eventually, the long-term time series obtained from repeated oceanographic sampling along the Makkovik Bank and the Beachy Island sections will provide some indication of the trends in the physical and biological drivers in the study area. Monitoring conducted for other research programs can also be leveraged to fill knowledge gaps for the inshore. For example, inshore water temperature records have been collected as part of Atlantic Salmon and Arctic Char monitoring work conducted by DFO. Temperature recorders have also been deployed in several salmon rivers along the Labrador Coast through RivTemp, a partnership between universities, provincial and federal governments, watershed groups, and organizations dedicated to Atlantic Salmon conservation.

The limited opportunities to conduct ship based oceanographic monitoring means additional study of the oceanography of the study area will likely require investment in modern technology such as autonomous vehicles fitted with scientific instruments (ocean gliders), new continental shelf versions of Polar Argo drifters with under-ice profiling capabilities and long-term deployments of automated collection devices on oceanographic moorings.

Community based monitoring of key oceanographic parameters at selected coastal sites throughout the year, including during the ice season, are being developed and supported by the Imappivut initiative, community groups, and academic researchers. These efforts will contribute significantly to address data gaps in the inshore regions, particularly during the winter months.

5. Biological Oceanography

The report on biological oceanography of the study area draws extensively on information obtained from the AZMP (Therriault et al. 1998) that was implemented in 1998 with the aim of increasing DFO capacity to understand, describe, and forecast the state of the marine ecosystem and to quantify the changes in the ocean physical, chemical and biological properties. A critical element of the AZMP involves an observation program aimed at assessing the variability in nutrients, phytoplankton and zooplankton along standard ocean sections (Figure 5.1). A description of the seasonal patterns in the distribution of phytoplankton (microscopic plants) and zooplankton (microscopic animals) provides important information about organisms that form the base of the marine food web. An understanding of the production cycles of plankton, and their interannual variability, is an essential part of an ecosystem approach to oceans management.

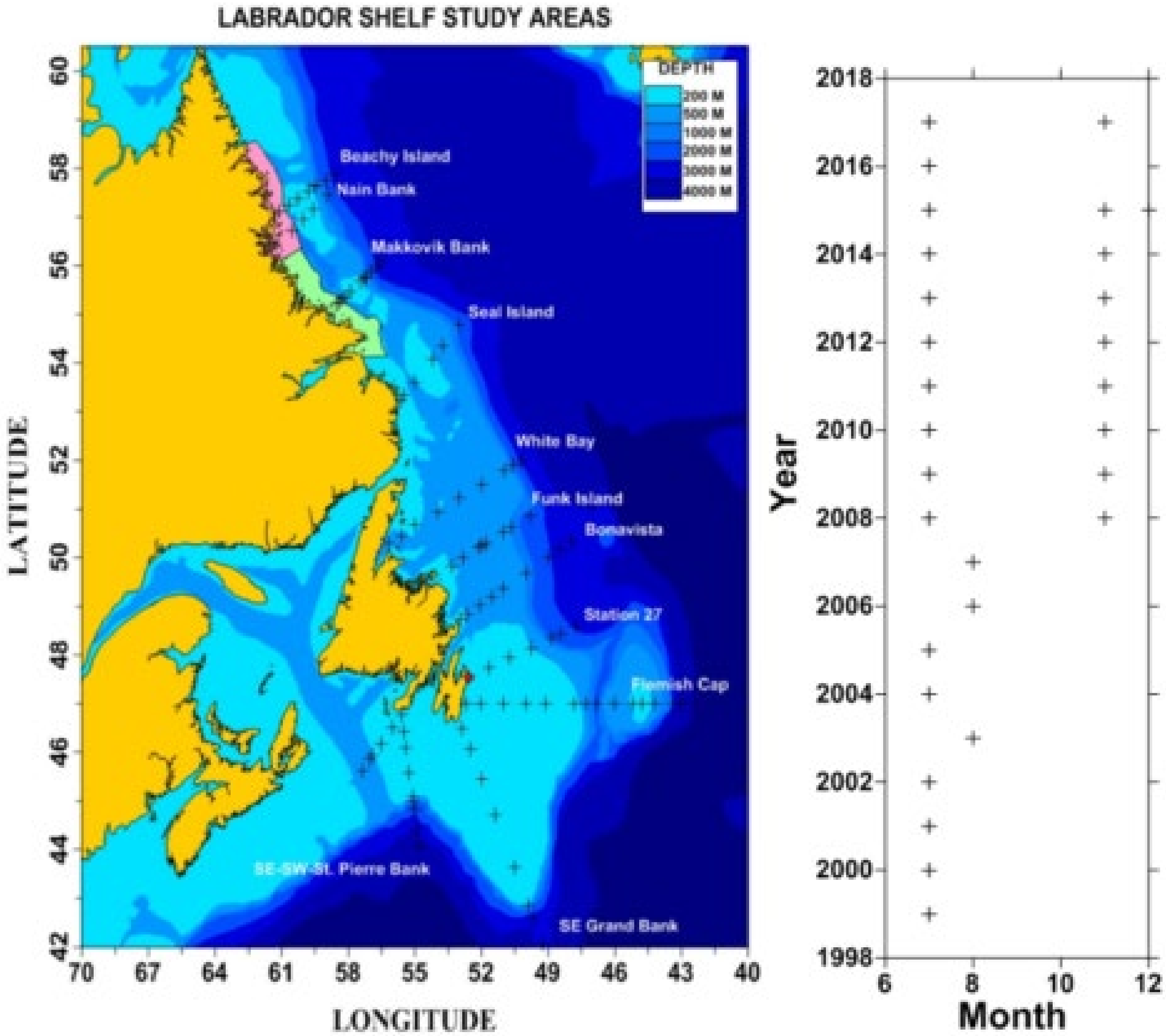


Figure 5.1: Location of the northern (pink) and southern (light green) study area on the Labrador Shelf, and primary biological stations sampled seasonally by the Atlantic Zone Monitoring Program in the Newfoundland and Labrador Region (plus sign; left panel). Red circle indicates the location of the high frequency sampling station (station 27). Seasonal sampling coverage for Labrador (Beachy Island, Nain Bank, Makkovik Bank, and Seal Island) ocean sections during 1999–2017 (right panel).

The AZMP derives its information on the marine environment and ecosystem from data collected at a network of sampling locations (fixed point, high frequency sampling stations, cross-shelf sections, ecosystem trawl surveys) in each DFO region (Québec, Gulf, Maritimes, and Newfoundland and Labrador), sampled at a frequency of twice-monthly to once-annually. The sampling design provides basic information on the variability in physical, chemical, and biological properties of the northwest Atlantic continental shelf on annual and interannual scales. Ecosystem trawl surveys and cross-shelf sections provide information about broad-scale environmental variability but are limited in their seasonal coverage. High frequency sampling stations complement the broad-scale sampling by providing more detailed information on annual changes in ocean properties. Recent published reports on biological oceanographic conditions in the Newfoundland and Labrador Region (Pepin et al. 2017) and ocean climate and physical oceanographic assessments of the Region (Colbourne et al. 2017) provide further context for the Northwest Atlantic.

5.1. Available Information

5.1.1. Phytoplankton Productivity

Phytoplankton growth is largely influenced by freeze-thaw cycles of sea ice and the high-latitude extremes in the solar cycle along the Labrador Coast. Solar energy that reaches the coastal waters along Labrador is seasonally highly variable with extreme low levels during late autumn and winter transitioning to long daily periods of insolation during late spring and summer. This makes the availability of sunlight one of the major limiting factors for plant-based photosynthesis in this area. The seasonal irradiance levels vary by latitude with peak energy during June-July and very low levels from late-October through until March (Figure 5.2). Light energy is captured by a series of pigments in phytoplankton, of which chlorophyll-*a* is the most important and is commonly used as a proxy of the standing stock.

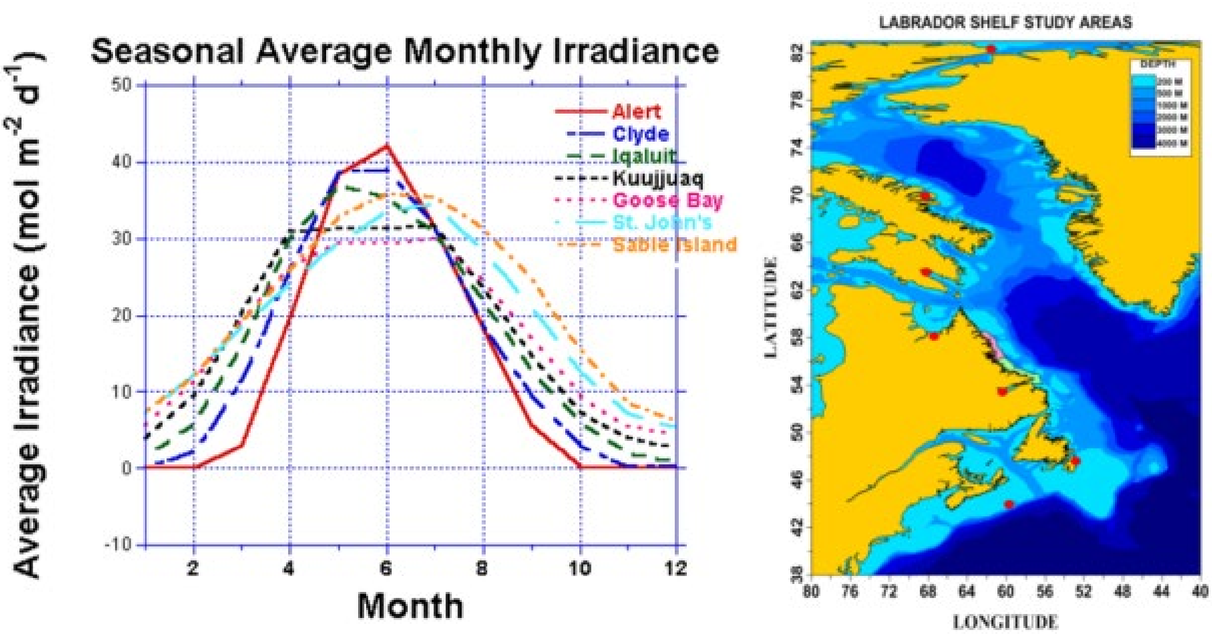


Figure 5.2: Seasonal average monthly irradiance (RF1-Global Solar Radiation) from measurements (1965–2012) made at Environment Canada land stations along the east coast of Canada and the eastern Canadian Arctic, 44–84 °N (from Harrison et al. 2013; left panel). Location of Environment Canada meteorological stations (red circles) where irradiance measurements were collected (right panel). The most northerly station is Alert and southerly location is Sable Island. The locations of the study areas are shown.

The inventory of macronutrients, principally silicate and nitrate, are important secondary factors that influence the magnitude and duration of primary production. The availability of data on nutrient concentrations is limited outside of the summer period due to the remote nature of the study area and extensive seasonal sea ice coverage that limits sampling opportunities. Biological production based on the process of photosynthesis is regulated by the inventory of key nutrients within the euphotic (upper sunlight portion of the water column) zone when the biological production cycle begins. The potential for phytoplankton growth in the upper water column is determined by the level of nutrients that are renewed from deeper layers during the winter and early spring through wind-induced mixing. Cross-shelf mixing and advection of water masses from the southerly flowing Labrador Current also contribute to the supply of macronutrients. Nitrate and ammonium are generally the most important sources of nitrogen to support phytoplankton growth although this can vary regionally across the North Atlantic. Due to climatological differences in nutrient availability in surface waters, Nitrate appears to be the limiting nutrient in the northwest and silicate appears to be limiting in the northeast Atlantic (Figure 5.3).

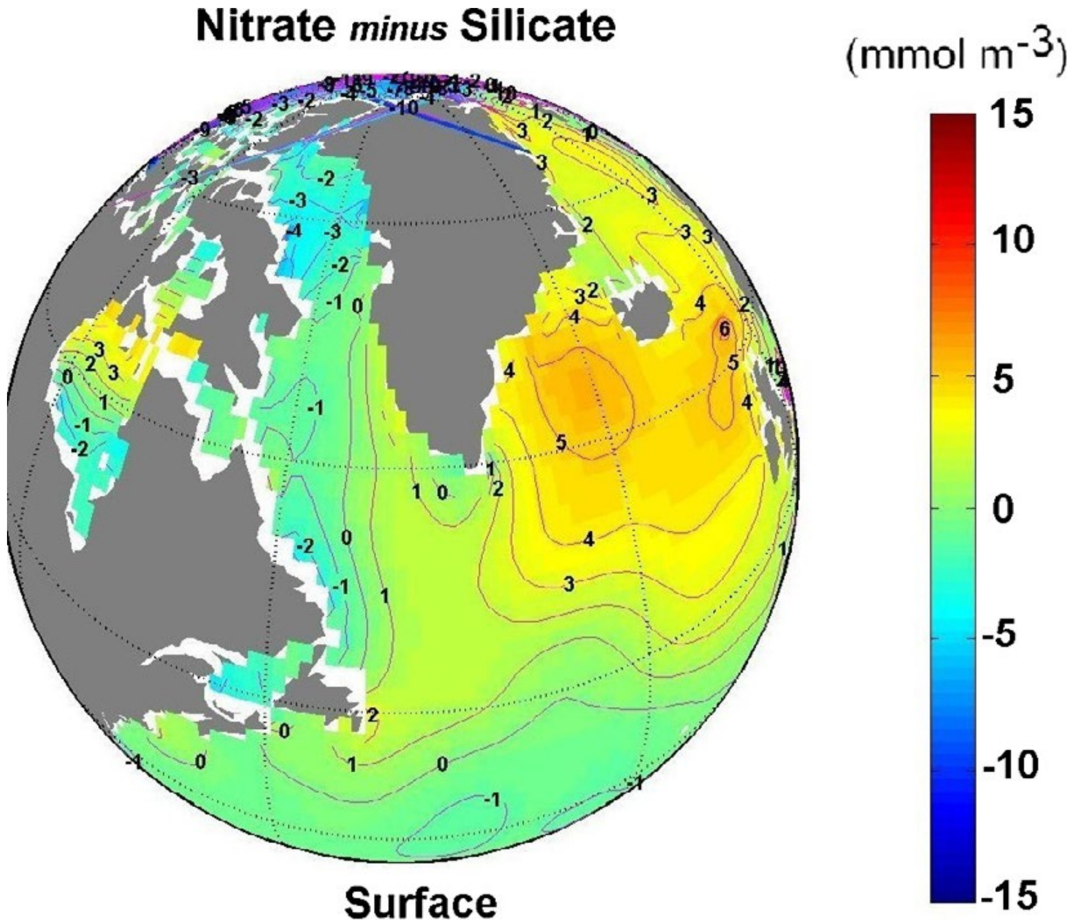


Figure 5.3: Nitrate minus silicate (mmol m-3) index in surface waters of the North Atlantic, annual average based on NODC climatologies (from Harrison et al. 2013). The northwest Atlantic is replete in silicate while the northeast shows the reverse trend with higher levels of nitrate. The Labrador Sea represents a transition zone between these conditions.

Vertical distributions of biogeochemical properties are available across the northern AZMP Labrador sections during summer occupations. The standard biogeochemical variables include chlorophyll *a* concentration (proxy of phytoplankton biomass), dissolved oxygen concentration, and concentrations of major macronutrients required for photosynthesis. We derived standard climatologies of biogeochemical variables by pooling all available occupations of the northern Labrador sections collected by the AZMP. The vertical distribution of chlorophyll an along the Beachy Island section indicated higher sub-surface concentrations at approximately 40 m depth across the section (Figure 5.4). Near-surface concentrations were relatively low suggesting possible nutrient limitation restricting photosynthesis to the nutricline (rapid change in nutrient concentration). Dissolved oxygen concentrations reached 8–9 mL L^{-1} in the upper 50 m of the water column over the coastal and inner shelf but declined to lower levels (~5 mL L^{-1}) in deep water (>200 m) along the outer shelf-slope waters. Major macronutrient concentrations were depleted in the upper 40 m of the water column but consistently showed evidence of upwelling near the shelf-slope front. Nutrient concentrations increased with depth, but the highest concentrations indicate different source origins across the study area (Figure 5.4). The source of deep nitrate originates from North Atlantic water enriched with higher concentrations than coastal and shelf derived water masses (Maillet et al. 2005). Higher concentrations for phosphate and silicate indicate the coastal and inner shelf are primary sources compared to North Atlantic water. Earlier studies provide evidence for the influence of water masses outflowing from the Hudson Strait north of the study area that can regulate spatial and temporal dynamics of key physical and biological oceanographic variability over the Labrador Shelf (Colbourne and Mertz 1998, Drinkwater and Jones 1987, Sutcliffe et al. 1983). These studies suggest potential pathways for nutrient supply to the Labrador Shelf that include cross-shelf advective transport, wind-induced vertical mixing, in-situ regeneration, and southward advective transport from the Hudson Strait. The authors suggest that southward flow from the Hudson Strait is the predominant source of nutrients on the Labrador Shelf, but terrestrial sources are likely contributing to inputs of macronutrients in fjords, fjards, and other coastal sites in the study area.

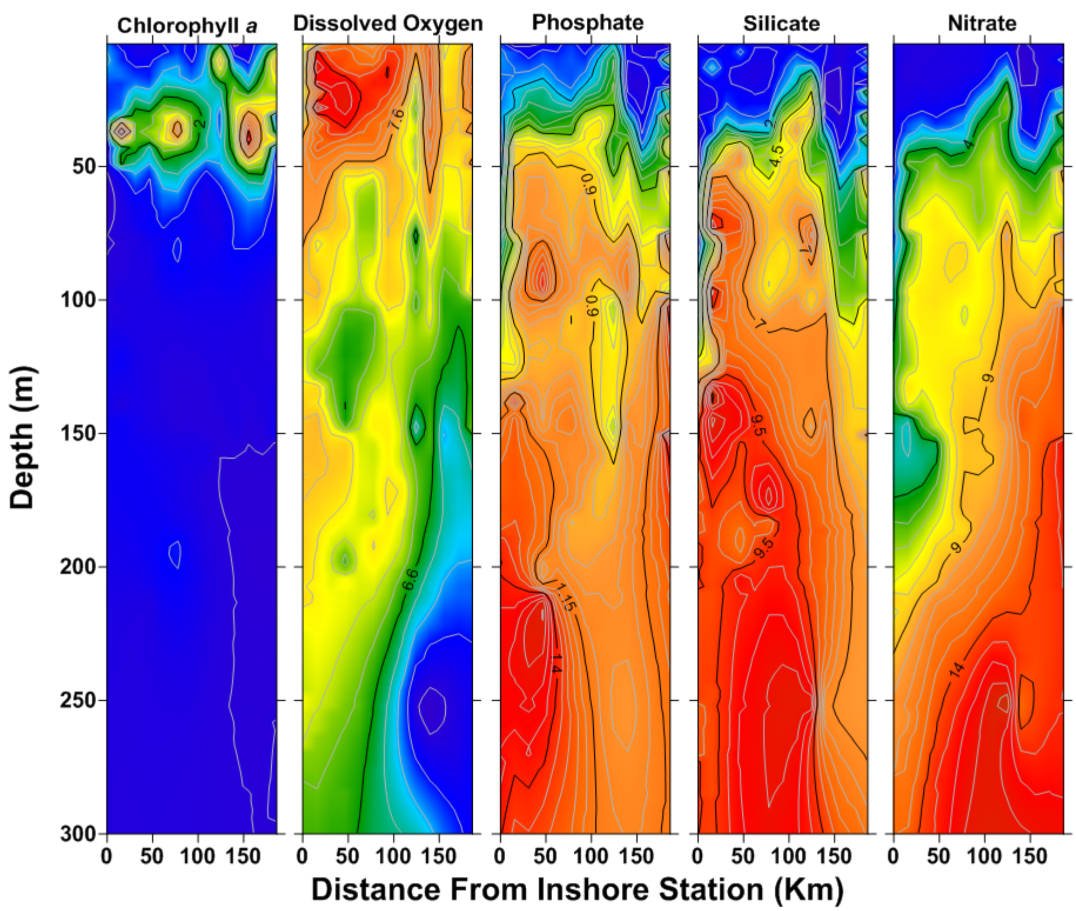


Figure 5.4: Climatology of vertical distributions of biogeochemical properties in the top 300 m along the Beachy Island section derived from all summer (July-August) occupations of standard stations from inshore to offshore during 1999–2017. Only the first two inshore stations fall within the boundary of the study area with the majority of the stations located on the adjacent shelf and slope waters (see Figure 1). The biogeochemical variables include calibrated chlorophyll a from fluorescence measurements (mg m^{-3}), calibrated dissolved oxygen in mL L^{-1}, and concentrations of major macronutrients (phosphate, silicate, and nitrate) in mmol m^{-3}.

The vertical distributions of biogeochemical variables along the MB section followed similar patterns observed for the most northern section. The highest concentrations of chlorophyll-a were observed sub-surface at depths ranging from 40–60 m in close proximity to the nutricline depth. Concentrations of dissolved oxygen were highest in the upper 40 m of the water column reaching 8–9 mL L^{-1} and were depleted in deep (> 100 m) waters in slope water stations (Figure 5.5). Although nitrate concentrations were elevated in the deep shelf-slope region similar to Beachy Island, the concentrations of phosphate and silicate were relatively well mixed across the entire section with little evidence of cross-shelf gradients. The vertical gradients in phosphate and silicate showed higher spatial variability compared to BI section. The concentrations of silicate and nitrate again showed clear signs of depletion during summer within the upper 40 m but less so for phosphate. In addition, the incidence of upwelling which was prominent along the BI section was less apparent along MB.

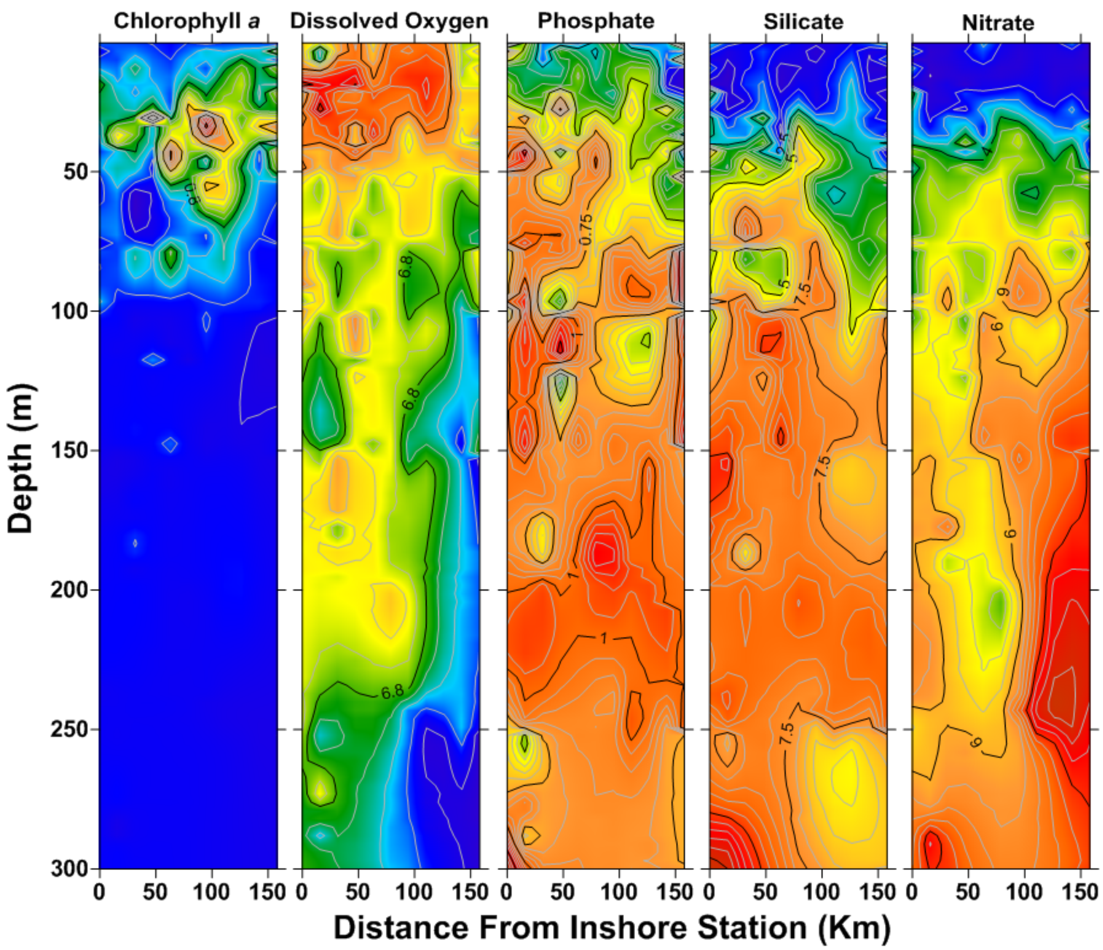


Figure 5.5: Climatology of vertical distributions of biogeochemical properties in the top 300 m along the Makkovik Bank section derived from all summer (July-August) occupations of standard stations from inshore to offshore during 1999–2017. Only the first two inshore stations fall within the boundary of the study area with the majority of the stations located on the adjacent shelf and slope waters (see Figure 1). The biogeochemical variables include calibrated chlorophyll a from fluorescence measurements (mg m-3), calibrated dissolved oxygen in mL L-1, and concentrations of major macronutrients (phosphate, silicate, and nitrate) in mmol m-3.

Annual changes in deep-water (50–150 m) inventories of nitrate are monitored during summer and autumn and reported just south of the study area along the Seal Island section. The deep water inventories provide information regarding availability of nitrate in the following production cycle assuming upwelling and mixing occurs to bring these nutrients to the upper water column for uptake by phytoplankton. In general, the trend in deep water inventories have been in decline across the Seal Island section since monitoring began in the late-1990s (Figure 5.6). Although the deep nitrate inventories for the northern sections along BI and MB are limited annually, the available annual inventories generally track the levels observed along the Seal Island section located just south of the study area.

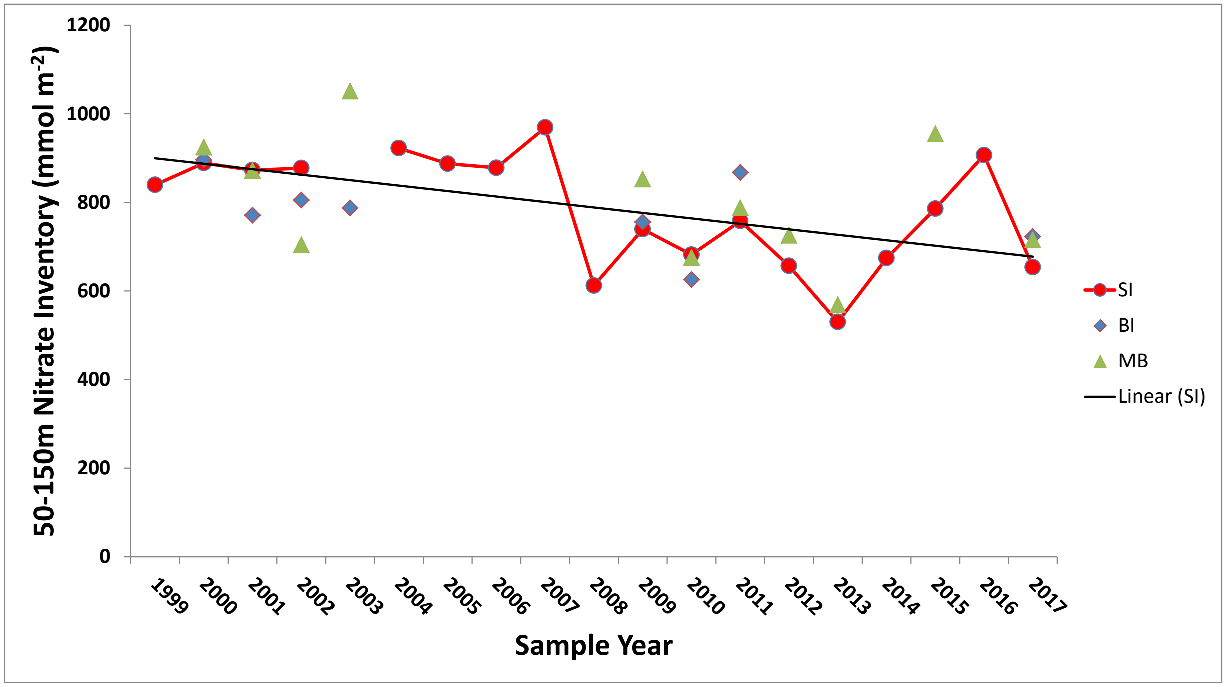


Figure 5.6: Time series of deep (50–150 m) nitrate (combined nitrite and nitrate) inventories averaged across from the SI section during 1999–2017 (missing data from 2003). The average annual summer values of available data from BI and MB are provided for comparison. The observed negative trend in deep nitrate inventory along the Seal Island section is statistically significant ($p < 0.05$).

Annual changes in integrated (0–100 m) chlorophyll-a along the Seal Island section have also generally trended downward over the available time series during 1999–2017 (Figure 5.7). The chlorophyll-a inventories for the northern sections (BI and MB) follow the general trend along the Seal Island section although some exceptions are observed spatially and temporally throughout the available time series. The large-scale trends in nitrate inventories are generally positively associated with the trend in chlorophyll biomass over the northwest Atlantic suggesting regulation of phytoplankton productivity through nitrate availability (Bélanger et al. 2018).

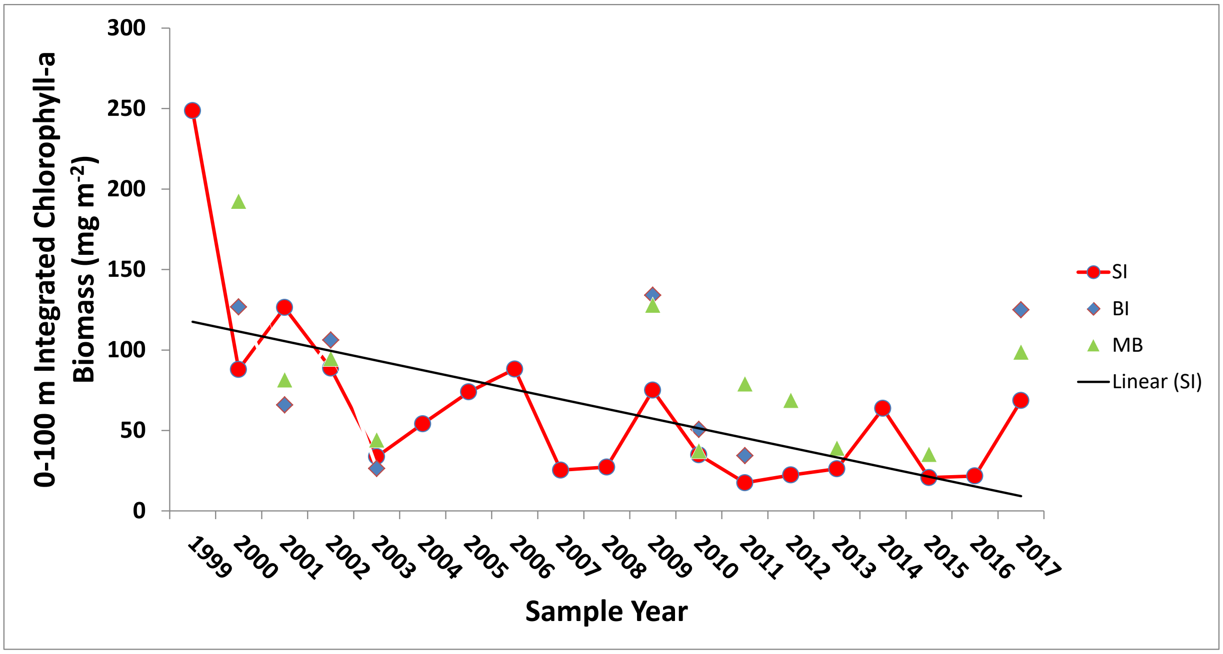


Figure 5.7: Time series of integrated (0–150 m) chlorophyll-a inventories averaged across from the SI section during 1999–2017. The average annual summer values of available data from BI and MB are shown. The observed negative trend in the chlorophyll a inventory along the Seal Island section is statistically significant ($p < 0.01$).

Satellite ocean colour data provides a large-scale perspective of surface phytoplankton biomass over the whole of the Northwest Atlantic that is not possible for conventional vessel-based sampling. Using two week satellite composite images provides seasonal coverage and a large-scale context with which to interpret seasonal dynamics of primary production. The ocean colour imagery provides information about the timing and spatial extent of the spring and autumn blooms but does not provide information of the dynamics that take place below the top few meters of the water column.

Observations of ocean colour over the Labrador Coast reveal associated changes in the timing and intensity of the production cycle as detected by Visible-Infrared Imager Radiometer Suite (VIIRS) ocean colour imagery (Figure 5.8). The early development of enhanced surface blooms normally begins in early-June (coincident with the peak in the solar cycle) throughout the Labrador Coast following the retreat of extensive sea ice that normally covers the coastal areas throughout the winter into late spring. The imagery along the Labrador Coast in 2017 indicates limited surface blooms beginning in early-June with chlorophyll-a concentrations slightly greater (~1 mg m^{-3}) than background levels. In contrast, the Labrador Sea shows high intensity surface blooms with elevated chlorophyll-a (>10 mg m^{-3}) extending through July and early-August before return to pre-bloom levels (Figure 5.8). The imagery along the Labrador coastal and Shelf waters suggests primary production continues at low levels through October and early-November when the irradiance levels begin to limit growth of phytoplankton. Time series of ocean colour imagery from standard statistical sub-regions in the North Atlantic can be used to investigate seasonal and annual trends in phytoplankton biomass over the Labrador Shelf (Figure 5.9). Three sub-regions on the Labrador Shelf can be used to characterize the spatial and temporal trends in biomass from the southern Shelf (Hamilton Bank), mid-Shelf region (northern Labrador Shelf), to the northern sub-region which receives significant Arctic outflow through the Hudson Strait.

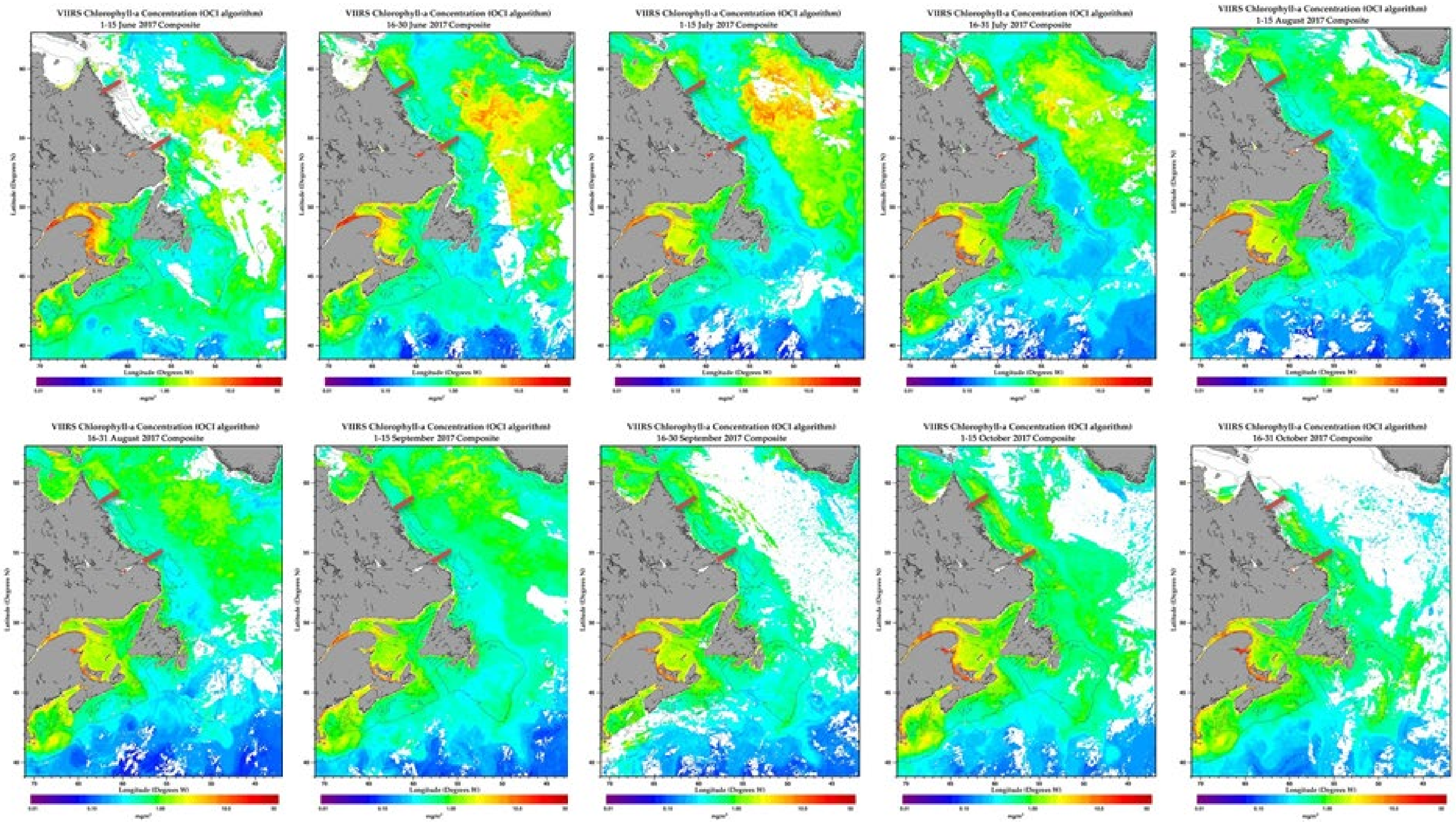


Figure 5.8: Biweekly surface chlorophyll-a concentrations (mg m^{-3}), from VIIRS ocean colour imagery in the North Atlantic during June through October 2017. The northern and southern boundary of the study area is provided (red bars). High chlorophyll-a concentration adjacent to the coastal boundary can be influenced by turbidity associated with inflow of freshwater. Normal ice-cloud-covered periods are depicted in white. Imagery obtained from the [Bedford Institute of Oceanography](#).

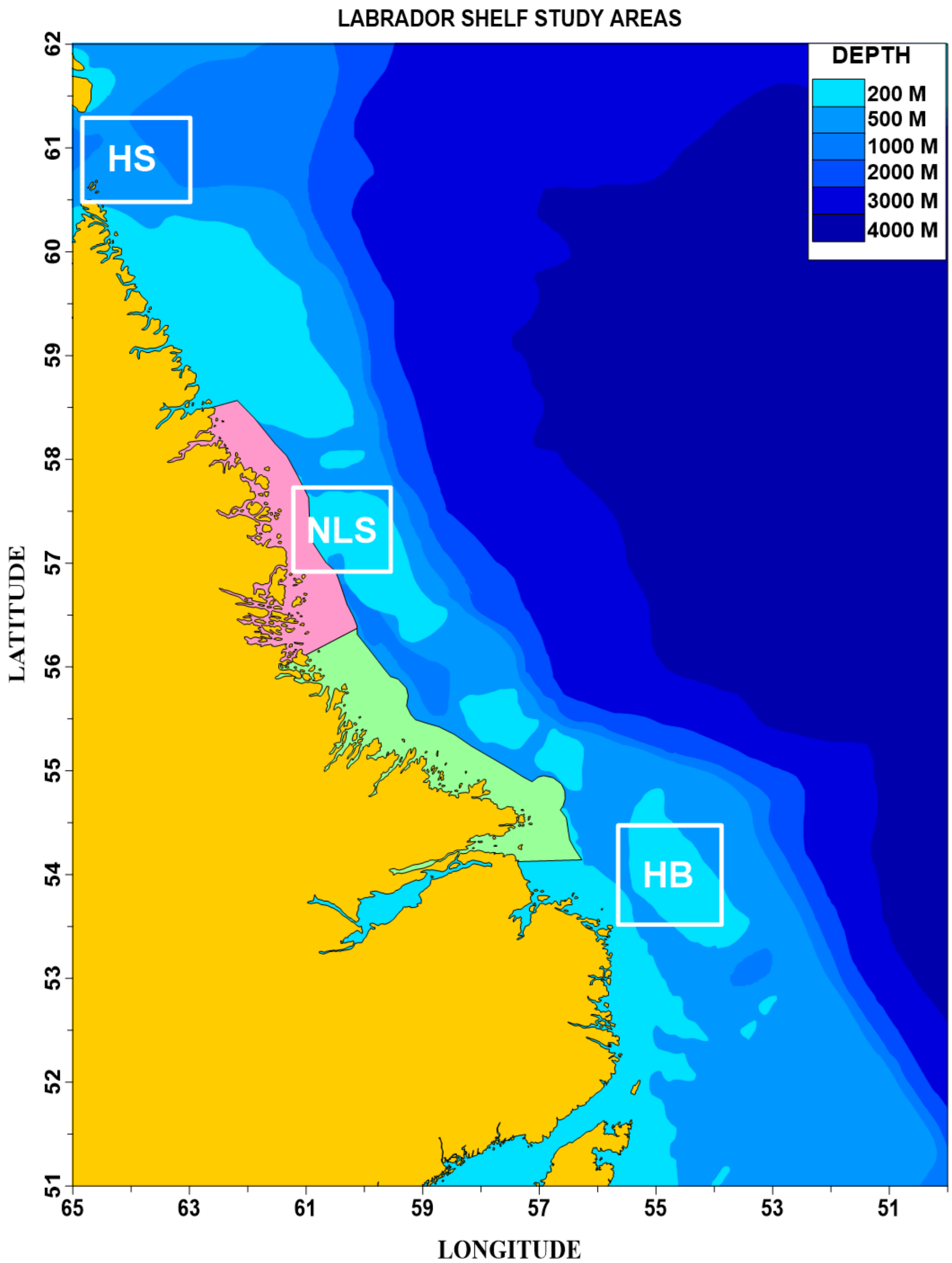


Figure 5.9: Statistical sub-regions in the Northwest Atlantic identified for spatial/temporal analysis of satellite ocean colour data. Sub-regions along Labrador include Hamilton Bank (HB), northern Labrador Shelf (NLS), and Hudson Strait (HS). The northern (pink) and southern (light green) boundary of the study area is provided.

Surface blooms in the northern region of the Labrador Shelf (Hudson Strait) are characterized by a single prolonged cycle that typically begins in late-May to early-June and persists until early-October when chlorophyll-a concentrations begin to return to background levels (Figure 5.10). Surface concentrations reach ~3 mg m^{-3} and remain relatively high throughout June-August. The intensity of surface blooms has declined in the northern sub-region since 2010 compared to the earlier years (Figure 5.10). Moving southwards to the northern Labrador Shelf sub-region, the transition to a discrete spring (May-June) and fall (September-October) bi-modal bloom cycle is observed (Figure 5.10). The spring bloom on the northern Labrador

Shelf is relatively short with production lasting several weeks before return to background levels. Concentrations of chlorophyll-a reach ~3 mg m^{-3} near the surface during the spring and somewhat higher during the autumn bloom in certain years. There is evidence of very weak spring blooms in certain years and a downward trend in intensity since 2012, similar to the decline observed in the Hudson Strait sub-region. The standard sub-region located on the southern Labrador Shelf (Hamilton Bank) also displays a bi-modal bloom cycle with an intense spring and weaker autumn blooms. Chlorophyll-a concentrations reach in excess of 5 mg m^{-3} during the spring followed by generally lower levels (1–2 mg m^{-3}) during the autumn. Reduction in the extent of autumn blooms is also apparent along the mid and southern sub-regions in recent years (Figure 5.10).

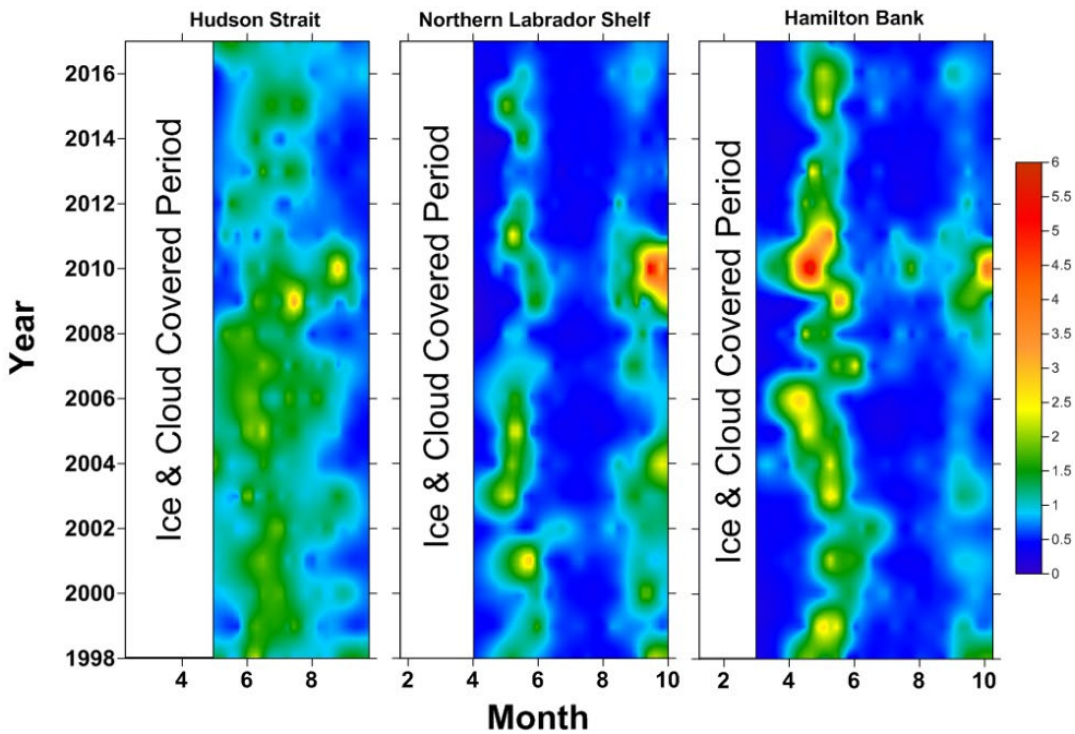


Figure 5.10: Time-series of surface chlorophyll-a concentrations (mg m^{-3}), from SeaWiFS, MODIS, and VIIRS ocean colour satellites along statistical sub-regions across the Labrador Shelf during 1998–2017. See Figure 5.9 for locations of statistical sub-regions in the Labrador area. Normal ice-covered periods are blocked out in white.

Ocean colour data were acquired from the Bedford Institute of Oceanography to construct a continuous time series from 1998 through to 2017. The Sea-Viewing Wide Field-of-View Sensor (SeaWiFS) provided data from 1998–2007, the Moderate Resolution Imaging Spectroradiometer (MODIS) "Aqua" sensor from 2008–11, and the Visible-Infrared Imager Radiometer Suite (VIIRS) sensor from 2012–17. We used the shifted Gaussian function of time model to describe the characteristics of the seasonal cycle of phytoplankton production (Zhai et al. 2011) for the study area (Figure 5.9). Four different metrics were computed using 8-day satellite composite data during the spring bloom to characterize the integral (magnitude) of chlorophyll-a concentration under the Gaussian curve (mg m-2 d^{-1}), peak intensity of the spring bloom (mg m^{-3}), the timing of the spring bloom peak (Julian day), and duration of the spring bloom (days). The characteristics of the bloom (amplitude, magnitude, timing, and duration) provide important information about regional variations in ecosystem productivity and are linked to the productivity of organisms that depend on the lower trophic levels. In fall, a secondary bloom, less intense than the spring bloom, also contributes to the functioning of the marine ecosystem.

Surface chlorophyll-a concentrations on the northern portion of the study area displayed consistent cycles of production from May-October with peak intensity ranging from 1–3 mg m^{-3} (Figure 5.11). There has been a clear reduction in the intensity of production since the mid-2000s compared to the earlier time series. The lowest levels of production were observed in 2013 and again in 2017. Some caution in the interpretation of this general decline is warranted due to the limited coverage of satellite observations in this northern zone along with production that may be occurring under sea ice and at depth which is not detectable with ocean colour imagery.

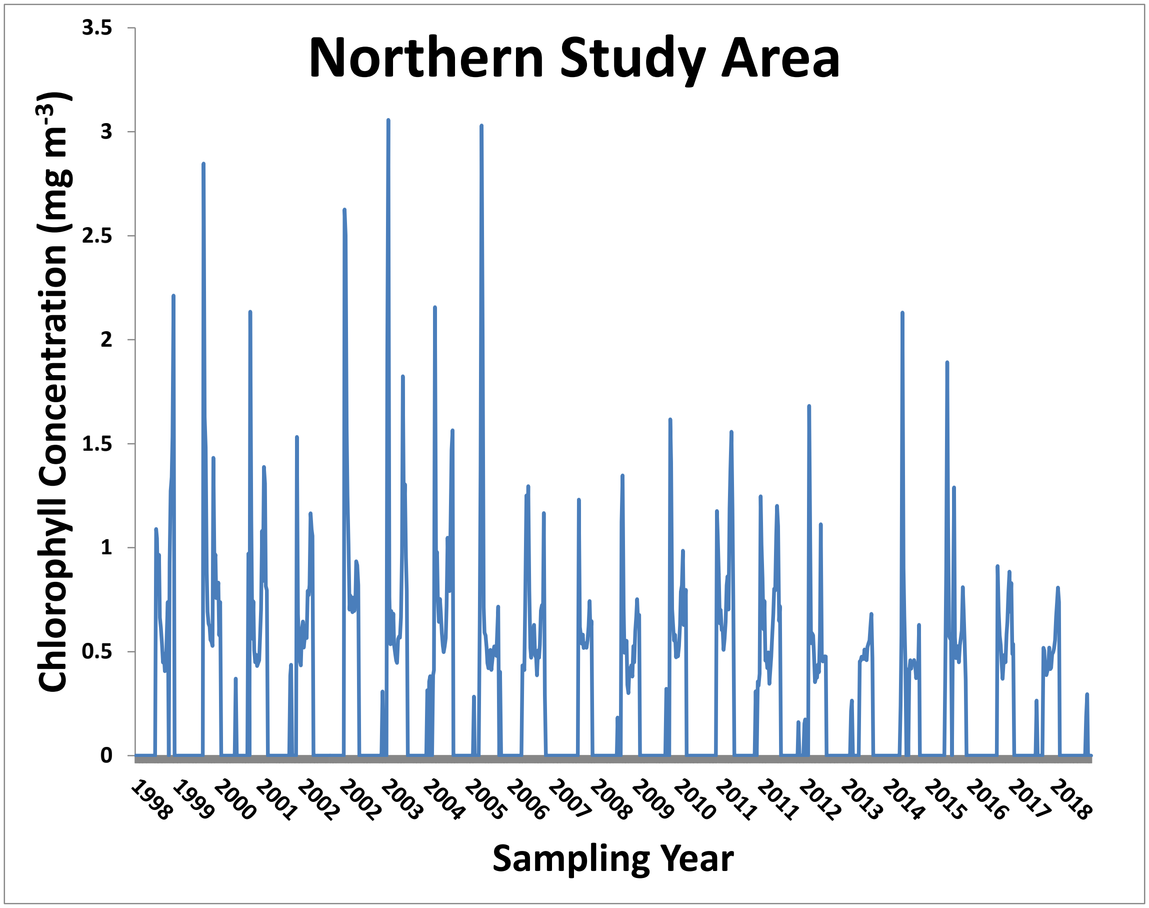


Figure 5.11: Annual dynamics of chlorophyll-a concentration estimated from SeaWiFS, MODIS, and VIIRS imagery during 1998–2017 for the northern portion of the study area.

The southern portion of the study area displayed consistent periods of bi-modal production beginning in late-April to early-May with an intense spring bloom followed by a smaller autumn bloom in September-October with chlorophyll-a concentrations ranging from 2–8 mg m^{-3} (Figure 5.12). The intensity of production has also trended downward after 2009 compared to the earlier time series. It is unclear what might be responsible for these changes in standing stocks of phytoplankton in both the northern and southern portions of the study area but as mentioned earlier, physical forcing through sea-ice dynamics and availability of solar radiation and nutrient inventories, and grazing pressure by zooplankton, all likely play an important role in regulating the dynamics of the production cycle.

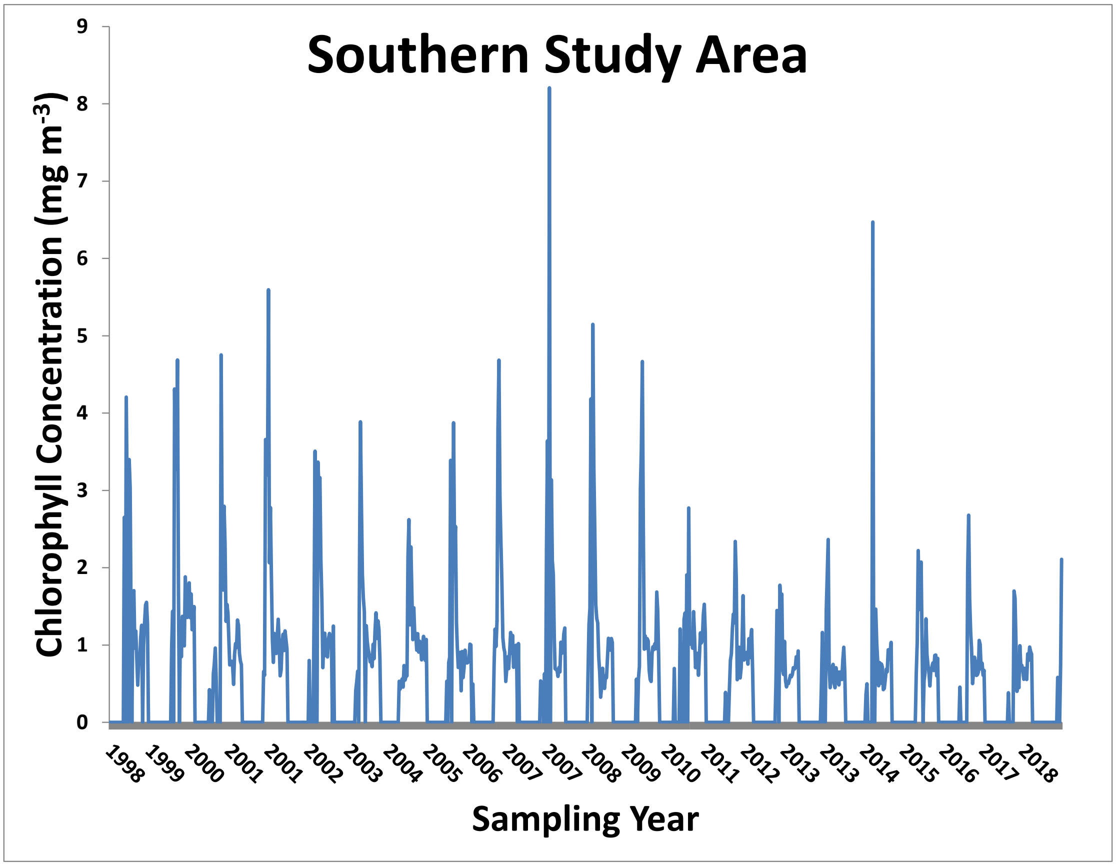


Figure 5.12: Annual dynamics of chlorophyll-a concentration estimated from SeaWiFS, MODIS, and VIIRS imagery during 1998–2017 for the southern portion of the study area.

The seasonal dynamics of chlorophyll-a concentration in the northern study area indicate background levels are detected in late-April in some years, with peak levels observed in June followed by decreasing concentrations through August until an autumn bloom occurs during September-October period (Figure 5.13). The seasonal dynamics of chlorophyll-a concentration in the southern portion of the study area indicate slightly higher background levels are detected in late-April in some years, with levels increasing through till June and then slowly declining through autumn. Although the timing of the autumn blooms is somewhat difficult to detect based on the seasonal observations in the southern area, the surface chlorophyll-a concentrations are comparable with observations in the northern area (Figure 5.13 and Figure 5.14).

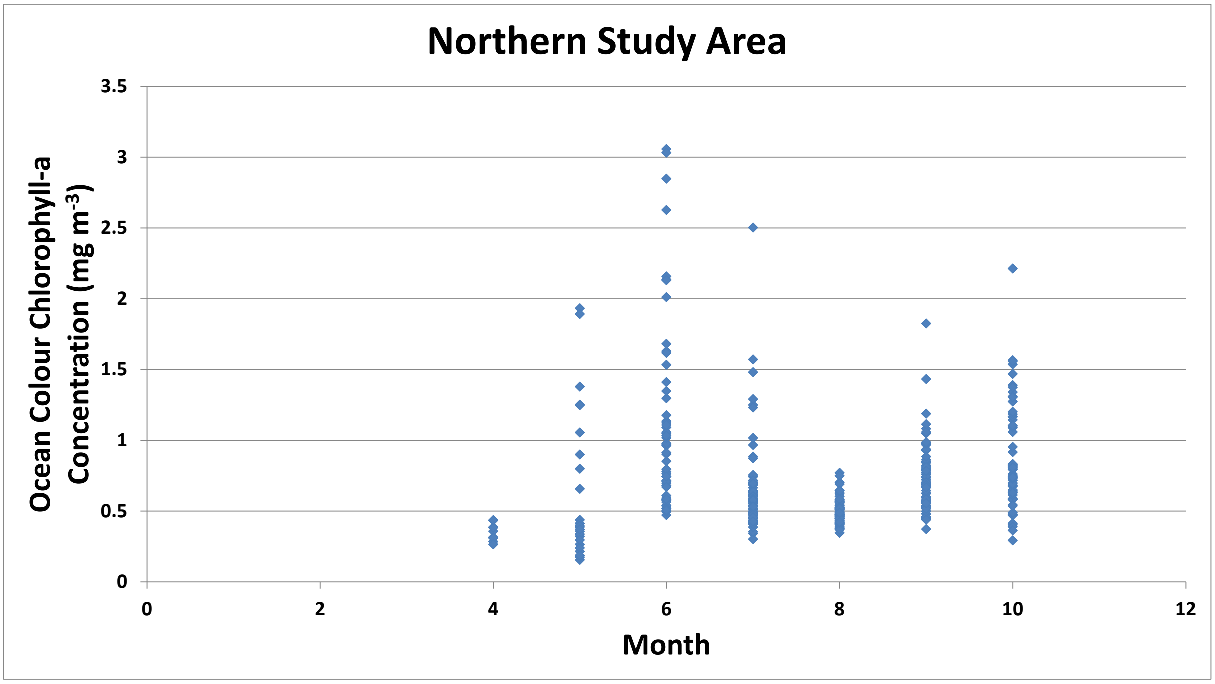


Figure 5.13: Monthly dynamics of chlorophyll-a concentration estimated from SeaWiFS, MODIS, and VIIRS imagery during 1998–2017 for the northern portion of the study area.

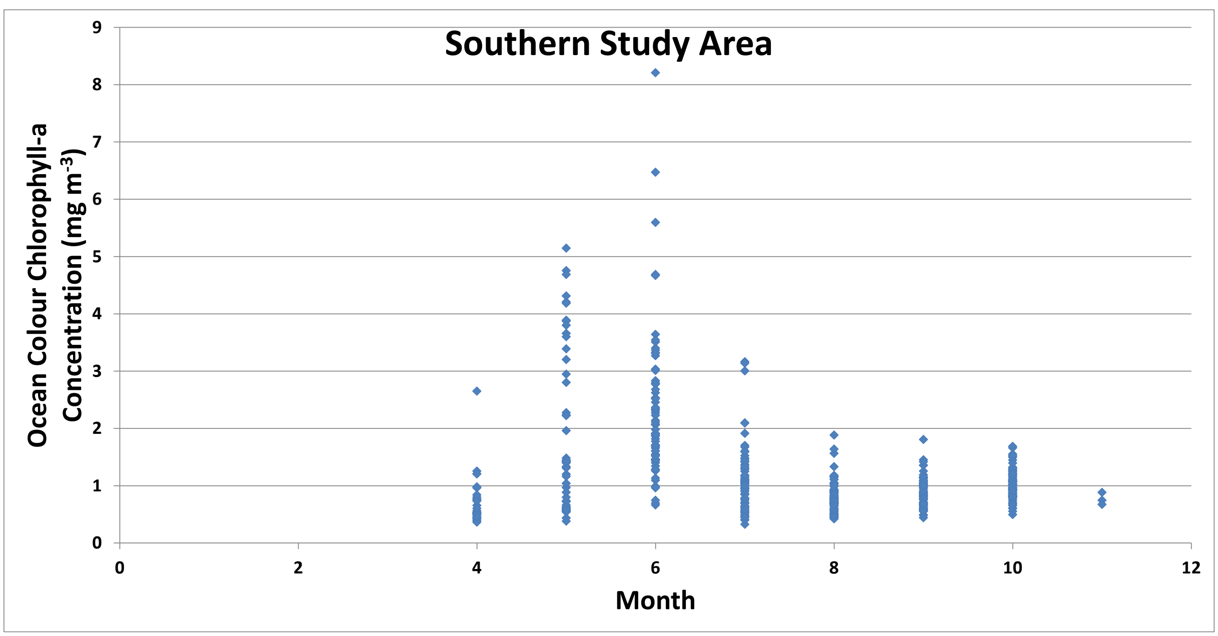


Figure 5.14: Monthly dynamics of chlorophyll-a concentration estimated from SeaWiFS, MODIS, and VIIRS imagery during 1998–2017 for the southern portion of the study area.

Interpolation of the seasonal satellite ocean colour data provides some further insights about changes in timing and intensity of surface blooms throughout the study area. The interpolated data clearly show highest chlorophyll-a biomass during the May-June period followed by limited autumn blooms (Figure 5.15). The southern area reveals 2-fold higher chlorophyll-a biomass levels compared to the northern area with generally lower levels throughout the spring and autumn periods. The time series suggest limited production during the spring bloom in certain years, particularly in the northern portion, along with a general decline in biomass throughout the zone. The northern and southern study area show significant reduction in the extent of autumn blooms, particularly from 2012–17. It remains unclear whether future impacts to spring and autumn phytoplankton blooms will remain ongoing in the study area into the future. The short-time series and variation in standing stocks of primary producers may be part of the natural variability inherent in the Labrador Coastal and Shelf ecosystem.

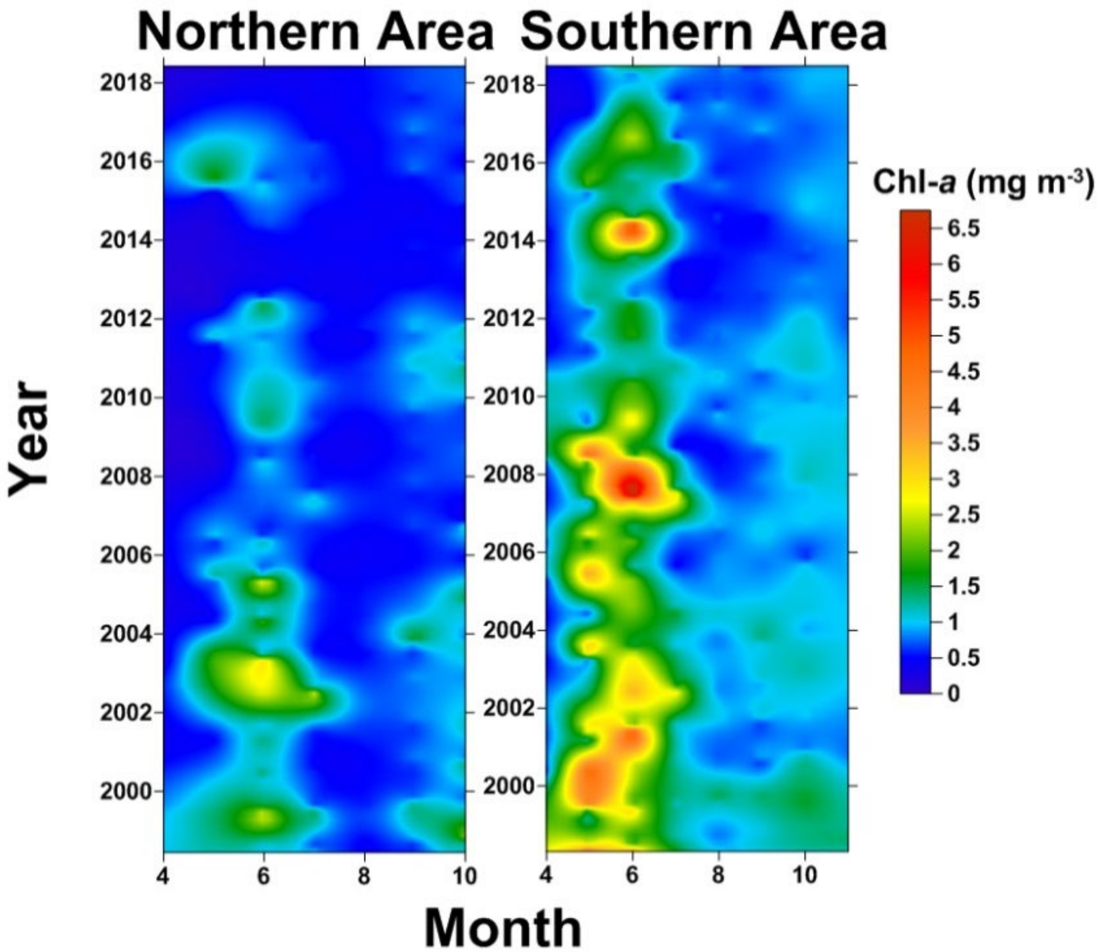


Figure 5.15: Intensity plots of surface chlorophyll-a concentration from semi-monthly remotely sensed ocean colour imagery in the northern and southern portions of the study area during 1998–2017.

A number of different metrics derived from satellite imagery using combined SeaWiFS, MODIS, and VIIRS imagery were examined to characterize the annual anomalies for the extent (magnitude and amplitude) and timing (peak timing and duration) indices of the spring bloom across the northern and southern parts of the study area. Data was insufficient in one year (2013) to permit parameter fitting and estimation of the different metrics. Overall, the magnitude (time-integrated chlorophyll-a biomass) and amplitude (peak intensity) anomalies of the spring bloom in both portions of the study area were mainly above normal in the late-1990s and early-2000s but have since transitioned to mostly below normal with a record-low observed in 2017 (Figure 5.16). There are some spatial differences in the anomalies for magnitude and amplitude of the spring bloom between the north and south study areas, particularly during 2006–10. The amplitude of the spring bloom has been mostly near or above normal until around 2010 when the standardized anomalies transitioned to mostly negative values (Figure 5.16). The record-low value for amplitude of the spring bloom was also observed in 2017. The reduction in the magnitude of the spring bloom in the northern study area has been on the order of ~80% between 2017 and the average of 1998–2015 while the southern area has declined by ~60% during the same time period. The amplitude has declined by roughly 60 and 75% for the northern and southern study areas respectively compared to the reference period.

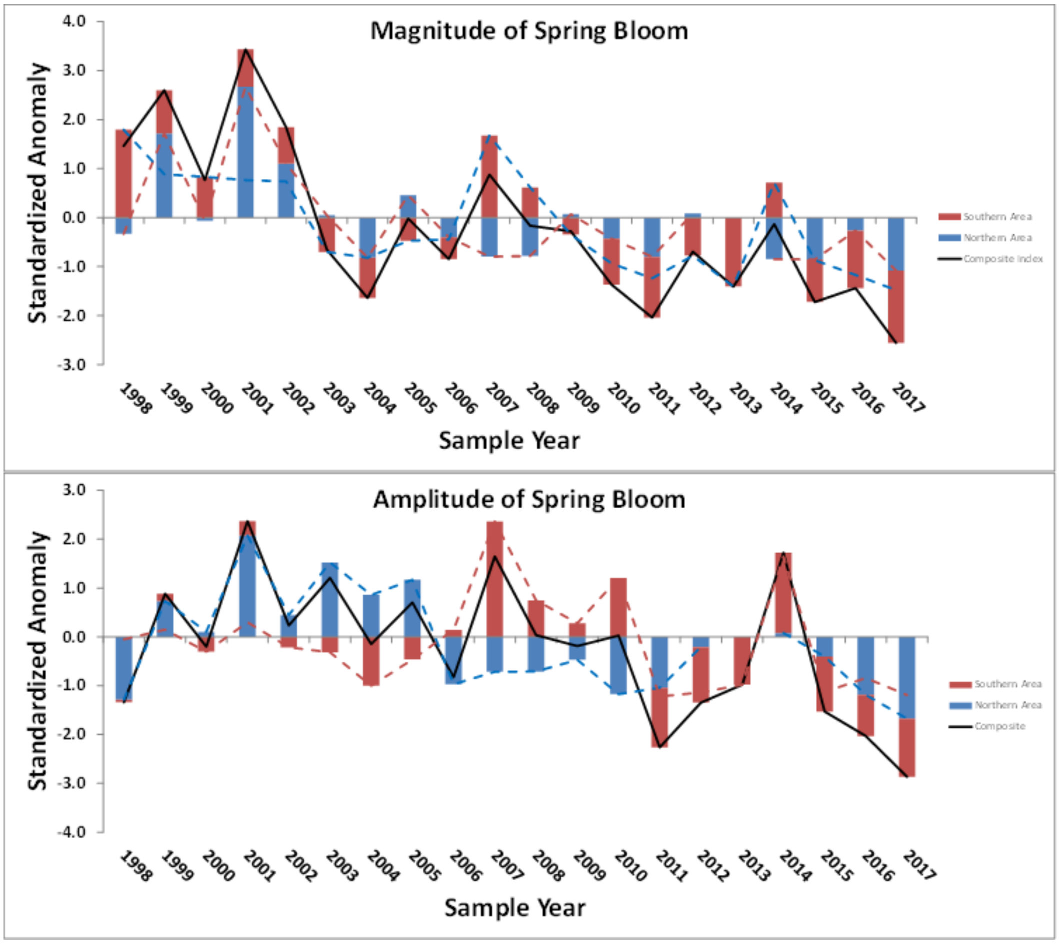


Figure 5.16: Summary of annual ocean colour anomalies across the northern and southern portions of the study area during 1998–2017. The magnitude and amplitude of the spring bloom were derived from the shifted Gaussian model based on Zhai et al. 2011. The standardized anomalies are the differences between the annual average for a given year and the long-term mean (1998–2015) divided by the standard deviation. The red dashed line tracks the annual anomaly for the southern area while the blue dashed line is for the northern area, the solid black line is the composite sum of the two areas.

The peak time of the spring bloom transitioned between periods of early (negative anomalies) versus late (positive anomalies) blooms throughout the 20-year time series based on the cumulative composite index (Figure 5.17). No long-term trends were apparent in the peak time of the bloom and the timing was not always coherent between the northern and southern areas. The earliest bloom was detected in 2006 while the latest was in 2002. The anomalies in timing have been mainly positive over the last decade indicating delayed blooms compared to the reference period (Figure 5.17). The trends in timing of the spring bloom have differed between the northern and southern study areas. In the north, the spring bloom has tended to occur earlier by ~11 days in contrast to the southern area which has occurred later by over two weeks compared to the standard reference period. The duration of the spring bloom has also varied throughout the time series with no apparent long-term trend. In addition, the duration of the spring bloom varied spatially with large differences observed in certain years (2010, 2016–17) with the northern study area showing positive anomalies in contrast to negative values in the south (Figure 5.17). The trends in duration of the spring bloom have also differed between the northern and southern study areas. In the north, the duration of the bloom is ~30 days longer in 2017 compared to the reference period. In contrast, the southern area duration is ~24 days shorter in 2017 compared to the long-term mean. It is unclear what may be driving these changes in primary production between the areas but changes in sea ice retreat, nutrient dynamics, timing of stratification and mixed layer depths, timing of zooplankton emergence and grazing pressure, along with irradiance levels all are likely to be contributing factors to variability in these bloom metrics.

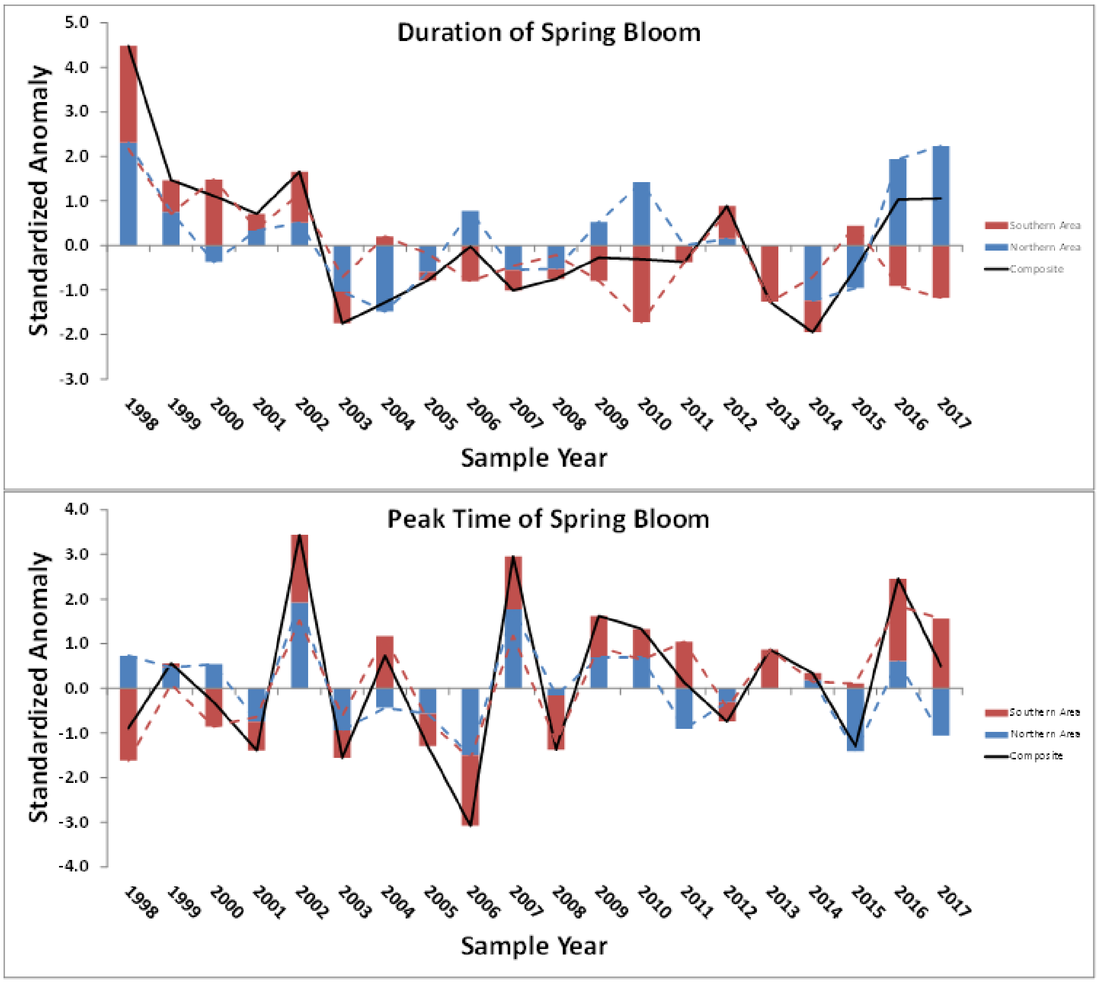


Figure 5.17: Summary of annual ocean colour anomalies across the northern and southern areas during 1998–2017. The timing indices were derived from the shifted Gaussian distribution based on Zhai et al. 2011. The standardized anomalies are the differences between the annual average for a given year and the long-term mean (1998–2015) divided by the standard deviation. The red dashed line tracks the annual anomaly for the southern area while the blue dashed line is for the northern area, the solid black line is the composite sum of the two areas.

5.1.2. Zooplankton

Zooplankton are composed of a variety of herbivore (plant feeders), omnivore (combined plant and/or animal feeding) and carnivorous (exclusively other zooplankton) animal taxa that remain suspended in the water column for the most-part with some limited ability to move vertically. Zooplanktons serve as the intermediate link between phytoplankton and higher trophic levels such as fish, seabirds, and marine mammals. Many zooplankton taxa exhibit an annual life cycle with new generations developing during the spring and summer by feeding on the seasonal phytoplankton bloom. The AZMP has been conducting vertically-integrated plankton tows along standard sections on the Labrador Shelf since the late-1990s. Those particular sections included inshore coastal areas that intersected the boundaries of the study area as well as the adjacent shelf and slope waters. Collections of zooplankton in northern Labrador are limited to July-August months due to the availability of ship time and extensive presence of sea ice through winter to late spring. The locations of collections within the study area were limited to the first few stations along the standard sections that include BI, NB, and MB in selected years (Figure 5.18).

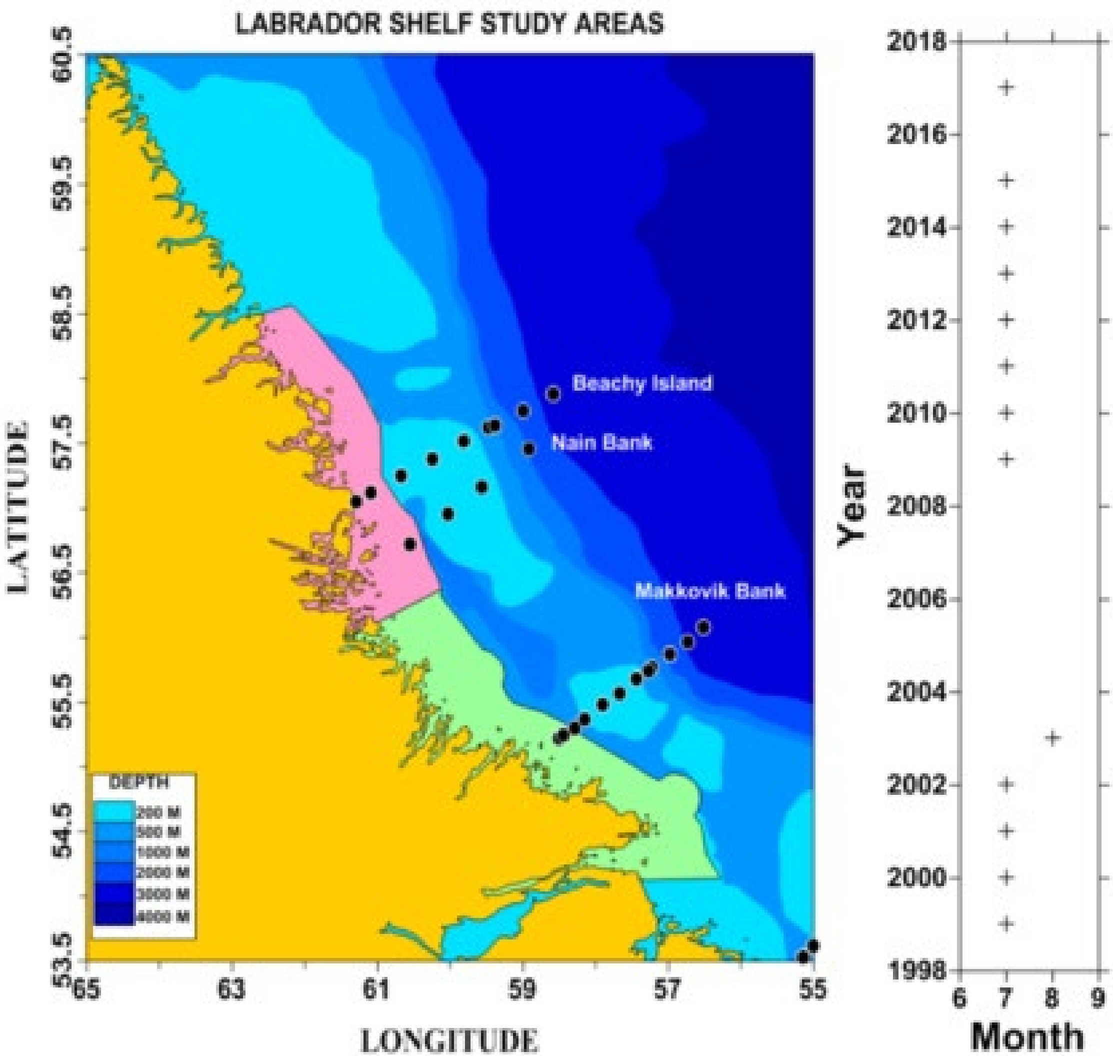


Figure 5.18: Locations of vertical net zooplankton tows along AZMP Labrador sections during July that intersect the southern and northern portions of the study area. Seasonal sampling coverage for northern Labrador (Beachy Island, Nain Bank, Makkovik Bank) ocean sections during 1999–2017 (right panel).

Significant temporal gaps occurred in sampling along the northern Labrador ocean sections in contrast to Seal Island (just south of the study area) that were routinely monitored for biological conditions since 1999.

5.1.3. Zooplankton Abundance

The major zooplankton taxa collected in the study area and adjacent Shelf regions are primarily composed of copepods, which make up nearly 90% of the organisms in terms of overall abundance (Figure 5.19). The other major taxa include appendicularia which are soft-bodied animals that filter feed on small phytoplankton, gastropods and ostracods which together make up an additional 8% of the composition. The other minor taxa are listed in the legend in Figure 5.19.

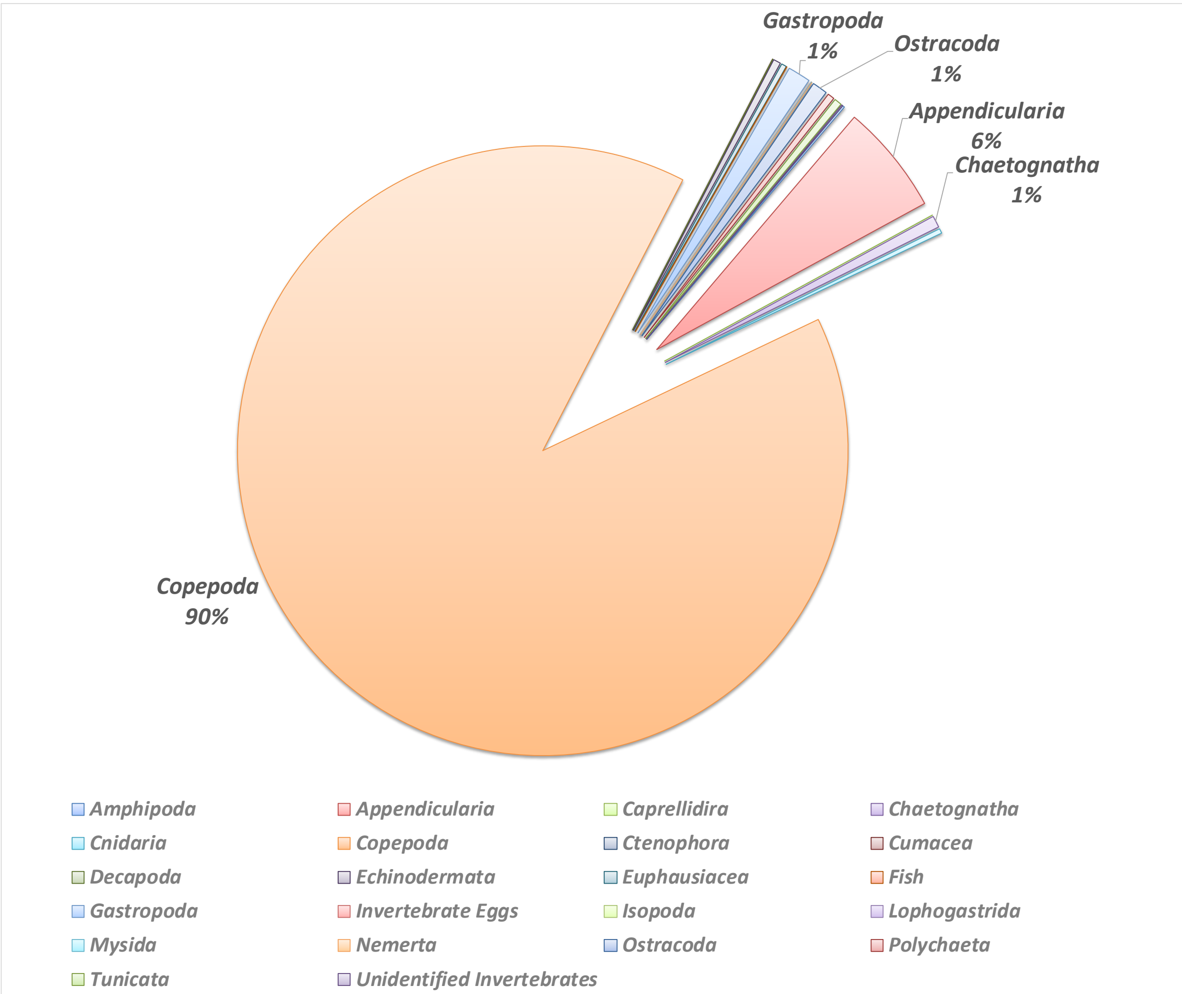


Figure 5.19: The percent composition of major zooplankton taxa collected in the study area (Beachy Island and Makkovik Bank sections) and outside Shelf areas during 1999–2017.

In terms of the copepoda, the calanoid copepods make up over 50% of the overall abundance and include *Calanus finmarchicus*, *C. glacialis*, *C. hyperboreus*, and *Pseudocalanus* spp., and *Microcalanus* spp. Calanoid copepods consist of both large and small species. Cyclopoid copepods are also very common members of the plankton with the genus *Oithona* contributing ~25% while the genus *Metridia* and *Oncaea* (small calanoids) each contribute an additional ~4% each (Figure 5.20). In addition, the larger, energy-rich calanoid copepods (*C. finmarchicus, C. glacialis, and C. hyperboreus*) make up a significant portion of the overall biomass of all copepod taxa due to their relatively large size and numerical abundance compared to other dominant small taxa such as *Oithona and Pseudocalanus*.

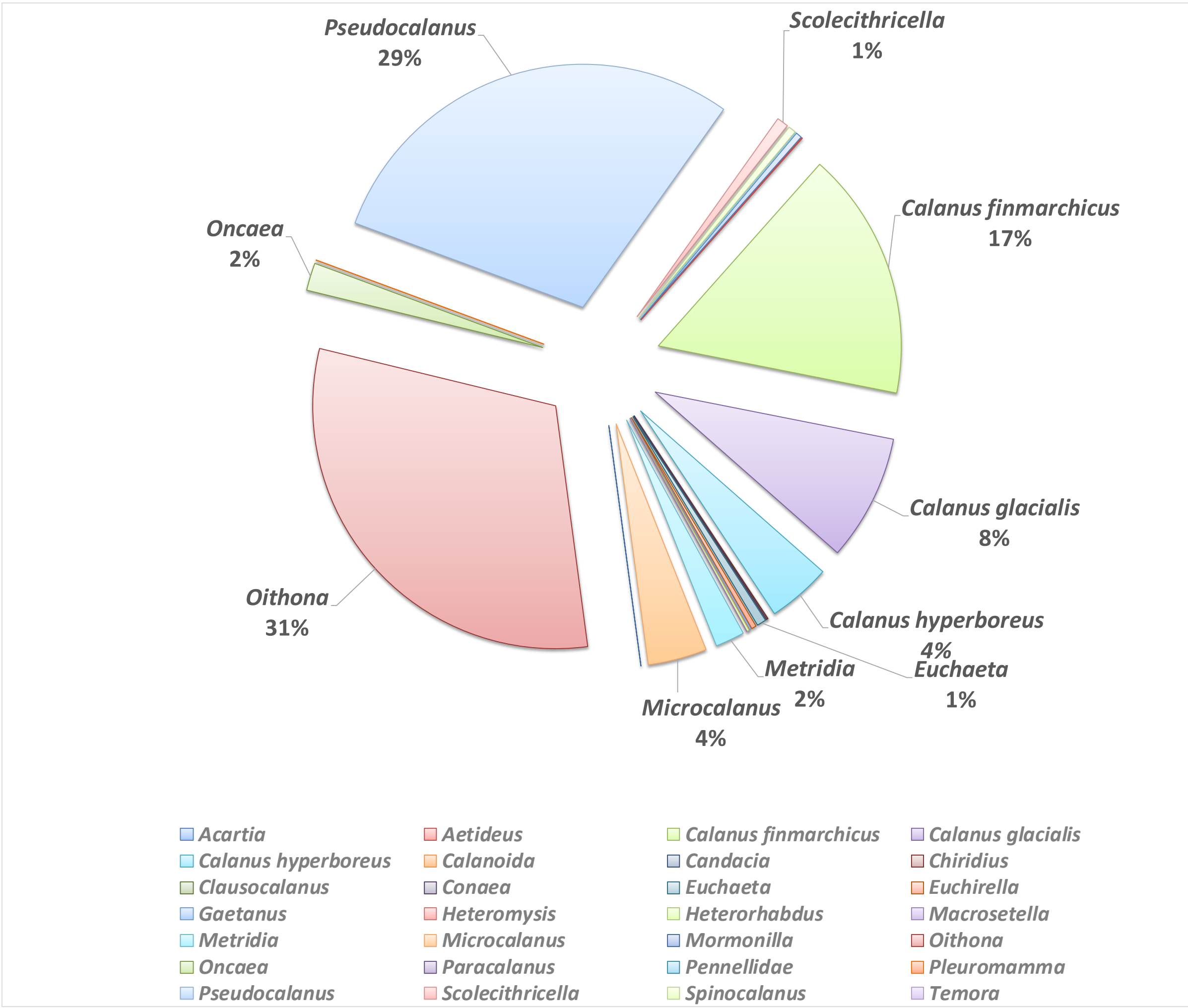


Figure 5.20: The major genera of the copepoda collected in the study area (Beachy Island and Makkovik Bank sections) and adjacent Shelf areas during 1999–2017.

Calanus finmarchicus is typically associated with a subarctic distribution observed throughout neritic and oceanic waters and numerically dominant among the calanoid copepods in the northwest Atlantic. The abundance of this keystone species in the Labrador ecosystem has demonstrated large interannual changes throughout the time series along the Labrador Shelf but levels have generally declined from peak levels observed in the mid-2000s compared to recent years (Figure 5.21). The other two large calanoid copepods (*C. glacialis* and *C. hyperboreus*) have an arctic-boreal association distributed in both neritic and oceanic waters with lower abundance compared to *C. finmarchicus*. The arctic taxa have generally increased in abundance in recent years on the Labrador Shelf (Figure 5.21). The time series for calanoid copepods along the Seal Island section which provides near-continuous observations from 1999–2017 reveal large interannual variability in abundance of calanoid copepods which appears to track observations further north along BI and MB sections.

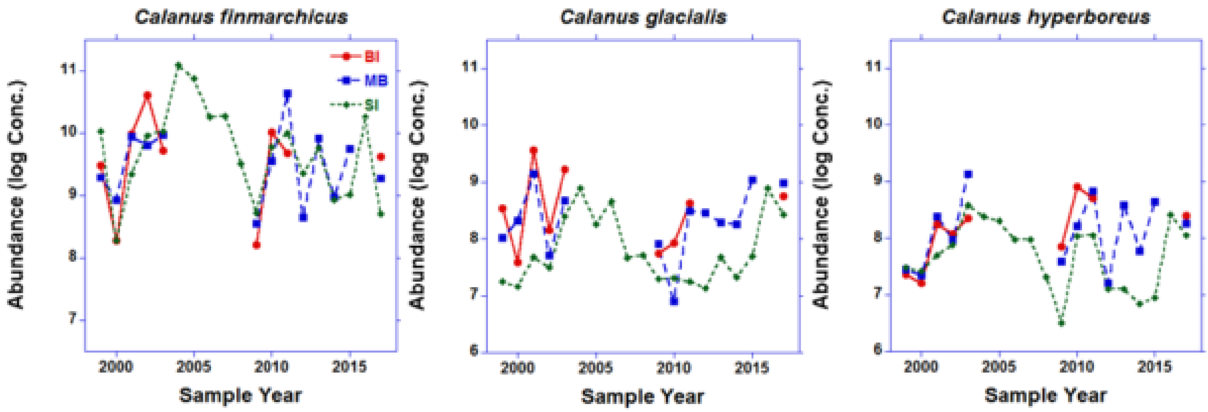


Figure 5.21: Abundance (natural log +1) of principal calanoid copepods estimated from vertical zooplankton profiles conducted during July along Beachy Island (BI), Makkovik Bank (MB), and Seal Island (SI) sections from 1999–2017. The northern sections had significant sample gaps during the time series.

In order to determine whether the Seal Island section located just to the south of the study area is representative of abundance trends further north, we evaluated the abundance relationship between the various sections. The relationship in abundance of the northern Labrador sections was significantly correlated with the Seal Island section (Figure 5.22). Based on these relationships, the Seal Island section may be useful as a proxy of abundance trends in calanoid copepods observed further north in the study area. Although the total number of data comparisons are limited (n=9 years for BI and n=12 years for MB), the correlation coefficients were high at > 0.6 and both statistically significant (Figure 5.22).

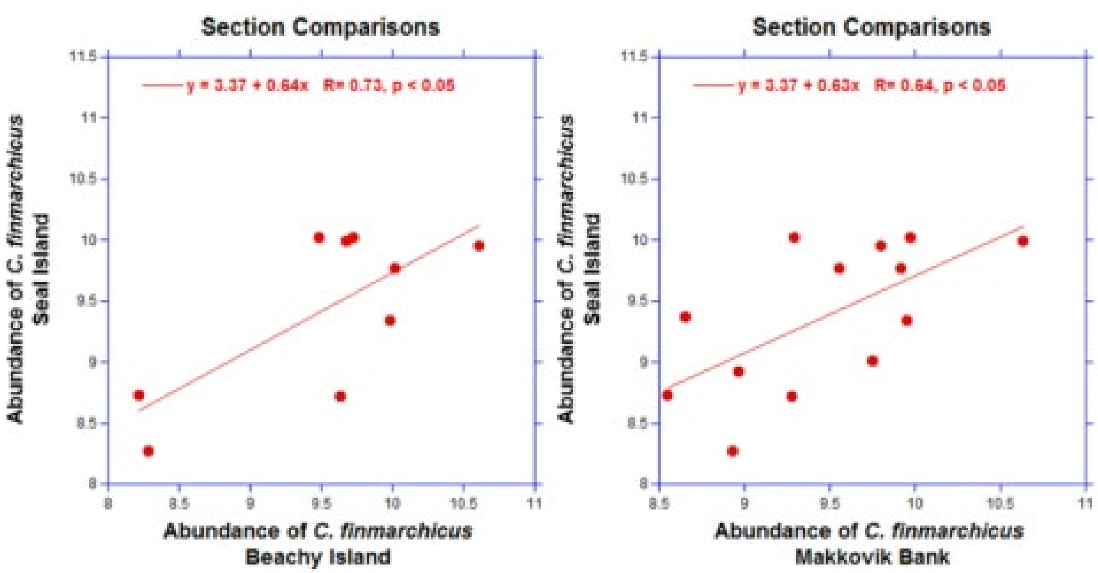


Figure 5.22: The relationship between abundance of Calanus finmarchicus for Beachy Island versus Seal Island (left panel) and Makkovik Bank and Seal Island (right panel) during 1999–2017. Linear regression, correlation coefficient (r) and p-value provided.

The reduction in abundance of the keystone *C. finmarchicus* has occurred during a period of change in the smaller copepod taxa. In general, the abundance of small copepods is increasing over the Labrador Shelf since the late-1990s (Figure 5.23). The exception to this general pattern is *Oithona* which has declined from high abundances observed in 2005 in the past decade. Although these taxa are considerable smaller in size compared to the large calanoids, they can exert considerable grazing pressure on phytoplankton due to their numerical abundance and widespread distribution throughout the North Atlantic.

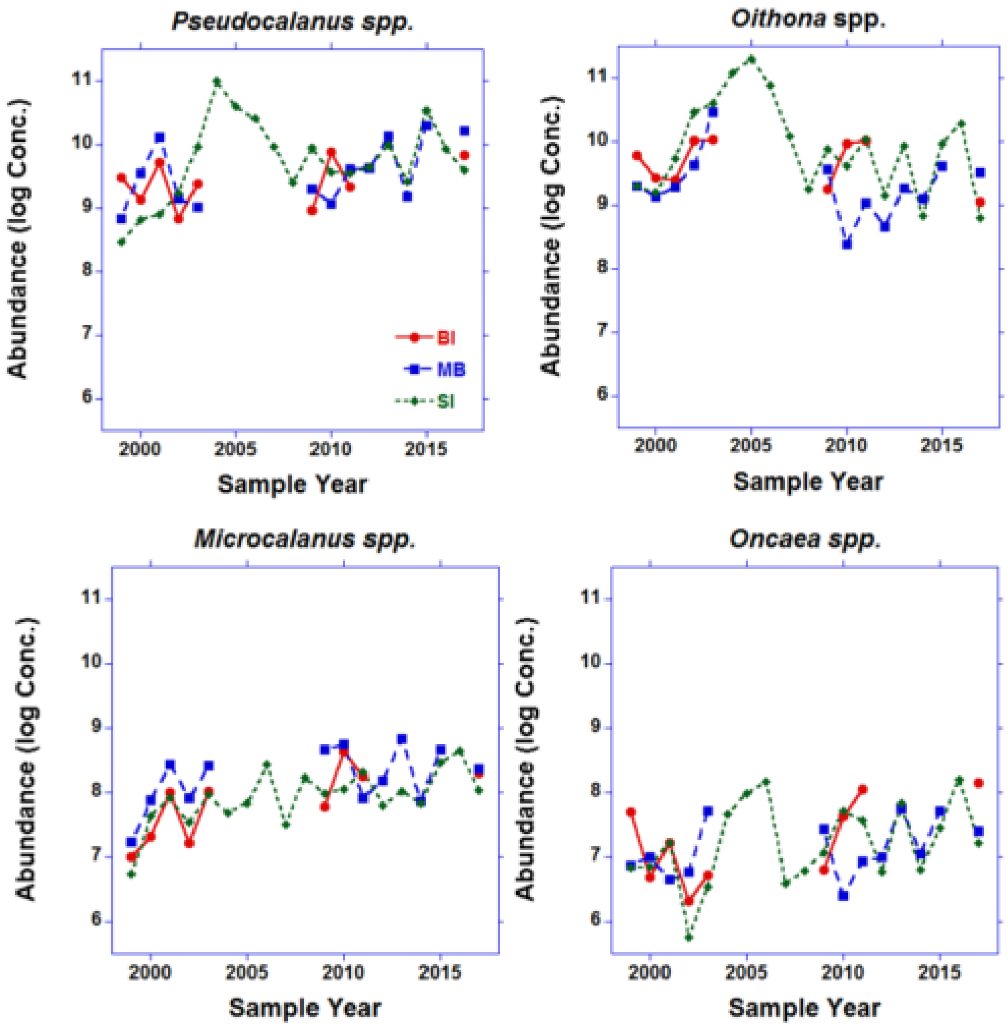


Figure 5.23: Abundance (natural log +1) of small copepods estimated from vertical zooplankton profiles conducted during July along Beachy Island (BI), Makkovik Bank (MB), and Seal Island (SI) sections from 1999–2017. The northern sections had significant sample gaps during the time series.

In addition to changes in the abundance of dominant copepods along the Labrador Shelf, observations of gelatinous zooplankton that include jellyfish (*cnidarian*), ctenophores and pelagic tunicates indicate these taxa are generally increasing in recent years. The abundance of the pelagic tunicate Oikopleura has been increasing steadily since 2014 at all of the northern sections along the Labrador Shelf (Figure 5.24). Given the shift from large to smaller copepod taxa along with the increase in abundance of gelatinous zooplankton with ~95% water content compared to 60–70% for marine crustaceans, may have associated impacts to the zooplankton biomass and ecosystem production potential along the Labrador Shelf (Koen-Alonso et al. 2013).

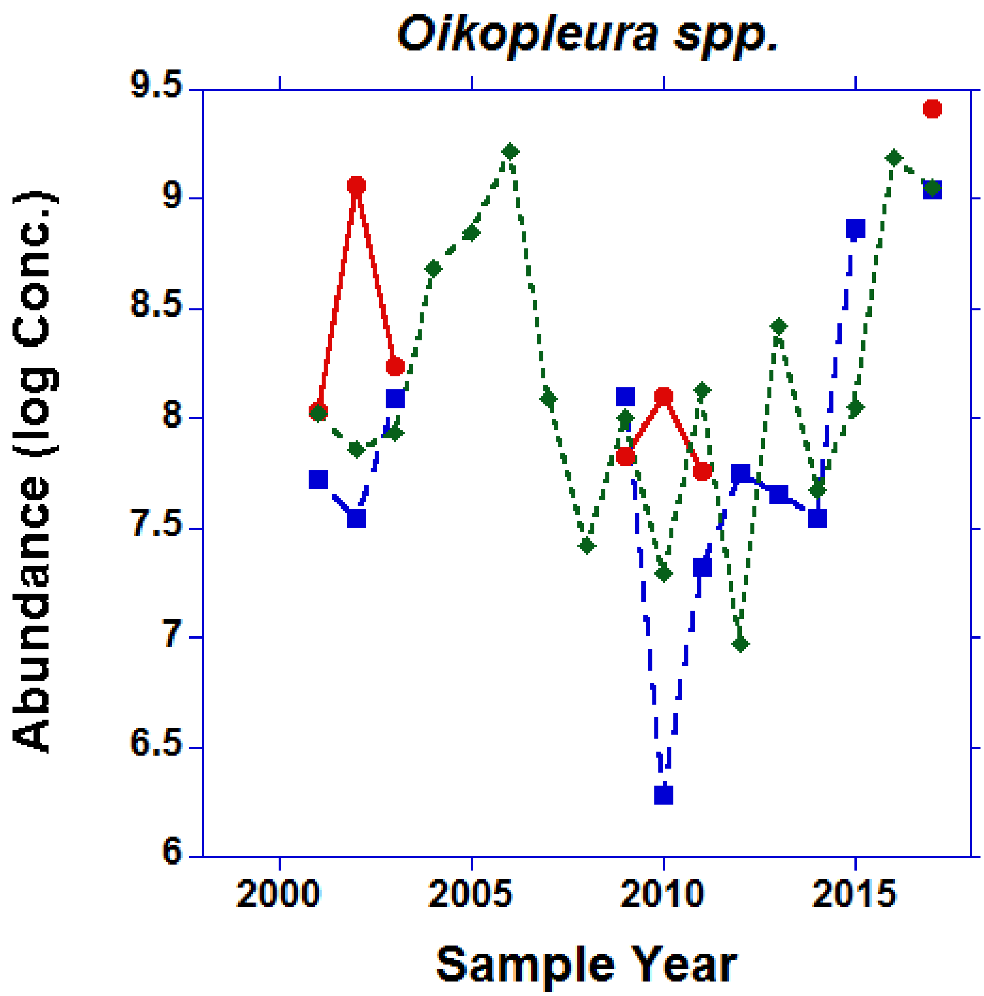


Figure 5.24: Abundance (natural log +1) of the pelagic tunicate Oikopleura estimated from vertical zooplankton profiles conducted during summer along BI, MB, and SI sections from 1999–2017. The northern sections had significant sample gaps during the time series.

5.1.4. Zooplankton Biomass

Routine monitoring of zooplankton biomass is conducted as part of the taxonomic analysis of samples along the AZMP standard sections. The standard protocol for zooplankton biomass partitions the collections into two size classes. The small (<1 mm) size fraction consists mainly of small copepods and earlier copepodite stages of the large calanoids while the large (>1 mm) fraction is composed mainly of the larger sub-arctic and arctic adult calanoid stages and macrozooplankton such as euphausiids and amphipods. The small-size fraction showed a 4-fold increase in biomass during 2002–06 across the Seal Island section (no data from Beachy Island and Makkovik Bank during 2004–08 and Beachy Island during 2012–16) but rapidly decreased thereafter and has remained relatively low through to 2017 (Figure 5.25). In contrast, the biomass of the large size fraction declined during 2002–06 with higher levels observed during the early and later time periods. The biomass of the large size fraction has also declined to relatively low levels in recent years (2015–17).

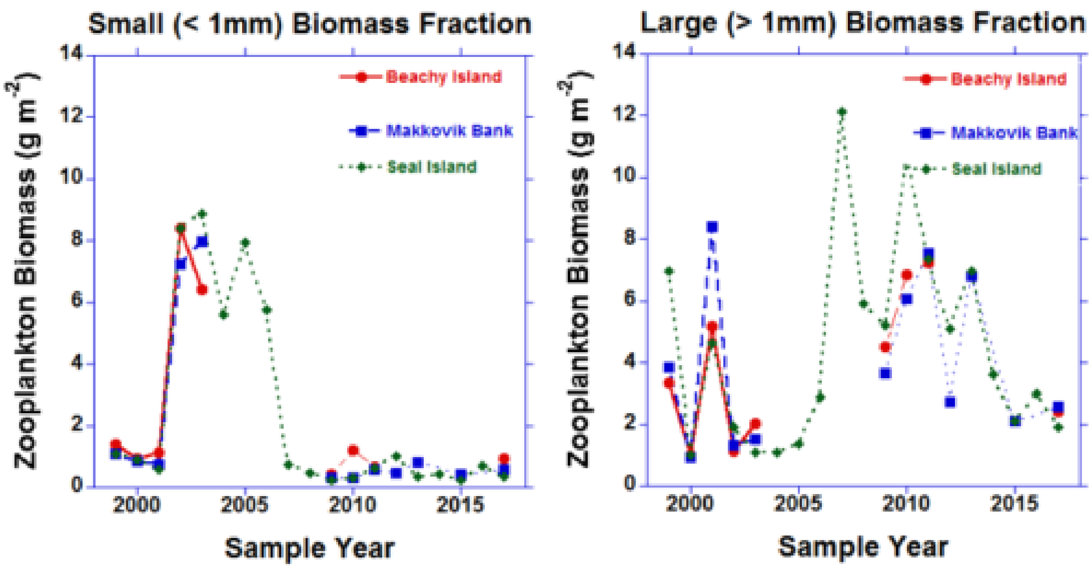


Figure 5.25: Average annual zooplankton biomass (g m-2) for the small (<1 mm) and large (>1 mm) size fractions estimated from vertical zooplankton profiles conducted during July along BI, MB, and SI sections from 1999–2017. The northern sections had significant sample gaps during the time series.

Combining the data for both size fractions indicates an overall declining trend in zooplankton biomass across the Labrador Shelf from the early-2000s through to 2017 (Figure 5.26). The peak in zooplankton biomass occurred in the mid-2000s on Seal Island (no data available for northern sections at that time) section but has declined nearly 5-fold in 2017 across all areas. The increase in the abundance of smaller copepods and gelatinous zooplankton with associated reductions in *C. finmarchicus* may be in part responsible for the observed decline in zooplankton biomass.

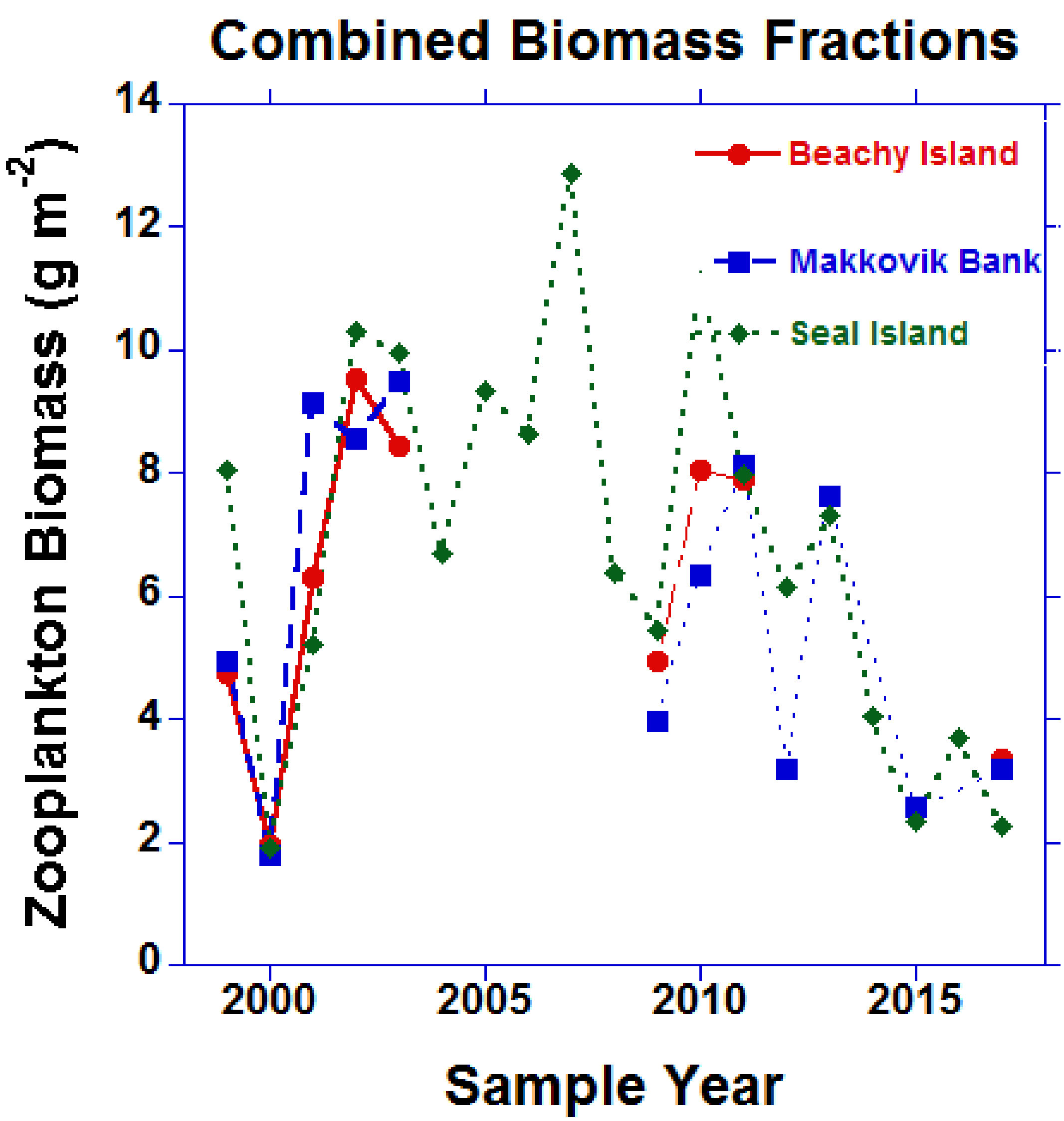


Figure 5.26: Average annual zooplankton biomass (g m-2) for combined size fractions (<1 mm and >1 mm) estimated from vertical zooplankton profiles conducted during July along BI, MB, and SI sections from 1999–2017. The northern sections had significant sample gaps during the time series.

We also evaluated whether the Seal Island section is representative of biomass conditions further north. The annual combined zooplankton biomass fractions in both study area zones were significantly correlated with the Seal Island section (Figure 5.27). Based on these relationships, the Seal Island section appears to be representative of conditions observed further north in the study area (Figure 5.27).

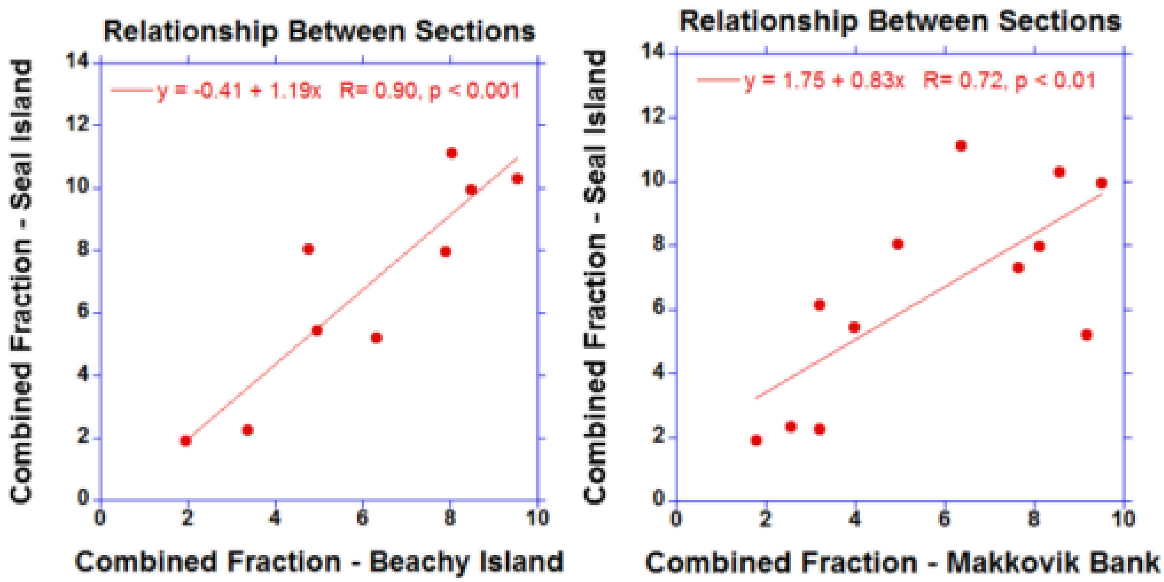


Figure 5.27: The relationship between the combined zooplankton biomass size fractions for BI versus SI (left panel) and MB and SI (right panel) during 1999–2017. Linear regression, correlation coefficient (r) and p-value provided.

5.1.5. Previous Studies

Some of the earliest records for taxonomic information on planktonic organisms on the Labrador Shelf include the 1928 GODTHAAB expedition on the Labrador Shelf at a station located just outside the study area at 55° 00' N and 56° W 34' at a depth of 314 m (Kramp 1963). Vertical net hauls were conducted in the upper 100 m of the water column with large quantities of *Calanus finmarchicus* observed. Other abundant copepods included *C. hyperboreus* and *Metridia longa* but were only observed in the deeper net hauls from 100–300 m. Other important zooplankton included *Aglantha digitale* (cnidaria) along with chaetognatha (*Sagitta elegans*, *Eukrohnia hamata*), pteropods (*Limacina helicina*, *L. retroversa*, *Clione limacina*), ctenophores (*Beroe cucumis*) were also relatively abundant.

Additional biological records on plankton and fish were conducted by the Research Vessel Blue Dolphin Labrador Expedition that was conducted during 1949–54. Much of the original focus of these oceanographic studies were focused on the physical dynamics but included information on nutrients, plankton, benthic organisms, and fishes throughout the Labrador Coastal region (Grainger 1964, McGill and Corwin 1965, Nutt and Coachman 1956). We were not able to obtain the biological summaries before submission of this summary report on biological oceanography. This information may be relevant given the Blue Dolphin studies included large parts of the current study area including coastal bays and fjords.

The Offshore Labrador Biological Studies (OLABS) program conducted oceanographic sampling to collect baseline biological information on nutrients, phytoplankton, and zooplankton from coastal bays across the continental shelf from 52° N to 61° N during the summer of 1979 (Buchanan and Foy 1980, Buchanan and Browne 1981). The northern ocean sections intersected the inner study area and were partially aligned with ongoing ocean monitoring program (AZMP). The LH, LG, LF, LE and LD ocean sections along with the inner bay stations intersected the study area (Figure 5.28). The details of sampling are briefly discussed in the above publications but were closely aligned with sampling protocols and methodology conducted by the AZMP (Mitchell et al. 2002).

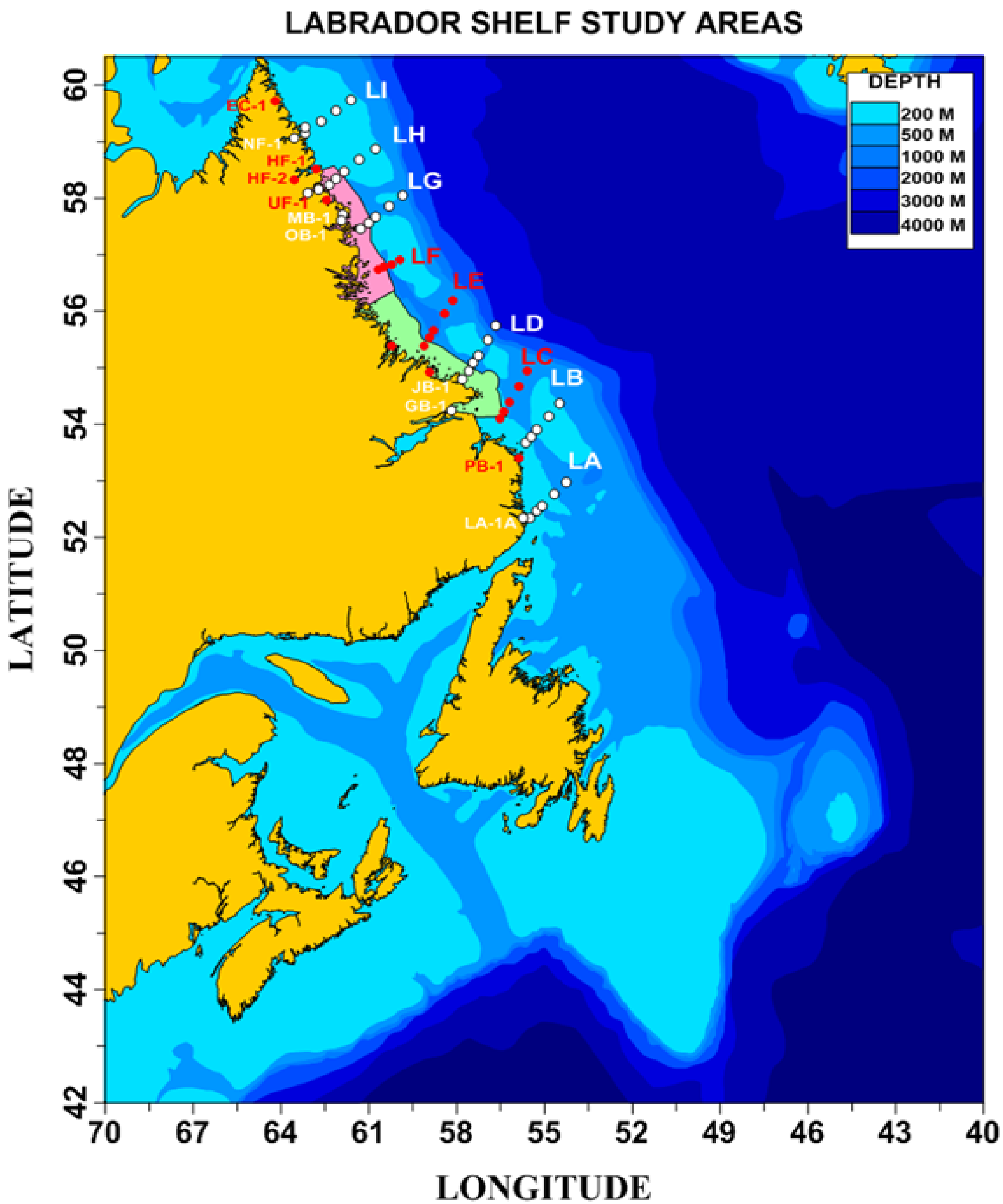


Figure 5.28: Station locations for the oceanographic studies conducted by the Offshore Labrador Biological Studies (OLABS) program conducted in summer of 1979 for collection of nutrients, phytoplankton and zooplankton samples. The zooplankton stations are identified as white circles. The red circles denote stations locations for the collection of nutrients and chlorophyll a, phytoplankton and ichthyoplankton.

5.1.6. Nutrients

High variability in integrated nitrate concentrations was observed across the various sampling locations during the OLABS study period (Figure 5.29). This is likely attributable to uptake and utilization of nitrate by phytoplankton along with various inputs from coastal runoff, regeneration, and southern transport of arctic waters from the Hudson Strait into the study area. Phytoplankton productivity would normally be well underway at the time of sampling by the

OLABS program during summer and may reflect the normal drawdown in nutrient levels that occur during bloom periods. One would also expect nitrate concentrations to increase from inshore to offshore across the shelf due to higher levels in North Atlantic (Slope) water compared to Arctic sources. This was not always the case based on the spatial distribution of nitrate inventories but could vary on short time scales for the reasons identified above.

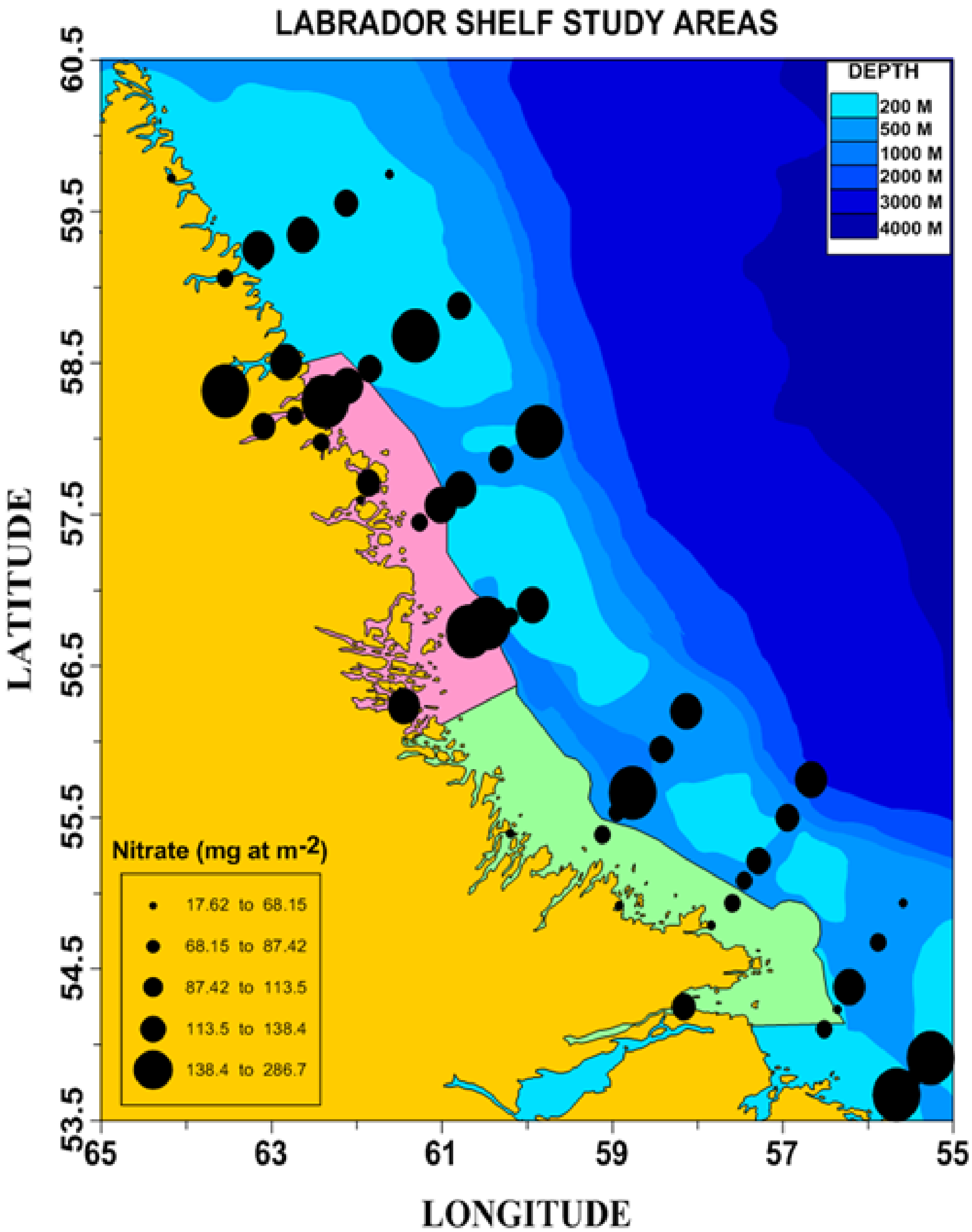


Figure 5.29: Distribution of integrated nitrate concentrations (mg m^{-2}) in the upper 50 m of the water column along the Labrador Coast and Shelf during the Offshore Labrador Biological Studies (OLABS) program conducted in the summer of 1979 (adapted from Buchanan and Foy 1980).

5.1.7. Phytoplankton

The phytoplankton community was dominated by unidentified small micro-flagellates and diatoms which made up over 90% of the taxa in Labrador coastal and shelf waters during the OLABS study period (Figure 5.30). Diatoms traditionally dominant the spring bloom in boreal and sub-arctic waters in the North Atlantic and are important due to their large relative size and nutritional content compared to micro-flagellates. The main phytoplankton genera for diatoms included *Chaetoceros*, *Thalassiosira spp*., *Nitzschia*, and *Dinobryon*. During the post-bloom phase of the production cycle, the large diatom taxa are important for energy fluxes to the benthos due to their rapid settling rates and contribute to secondary production of benthic organisms.

Measurements of integrated chlorophyll a pigment within the water-column provided information on the spatial distribution of phytoplankton biomass over the Labrador Coastal and Shelf areas during the OLABS program. Areas of high biomass were often associated with the outer continental shelf across the various banks, but some inshore coastal sites also showed similarly high levels (Figure 5.31). Standing stocks of phytoplankton were highest over Saglek Bank just north of the study area compared to ocean sections located further south. Areas of low biomass were typically associated with the inner to mid shelf areas along the Labrador Region. Given the relatively short duration of phytoplankton blooms in the summer across this region, one might expect to observe large changes depending on the phase of the production cycle in a given year based on the variability observed in general timing indices derived from remote sensing data.

Figure 5.30: The percent composition of major phytoplankton taxa and one miscellaneous category) collected during the Offshore Labrador Biological Studies (OLABS) during the summer of 1979 (adapted from Buchanan and Browne 1981, and Buchanan and Foy 1980).

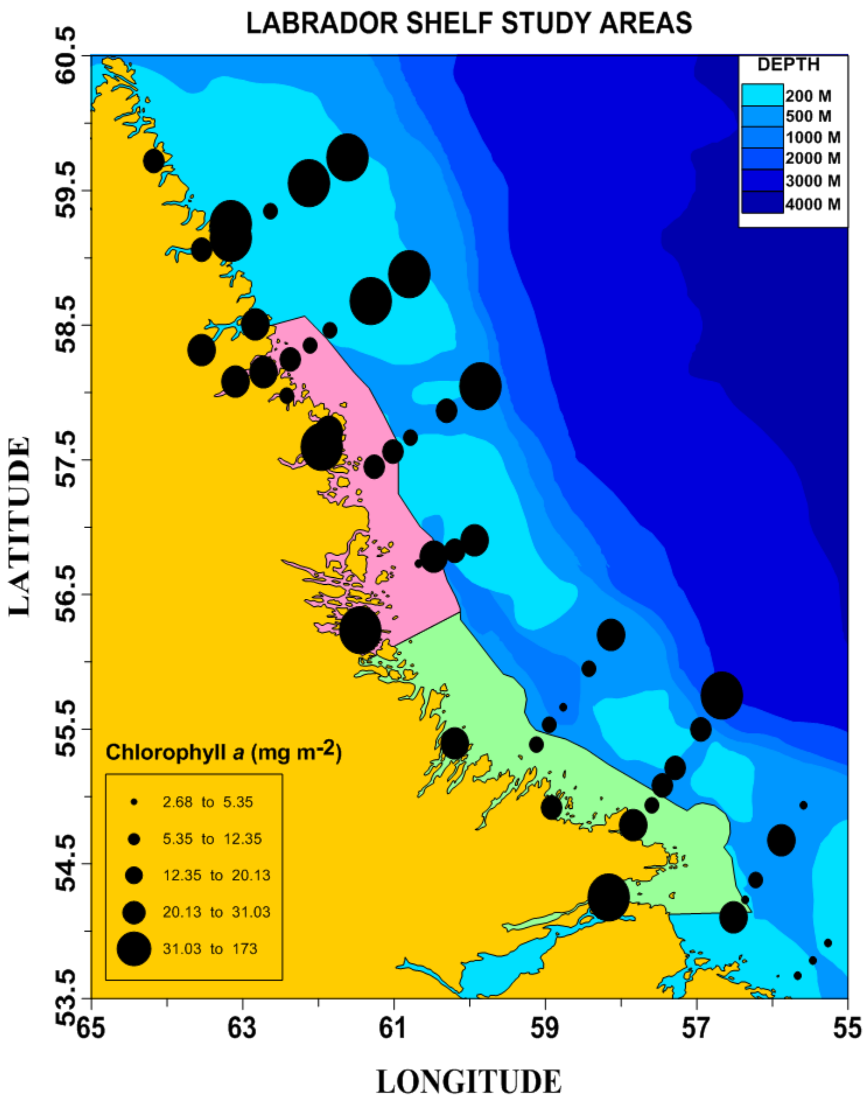


Figure 5.31: Distribution of integrated chlorophyll a concentrations (mg m^{-2}) in the upper 50 m of the water column along the Labrador Coast and Shelf during the Offshore Labrador Biological Studies (OLABS) program conducted in the summer of 1979 (adapted from Buchanan and Foy 1980).

5.1.8. Zooplankton

The information on the spatial distribution of zooplankton taxa for the OLABS program was provided to supplement earlier studies on species composition and seasonal dynamics in Canadian subarctic waters. The zooplankton information on abundance and biomass were obtained from vertical net hauls across the standard ocean sections conducted by OLABS from inshore to offshore locations (see Figure 5.28 for sampling locations). The data for abundance and biomass was averaged across the inshore coastal (Bays and inner Shelf) and offshore Shelf stations based on available tabulated data. A total of 117 species of zooplankton were observed in coastal and shelf waters during the OLABS sampling program. The abundance of zooplankton along the coastal and shelf stations was dominated by calanoid copepods which were comprised of *Pseudocalanus minutus*, *Calanus finmarchicus*, *C. glacialis*, and *C. hyperboreus* (Figure 5.32). Other important taxa across the study area included barnacle larva (Cirripedia), euphausiids and decapods, along with small cyclopoid copepods (e.g., *Oithona spp.*). The calanoid and cyclopoid copepods made up a larger proportion in terms of abundance along the shelf versus the inshore coastal stations. In contrast, the proportion of barnacle larvae and decapod crustaceans were much greater in the coastal versus the shelf stations.

Not surprisingly, given the numerical dominance of calanoid copepods in coastal and offshore shelf waters, biomass of these particular taxa represented between 60% and 75% respectively (Figure 5.33). Soft-bodied larvaceans (gelatinuous zooplankton) were only identified by presence/absence observations but were weighed and made up ~10% in terms of biomass across the Labrador study area. Other minor zooplankton taxa contributing to biomass in coastal areas included jellies (Cnidaria and Ctenophora), mollusc pteropods (Pteropoda), barnacle larvae (Cirripedia), amphipods (Amphipoda), euphausiids (Euphausiaces), and decapods (Decapoda e.g., shrimp, crab larvae).

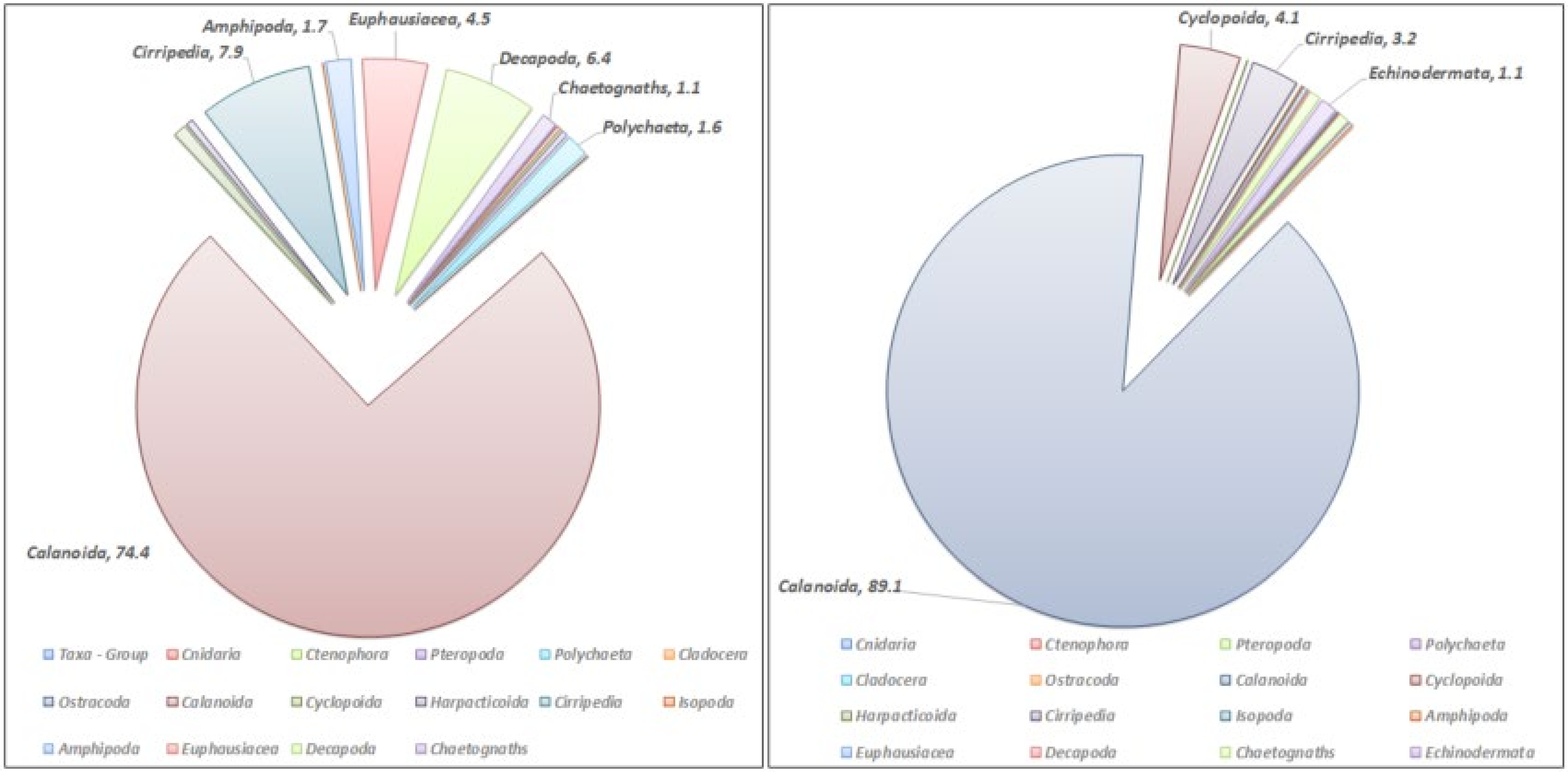


Figure 5.32: The percent composition of major zooplankton taxa along inner bay and coastal (left) and outer Shelf stations (right) collected during the Offshore Labrador Biological Studies (OLABS) during the summer of 1979 (adapted from Buchanan and Browne 1981).

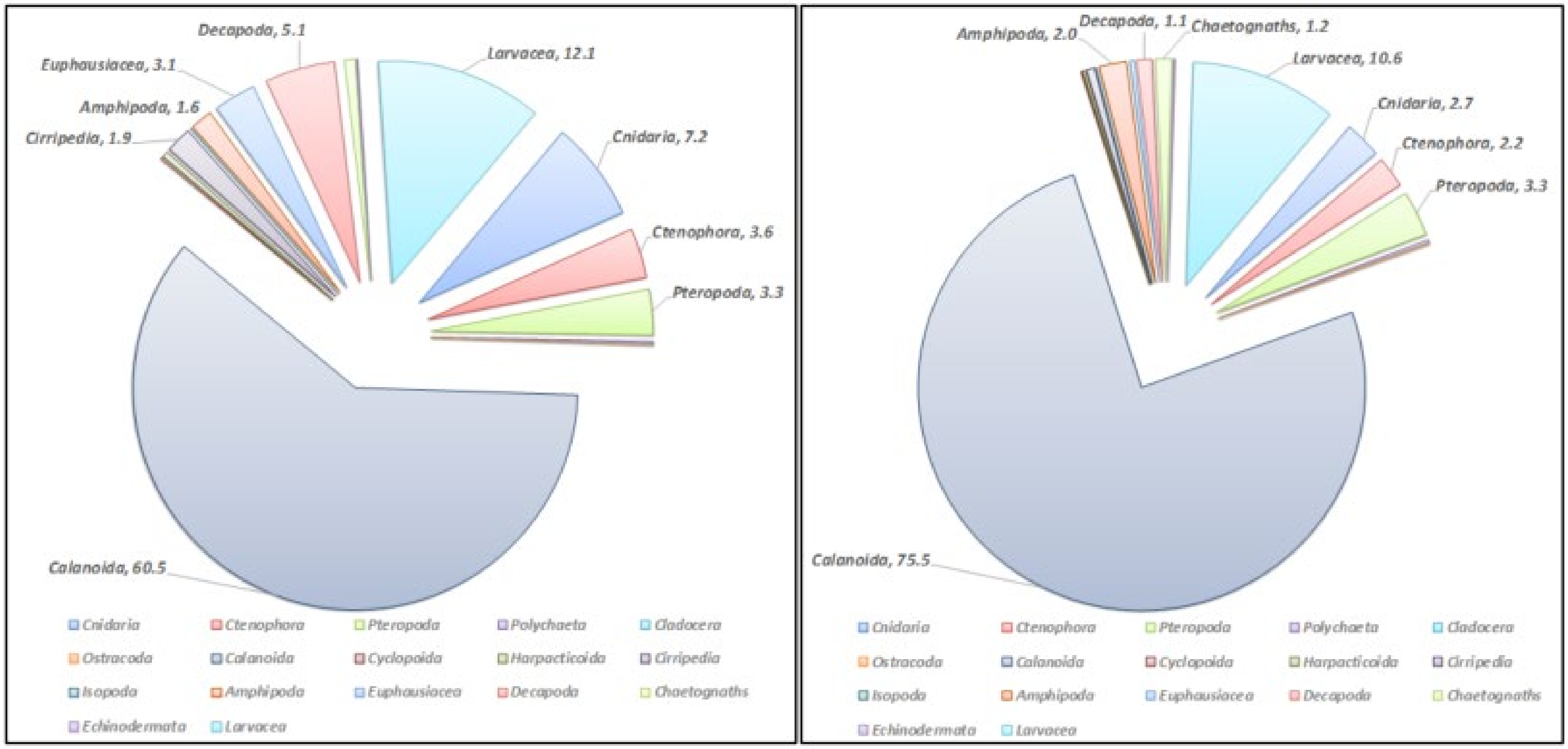


Figure 5.33: The percent biomass composition of major zooplankton taxa along inner bay and coastal (left) and outer Shelf stations (right) collected during the Offshore Labrador Biological Studies (OLABS) during the summer of 1979 (adapted from Buchanan and Browne 1981).

The abundance of zooplankton generally increased from inshore coastal sites to offshore Shelf areas in the study area (Figure 5.34). The biomass of zooplankton was relatively stable between 500–600 mg m^{-3} across the Labrador Shelf with the exception of an inshore station (Stn #1) that had nearly 2-fold higher levels. The higher biomass of zooplankton at this inshore coastal station was primarily attributed to increased levels of calanoid copepods.

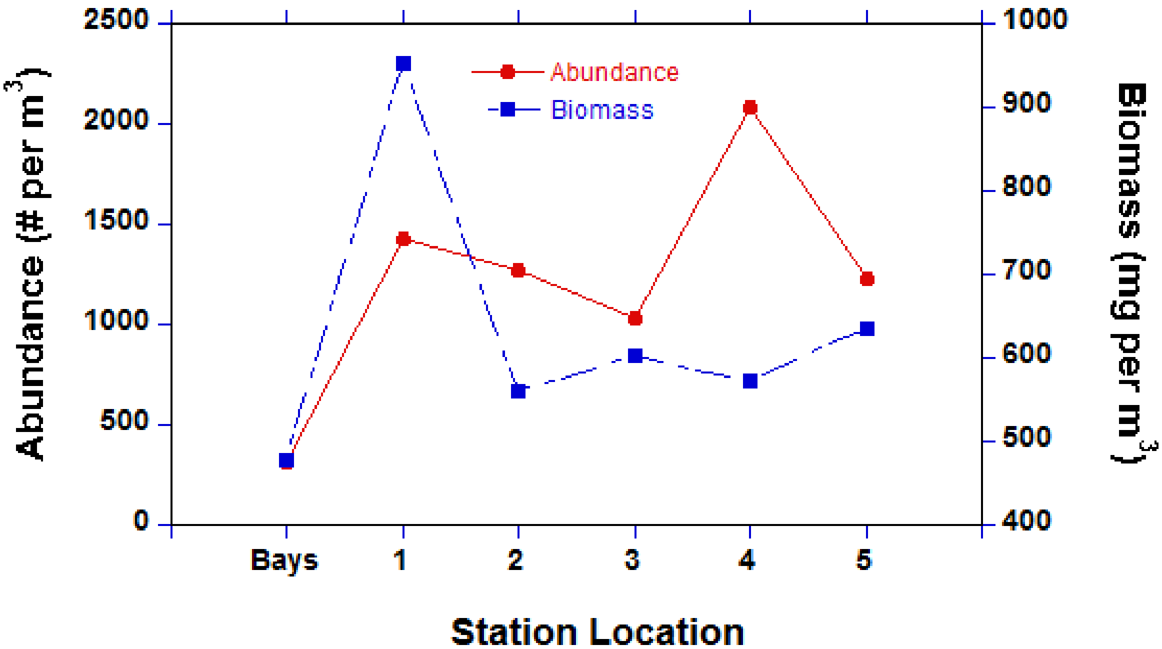


Figure 5.34: Trend in abundance and biomass from inshore coastal to offshore stations conducted during the Offshore Labrador Biological Studies (OLABS) during the summer of 1979 (adapted from Buchanan and Browne 1981).

5.1.9. Ichthyoplankton

Young of the year fish (ichthyoplankton) were collected inshore and along oceanographic sections using conventional high-speed sampling gear (bongo nets) during the OLABS program in 1979. Over 25 species of ichthyoplankton representing 12 families were identified from the Labrador Coast that intersects the study area (see Figure 5.28 for sampling locations). The dominant taxa in terms of both abundance and biomass included Arctic Cod (*Boreogadus saida*; *Gadidae*) which accounted for 76% and 71% respectively (Figure 5.35). Other important components of the ichthyoplankton community included sculpins and blennies (*Lumpenidae*) and combined with Arctic Cod made up ~97% in terms of abundance and biomass.

Mean densities and biomass of ichthyoplankton varied spatially across the Labrador Coast and Shelf region. The largest densities were associated near-shore in the coastal bays and inner continental shelf and decreased in the offshore areas (Figure 5.36). The fish taxa that contributed to the bulk of the abundance and biomass, such as Arctic Cod, sculpins and blennies had consistently higher levels in the coastal bays compared to the offshore. In contrast, some of the other minor fish taxa such as Redfish (*Scorpaenidae*) were more abundant in the offshore while alligatorfish and sea poachers (*Agonidae*), sand lance (*Ammodytidae*) and Arctic Shanny (*Stichaeidae*) had no clear distributional pattern associated with distance from shore.

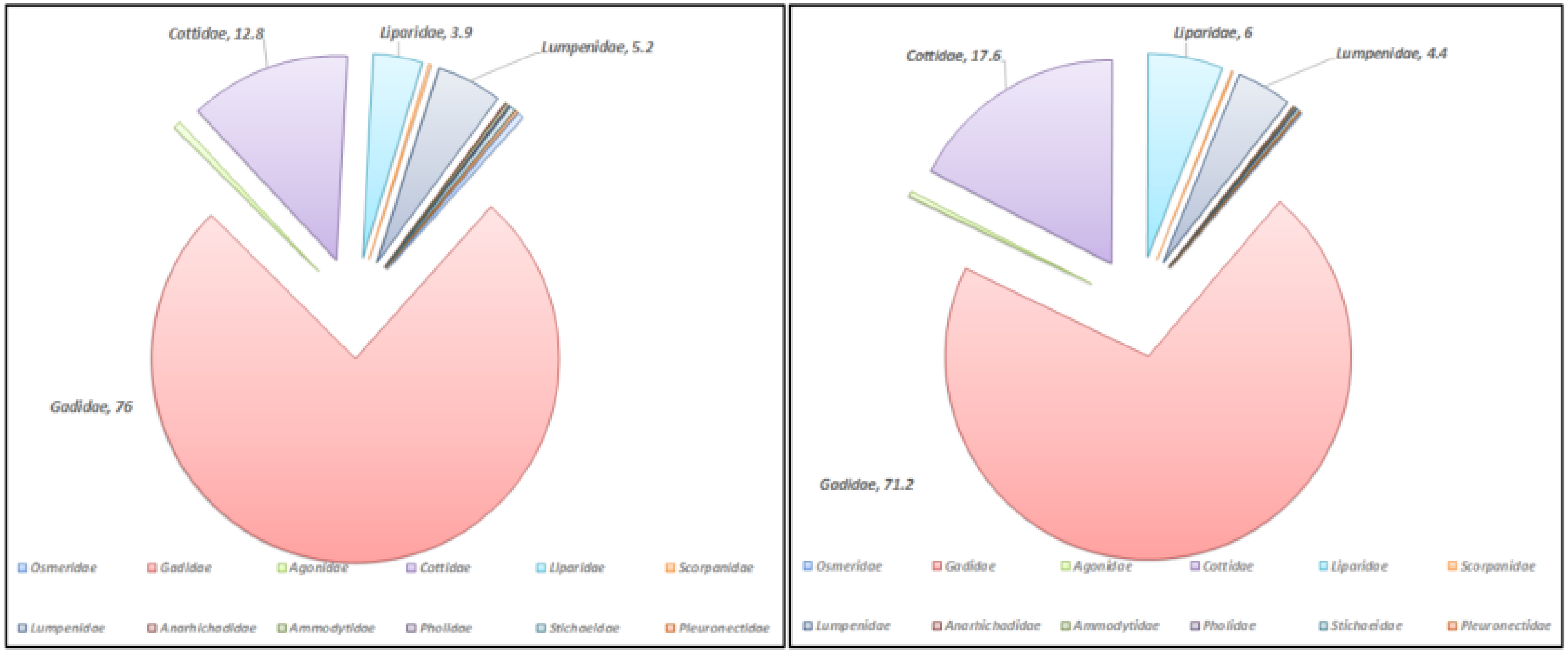


Figure 5.35: Percent distribution of abundance (left panel) and biomass (right panel) of young of the year fish (ichthyoplankton) collected in Bongo tows during the Offshore Labrador Biological Studies (OLABS) program conducted in the summer of 1979 (adapted from Buchanan and Foy 1980).

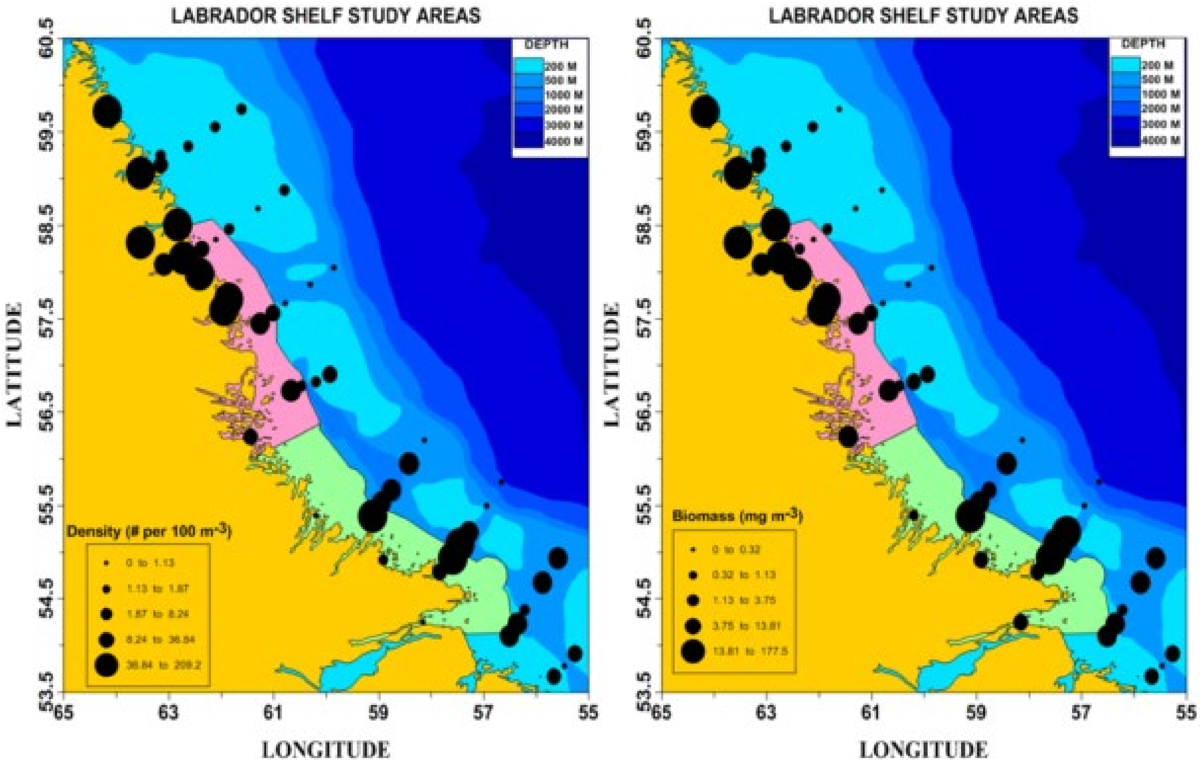


Figure 5.36: Density in numbers per 100 m^3 (left panel) and biomass in mg m^3 (right panel) of young of the year fish along the Labrador Coast and Shelf during the Offshore Labrador Biological Studies (OLABS) program conducted in the summer of 1979 (adapted from Buchanan and Foy 1980).

5.2. Sensitive Habitats and Species

As limited knowledge of plankton communities exists from the study area, establishing information regarding the seasonal trends in abundance and biomass of major functional phytoplankton (e.g., diatoms) and zooplankton (e.g., calanoid copepods) groups along with their responses to ocean climate conditions would improve our understanding of important ecological drivers in the ecosystem. The study area represents a transition zone between arctic, sub-arctic, and boreal zones that may have differential impacts on various planktonic organisms due to changes in ocean climate conditions on various physiological processes and phenology. In addition, polar and subpolar seas are hypothesized to be a bellwether for potential impacts due to ocean acidification on calcifying marine organisms (Fabry et al. 2009) which may also contribute to differential impacts to community structure of plankton in the study area. The timing of seasonal production of plankton which coincides with rapid changes in solar irradiance and sea ice retreat in the study area represents a critical period characterized by a tight coupling of primary and secondary production and relatively large fluxes of energy to the higher trophic levels. Previous oceanographic studies conducted by the Offshore Labrador Biological Studies (OLABS) on distribution, abundance, and biomass of plankton indicate the potential importance of inshore high secondary productivity and coastal nursery areas for a variety of taxa such as Arctic Cod.

5.3. Key Uncertainties and Approaches to Address Data Gaps

While an understanding of the lower trophic levels and important physical forcing conditions are being made through seasonal collection of ongoing time series from standard ocean sections conducted by the AZMP and earlier retrospective studies, oceanographic sampling within the study area remain relatively limited. The long-term trends derived from repeated oceanographic sampling in the near vicinity (downstream and adjacent areas) is likely to provide some indication of the trends and important drivers in this region. Although the principle limiting nutrient is generally declining across the Labrador Shelf based on annual observations conducted by the AZMP, the abundance of phytoplankton and zooplankton can change substantially from year-to-year. The absence of observations of primary productivity limits our ability to infer the effect of variations in phytoplankton standing stock on secondary productivity. Understanding variations in secondary production are also confounded by the potential for differential effects of ocean temperature on the physiological processes that affect arctic, sub-arctic and boreal zooplankton taxa. Potential expansion into the nearshore coastal areas of the study area through extension of the sampling programs by the AZMP could provide additional complementary information. The majority of the data provided in this section of the report have been obtained with conventional sampling systems such as plankton nets, Niskin bottles, and instrumented CTD's. Sampling and observation systems are advancing rapidly and AZMP data can also be supplemented by newer and existing technologies such as under-ice profilers, satellite remote sensing of sea surface temperature and ocean colour, automated sensor buoys and acoustic sampling of the water column (from moorings or ship-based) to understand the depth distribution of pelagic organisms as well as establishing baseline environmental DNA (eDNA) collections. The trophic links of zooplankton should also be explored through diet analyses of higher organisms (i.e., stomach content and tissue stable isotope and fatty acid analyses). Sediment traps, set on moorings, could provide important information on benthic-pelagic coupling; which may be affected by the interannual variability in productivity across the study area.

6. Macrophytes-Seaweeds and Seagrasses

Aquatic macrophytes are diverse and widespread in intertidal and sub tidal habitats. They have evolved many different strategies to take advantage of a physically and ecologically challenging environment. The distribution of aquatic plants in coastal regions is determined by a combination of physical and biological factors (Adey and Hayek 2011). Substrate, exposure, light, and ice scour limit distribution and community composition in sub polar regions. Within these communities biotic interactions also affect distribution, recruitment, persistence, and productivity. The kelp forests of coastal Newfoundland are in a dynamic relationship with the Green Urchin (*Strongylocentrotus drobachiensis*); urchin grazing can create extensive barrens (Figure 6.1, Himmelman 1985). Some species have developed defense mechanisms that allow them to avoid grazing pressure and persist. For example, annual brown alga *Desmarestia viridis* stores sulfuric acid that makes it distasteful to urchins (Gagnon et al. 2013) *and Agarum clathratum* is rarely grazed because of tough fronds and distasteful phytochemicals (Figure 6.1, Blain and Gagnon 2014). Stands of *A. clathratum* are common in the lower intertidal in Newfoundland and Labrador and clumps shelter more palatable species such as *Alaria esculenta* within their canopy (Blain and Gagnon 2014). Taxonomy of intertidal and subtidal macroalgae has changed considerably in recent years as common names are varied and differ among cultures and communities (Table 6.1).

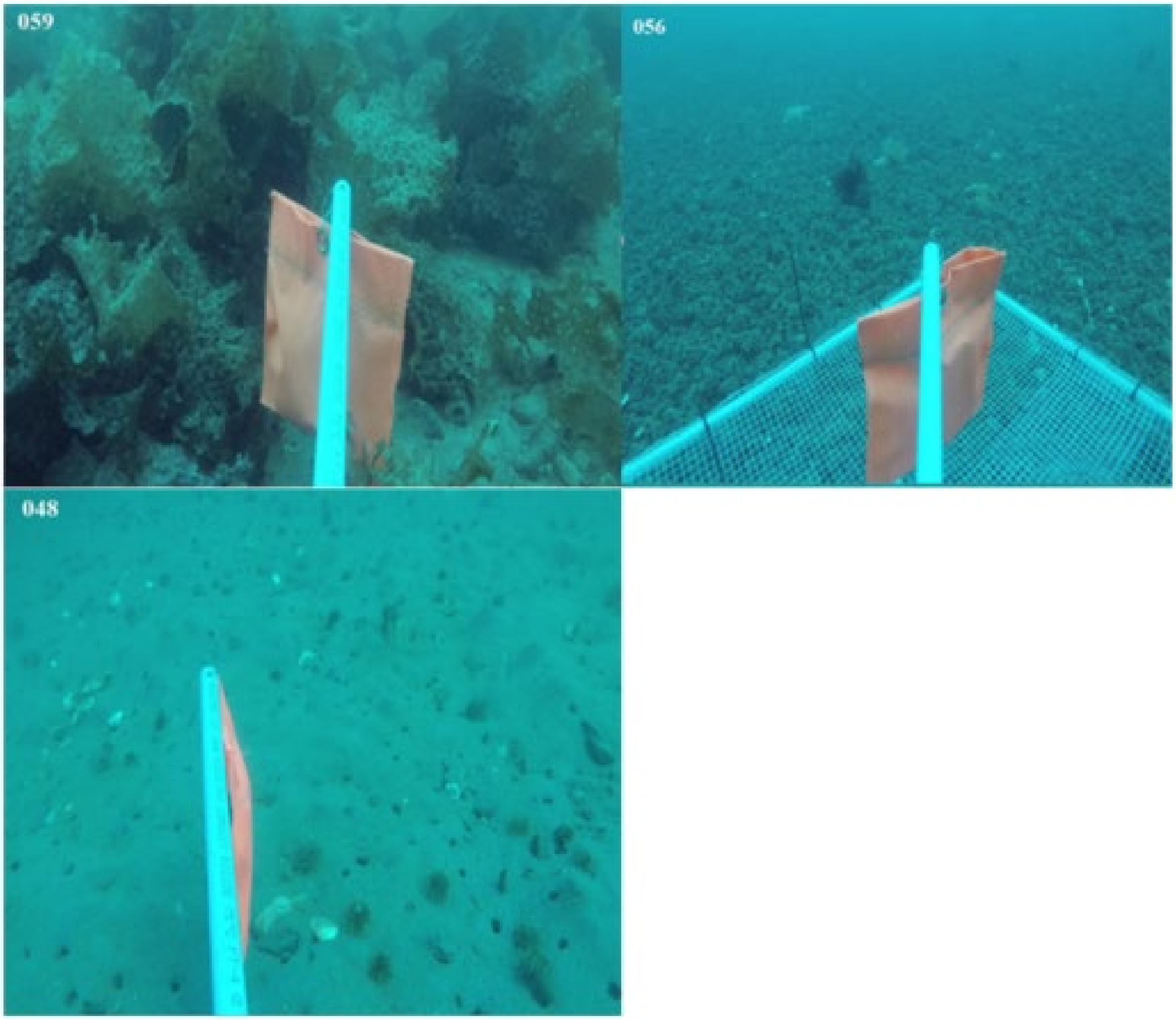


Figure 6.1: The widespread brown algae Agarum clathratum (top left), rhodolith beds comprised of coralline algae (top right) and urchin barrens (bottom left). Photos from Okak at approximately 10 m depth (Photo credit D. Cote).

Terminology, taxonomy, and common names: the taxonomy of many littoral plants particularly the kelps, has changed considerably over the years and many of the Latin names used in early studies are no longer accepted. Table 6.1 lists some earlier names of the common species referred to in this chapter. Common names are also variable and may be applied to different species in different places. Where available, the table also includes the local name for a species or group. A comprehensive list of local names is critical for collecting valuable local ecological knowledge about these species.

Table 6.1: Latin and common English names of common coastal macroalgae species.

Latin Name	Other Names	Common Name	Local Name/Use
Alaria esculenta	*Alaria grandifolia*?**	Kelp	Shark blanket
Ascophyllum nodosum	-	Bladderwrack, rockweed	-

Latin Name	Other Names	Common Name	Local Name/Use
Fucus vesiculosus	-	rockweed	-
Fucus distichus	-	rockweed	-
Saccharina longicruris	*Laminaria longicruris*	Kelp	-
Saccharina latissima	*Laminaria saccharina*	Kelp, Sugar kelp	-
Laminaria solidungula	-	Kelp	-
Laminaria digitate	-	Kelp	-
Agarum clathratum	*Agarum cribosum*	Kelp, Colander kelp	-
Desmarestia viridis	-	Sour weed	-
Zostera marina	-	Eelgrass	-
Lymus mollis	*Elymus mollis*	Sea grass, Strand wheat, Beach grass	Luther E. (n.d.) basket making

***Kraan et al. 2001*

Aquatic macrophytes create habitat and structure in the nearshore environment (Table 6.2). Kelp, the brown algae that dominate subtidal communities in sub polar regions, are major primary producers and ecosystem engineers (Teagle et al. 2017). They play an important role in nutrient cycling, carbon capture and transfer. They also provide substrate for colonizing organisms, and three-dimensional habitat structure by increasing habitat volume, heterogeneity and complexity, and direct provision of food and shelter for many marine plants and animals, including a number of commercially important species (Teagle et al. 2017).

Table 6.2: Names of habitats discussed in the text.

Habitat	Dominant species	Reference
Eelgrass meadow	*Zostera marina*	-
Kelp forest	Large brown algae of the order laminariales	Teagle et al. 2017
Rockweed beds	*Ascophyllum nodosum*, and *Fucus* sp.	Schmidt et al. 2011
Breach wrack *or* Beach cast drift	The plant material tossed up on the shore by wind and waves	Barreiro et al. 2011
Rhodolith beds	coralline algae - free living or attached to small pebbles - may form extensive beds	Jørgensbye and Halfar 2017
Maerl	Habitat dominated by coralline red algae	van der Heijden and Kamenos 2015

Habitat	Dominant species	Reference
Urchin barrens	Habitat denuded of foliose algae by urchin grazing, dominated by crustose coralline algae	Himmelman 1985
Bolder barricade	Boulders deposited in the lower intertidal/upper subtidal by ice colonized by rockweed and attached invertebrates such as mussels and barnacles	Rosen 1979

Eelgrass is a perennial vascular plant that forms extensive meadows on soft sediments. It has been designated as an ecologically significant species in Canada (DFO 2009) because of its contribution as nearshore habitat, its significant contributions to nutrient cycling and its sensitivity to anthropogenic disturbance. Eelgrass meadows serve as important nursery habitat and feeding grounds for many ecologically and commercially important species of fish, invertebrates and seabirds (Moore and Short 2006, Schmidt et al. 2011). They are important nursery habitats for a variety of marine fish in coastal Newfoundland (Coté et al. 2013) including Atlantic Cod (Gotceitas et al. 1997).

The intertidal rockweed *Ascophyllum nodosum* stands provide shelter and moderate extremes of temperature for intertidal invertebrates such as mussels and barnacles (Ørberg et al. 2018). As with eelgrass meadows and kelp forests, rockweed beds provide important littoral habitat and other ecosystem services. Canopy structure plays a key role in the types of services provided and they differ from those of other vegetated habitats (Schmidt et al. 2011).

Aquatic macrophytes are the world’s most productive habitats (Smith 1981). As a result, they play an important role in the global carbon cycle. Carbon capture by seagrasses, salt marsh and mangroves have been termed Blue Carbon (Nellemann et al. 2009) and represents a significant contribution to annual carbon sequestration. More recently the carbon captured by kelp forests (Duarte and Krause-Jensen 2017) and coralline algae beds (Jørgensbye and Halfar 2017) have also been considered as part of blue carbon. The fate of the carbon captured by these seaweeds and seagrasses remains poorly quantified (Duarte 2017). Some is sequestered in place (burial in eelgrass meadow sediments, Duarte and Krause-Jensen 2017) and deposition as calcium carbonate in maerl beds (van der Heijden and Kamenos 2015) and rhodolith fields (Jørgensbye and Halfar 2017) some is exported as particulates, to the shore as beach wrack where it may be up to a meter thick after storm events and represents a significant subsidy for beach communities (Figure 6.2; Barreiro et al. 2011), or to deep water where it may form the dominant particulate organic matter in fjords and other sheltered environments (Krause-Jensen and Duarte 2016) and some is decomposed and exported as dissolved organic material.

Figure 6.2: Beach wrack from coastal Newfoundland composed of eelgrass and kelp (Photo credit M.R. Anderson).

Kelp and other macroalgae have developed a number of strategies for enhanced productivity in sub polar environments. They have the capacity to store organic carbon (more than 30% C by weight; Gevaert et al. 2001) and inorganic nutrients to be used for growth when light or nutrients are limiting. This allows them to grow rapidly under low light conditions under ice or in the winter. Their stores of inorganic nutrients also allow them to continue growing when the phytoplankton bloom would otherwise outcompete them in the spring (Chapman and Craigie 1977). When the stored nutrients are depleted the kelp once again store carbon for later use. In contrast, when nutrients are not limiting, in estuaries for example, kelp grow throughout the spring and summer and do not store carbohydrates or inorganic nutrients for growth under the ice (Anderson et al. 1981). In many places kelp are harvested for use as food or as carbohydrate sources for nutritional, pharmaceutical, biofuels and other uses (Nayar and Bott 2014). Beach wrack is also collected for use as a mulch, soil enhancer and fertilizer in many parts of the world including Newfoundland and Labrador.

6.1. Available Information

Subpolar species of seaweeds and seagrass dominate the attached vegetation of the Labrador coast and the species diversity is lower than similar temperate environments. Site specific records are limited however it appears that most species are found throughout the study area where suitable habitat is found.

Wilce (1959) surveyed the macroalgae from 19 sites on the Labrador coast, three south of Lake Melville, 15 north of Okak, and one at Hopedale on the central coast. The species he reports are predominantly subpolar species and are common all along the coast. His study focused on readily accessible intertidal sites with subtidal flora sampled in beach wrack or using a dredge. Wilce (1959) provides detailed composition records of the dominant flora associated with the substrate and exposure conditions found on the coast as well as the timing of recruitment and growth for each habitat. He identified five types of habitat on the coast of Labrador:

1. mud flats,
2. protected shallows,
3. moderately exposed coasts,
4. fully exposed coasts, and
5. tide pools (Wilce 1959) and subdivided these into littoral above the low spring tides and sub-littoral below. Mud flats are infrequent and most of those sampled were from Ungava Bay. More details on these habitats are included in Appendix C, Table C-2.

On hard substrates the intertidal zone is dominated by rockweeds principally *Ascophyllum nodosum* in sheltered areas and several species of *Fucus* in more exposed sites (Figure 6.3). Kelp which can form extensive forests dominate the biomass of the subtidal zone with red algae and other browns in the understory. Coralline red algae, in particular the crustose forms, continue into deeper waters below the kelp and can be found to depths of 70 m in other subpolar locations (Jørgensbye and Halfar 2017). Annual species are particularly important in ice scoured areas and many perennial species behave as annuals in sites with heavy ice scour. Unconsolidated and rough substrates provide some protection from ice, and it is common to find small pockets of perennial rockweeds in these habitats. Boulder barricades, a particular geomorphological feature of the Labrador coast (Rosen 1979), often have small pockets of rockweed associated with them (Barrie et al. 1980). These barricades also protect the intertidal from ice scours allowing the buildup of soft sediments and the formation of salt marshes (Hooper and Whittick 1984).

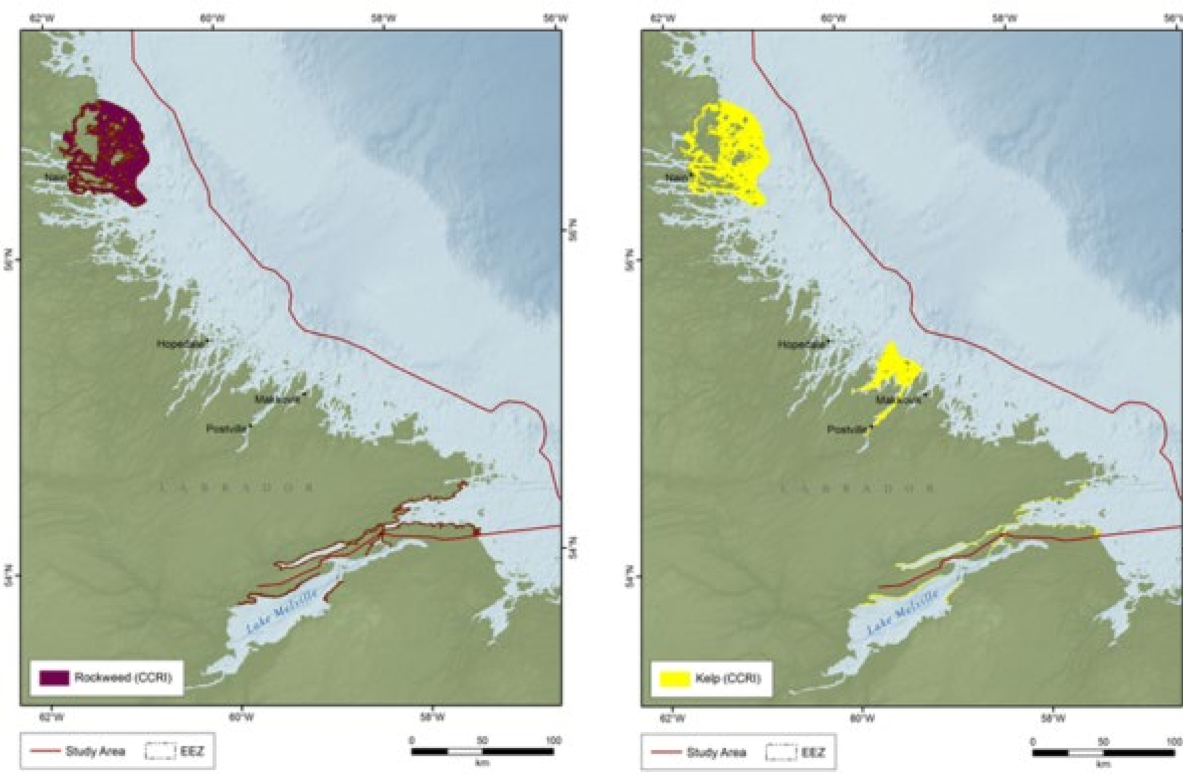


Figure 6.3: Distribution of rockweed (left) and kelps (right) recorded in the CCRI (O'Brien et al. 1998).

Hooper and Whittick (1984) reported finding 141 species of benthic algae in an extensive scuba survey of sites in Kaipokok, Makkovik, and Big River Bays. These included 38 species of chlorophytes, 56 phaeophytes and 47 rhodophytes. Some of these were new reports for the area but all were known from sites previously surveyed in Newfoundland.

Using literature reports and scuba surveys of southern Labrador, Adey and Hayeck (2011) identify the macroalagal communities as part of the Subarctic Region that differs from more temperate communities in species distribution and dynamics. They report significant biomass of kelps on rocky substrates (Figure 6.3). In particular, *Saccharina longicruris* and *Saccharina latissima* can reach almost 5 kg wet weight/m^2 (Adey and Hayeck 2011). The subtidal macroalagal communities of this region are structured by their interactions with the common grazer, the Green Sea Urchin (*Strongylocentrotus droebachiensis)*. Three of the four most abundant seaweeds in mid-deep water (*Agarum clathratum, Desmarestia viridis*, and *Ptilota serrata*) are protected from grazing by secondary chemicals. The kelp *Alaria esculenta* often forms a monocultural canopy in the shallow subtidal zone, and it is the second-most abundant seaweed in the Subarctic. Sea urchins form aggregations that graze back the *Alaria* in spring and summer when wave action is moderate, but the wide *Alaria* zone is persistent on more exposed shores. Urchins also consume other common kelp (*Saccharina longicruris* and *Saccharina latissima*). Brown algae in deeper water tend to form a savanna: dense patches of seaweeds separated by areas of coralline/urchin barrens (Himmelman 1985). These barren zones support a rich invertebrate infauna. The crustose coralline algae in these barrens (Figure 6.1) have longevities of decades to centuries (Kamenos 2010) and can contribute significant primary production and calcium carbonate deposition (van der Heijden and Kamenos 2015).

Z. marina is the dominant seagrass of the Northwest Atlantic (Moore and Short 2006) and the only species reported for the coast of Labrador where its range extends along the entire coast and into Ungava Bay (Blok et al. 2018). The CCRI database identifies extensive areas of eelgrass around Groswater Bay (Figure 6.4, O'Brien et al. 1998, DFO 2007). Substrate and exposure are the primary determinant of eelgrass habitat (Rao et al. 2014). Maps of eelgrass habitat based on these attributes have been shown to correctly identify eelgrass meadows for Newfoundland and southern Labrador (Rao et al. 2014).

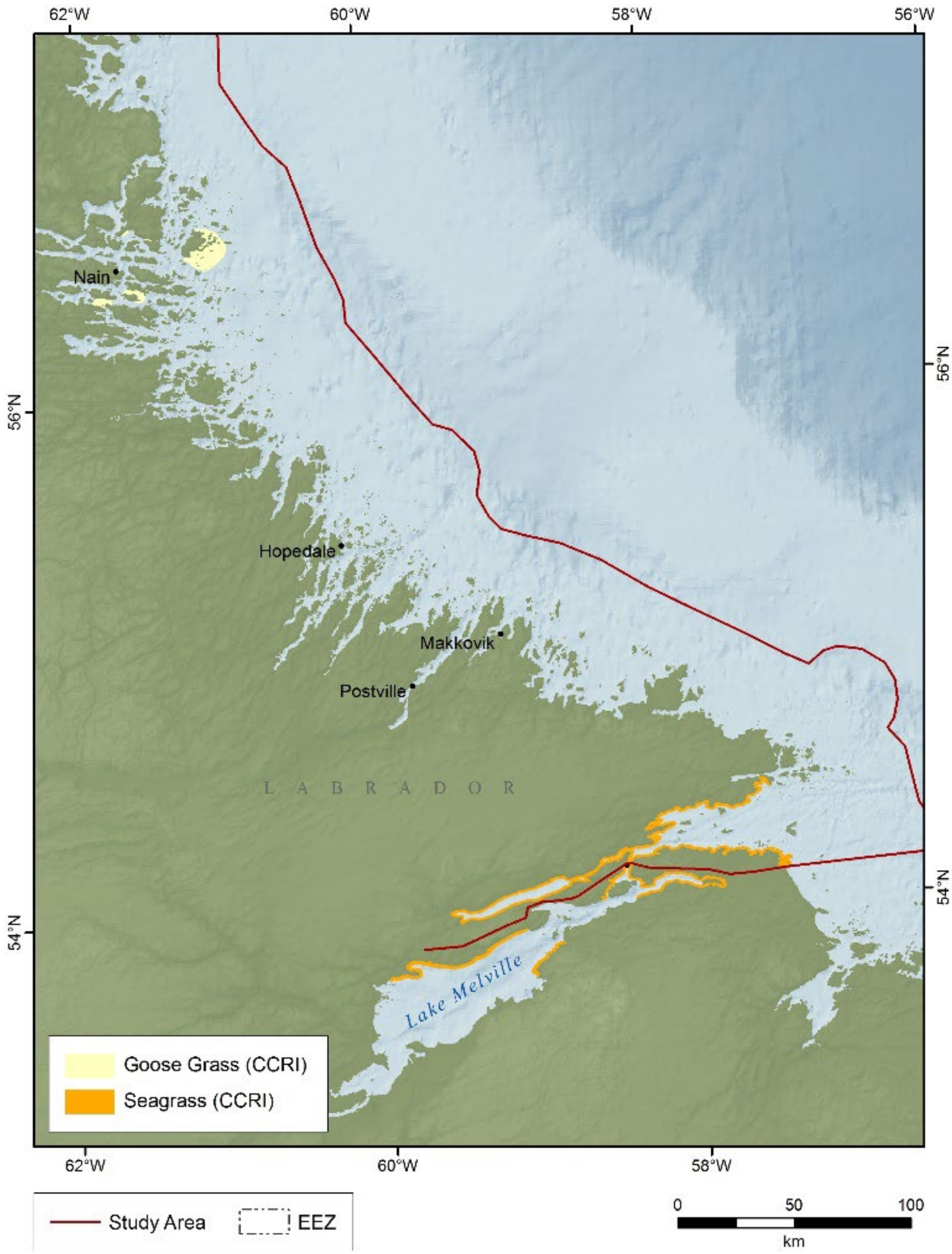


Figure 6.4: Eelgrass distribution from the CCRI database (O'Brien et al. 1998). Note that the local name goose grass refers to Lymus mollis, a coastal grass that grows in the supratidal (Table 6.1).

6.2. Sensitive Species and Habitats

Climate change has the potential to affect macrophytes in both positive and negative ways. Increases in temperature are predicted to spread the northward distribution of temperate kelp and rockweed species (Filbee-Dexter et al. 2019; Jueterbock et al. 2013; Müller et al. 2009) and to increase the production of eelgrass (Blok et al. 2018). Eelgrass meadows in Greenland are already showing a significant increase (over 6-fold between 1940 and the present) in productivity and carbon sequestration (Marbà et al. 2018).

While most plant species are somewhat resilient to changes in pH, some authors have proposed that coralline algae in the arctic may be particularly sensitive due to the long periods of darkness they experience. Hofmann et al. (2018) found however that coralline algae have strong biotic control over their calcium carbonate systems that protects them from pH extremes under normal winter darkness.

Several of the aquatic invasive species (AIS) that have been introduced to coastal insular Newfoundland have the potential to cause significant damage to macrophyte habitat. Similarly to indigenous temperate species, climate change may offer an opportunity for range expansion into the study area. Invasive Green Crab (*Carcinus maenas*) disturbs and destroys eelgrass meadows by uprooting the rhizomes and disturbing the sediments (DFO 2010a; Morris et al. 2011; Matheson et al. 2016). The northward spread of Green Crab may be limited by sea surface temperature (Jeffery et al. 2018) and risk assessment models indicate that invasion risk in Labrador is low, due to cold water temperatures (Therriault et al. 2008). However, cold-tolerant hybridized Green Crab populations have since been confirmed in Newfoundland waters (Best et al. 2017) and larvae may be transported in ballast water.

The lacy bryozoan (*Membranopora membranacea*) causes kelp senescence and die back when it over grows the fronds and weighs them down. This species is currently found on the south coast of Labrador and may be reaching the northern limits of its potential spread due to temperature limitations on recruitment (Caines and Gagnon 2012).

Presence of the invasive Coffin Box bryozoan has been confirmed in southern Labrador. Coffin Box may be transported great distances by currents and/or by bio-fouled vessels. This species is temperature limited, and the invaded range of Coffin Box does not appear to extend to the study area yet. Coffin Box colonize kelp, and may completely cover infected kelp blades, making the kelp rigid, increasing risk of blade breakage, and eventually killing the kelp (DFO 2011a).

While anthropogenic eutrophication is likely to be spatially limited within the study area due to the low human population density it may have local effects on aquatic vegetation. Eelgrass is sensitive to eutrophication which increases epiphyte density and reduces eelgrass competitive ability for light and nutrients. Eutrophication has been a serious problem for eelgrass in temperate estuaries (Moore and Short 2006). Increased nutrient loading can also cause changes in community composition and production of macroalage. Localized production of species associated with strongly “nitrogenous places” (communities, fish stages, and locations with high bird density) has been reported for some sites in the study area (Wilce 1959).

6.3. Data Gaps and Recommendations

With the exception of localized studies, maps of aquatic vegetation are very limited for coastal Labrador. Remote sensing techniques offer some promise of coarse scale mapping; however, there are significant limitations for mapping sparse or patchy vegetation at ecologically relevant scales. Gattuso et al. (2006) used SeaWiFS data to quantify the amount of irradiance available to benthic macrophytes in the coastal zone and from this calculated potential primary production on a worldwide scale, however this approach is very broad scale and subject to the limitations of adequate bathymetry and spectral characterization of nearshore waters. Harvey et al. (2018) reviewed the potential for remote sensing of coastal vegetation in Denmark and concluded that, while new possibilities are emerging for interpretation of satellite imagery, these are still limited by interference from water colour in the coastal zone and by water depth. Aerial photography and drone photography which show potential for mapping seagrass meadows at small scales still require groundtruthing (Harvey et al. 2018). The kelp signature seen in the raw data of multibeam acoustic surveys is currently cleaned out of the nearshore data used for bathymetric mapping (A. Roy, pers. comm.); however, this untapped data source may offer an opportunity to develop initial maps of kelp forest distribution on the coast.

Habitat mapping approaches using attributes of substrate fetch and exposure can provide preliminary identification of suitable habitats for eelgrass and macroalgae (Rao et al. 2014); however, groundtruthing is also required for this approach. Scientific surveys could be supplemented by local knowledge and by reports from fishers and other observers in the coastal zone.

Since macroalgae and eelgrass are sensitive to a number of anthropogenic disturbances, long term monitoring sites along the coast would provide information on community changes due to climate change and early warning of the northward spread of AIS into the study area. These monitoring sites could also be used to quantify the contribution of macrophytes on the Labrador coast to Blue Carbon uptake and sequestration.

Local use of macrophytes in Labrador has not been documented and opportunities for artisanal or commercial exploitation have not been studied (Table 6.1).

7. Benthic Communities

Macrobenthic fauna play a key role in ecosystem processes and marine food webs in the study area. Benthic invertebrates are important food sources for species occupying higher trophic levels in Arctic ecosystems (e.g., Brower et al. 2017; Young et al. 2017) and are frequently harvested by Labrador Inuit. While benthic species as a component of Labrador Inuit diets has not been quantified, they form an important aspect of Inuit harvesting practices and contribute to food security in Inuit communities. It is likely that sensitivities of benthic species to environmental changes and impacts on ecosystem processes, Arctic food webs, and Inuit food security associated with changes in benthic communities, will continue to emerge as these ecological communities are studied in more depth. This chapter addresses data on a range of macrobenthic invertebrate fauna in the study area across a range of taxa but does not cover coral and sponge communities, which are discussed in Section 8.

7.1. Available Information

Limited information has been collected on benthic communities in the study area; most studies have focused on regions farther offshore on the continental shelf and slope. Challenges related to the nature of research in the study area (e.g., cost, seasonal restrictions, weather constraints) require consideration in order to sustain ongoing research and produce long-term datasets. Most available information on benthic communities comes primarily from Local Knowledge collected by the Nunatsiavut Government (2018) and Brice-Bennett (1977), records collected by DFO RV survey, the Integrated Regional Impact Study (IRIS) (Allard and Lemay 2012), the Strategic Environmental Assessment Labrador Shelf Offshore Area (Sikumiut Environmental Management Ltd. 2008), a number of research studies (e.g. Gagnon and Haedrich 1991; Stewart et al. 1985), and a large database compiled by Stewart et al. (2001). Some additional information was compiled in the Labrador Sea Frontier Area Canadian Science Advisory Secretariat (CSAS) research document (Coté et al. 2019). One of the main challenges in reviewing information on benthic communities in the study area is the lack of recent data. The primary studies that established most of the baseline information on benthic communities in the study area are decades old and have not been sufficiently updated.

Despite the relative lack of comprehensive and recent data, the study area is rich with benthic life and these species play an important role in the food web of the study area. Much of the study area is characterized by a complex coastline made up of fjords and fjards, and shelf/slope benthic habitats that reach a maximum depth of 755 m out to the seaward extent of the study area (~22.2 km from land). The density and biomass of benthic species are impacted by a number of environmental features, such as depth, ice scour, riverine input, and location relative to shore and latitude (Sikumiut Environmental Management Ltd. 2008). Given the prevalent ice found in the study area, the habitat classification and characteristics of five Arctic benthic distributional zones (Carey 1991; Table 7.1) is likely applicable to much of the study area.

Table 7.1: Distributional zones of the benthic environment in the Arctic from Carey (1991).

Zone	Depth Range (m)	Characteristics
Nearshore zone	0–2	Annually depopulated by freezing and ice scour
Inshore zone	2–20	Strongly influenced by riverine and runoff inputs
Transitional zone	15–30	Subject to intense scouring by ice keels
Continental shelf	30–100	Biomass is higher at the shelf edge
Upper slopes[1]	>100	Biomass begins to decrease

[1]The continental shelf extends to deeper water (~250–300 m) in the study area than reported in Carey (1991) for the Arctic.

Labrador Inuit have used marine invertebrates as a food source for many generations. Archaeological studies have found evidence of Blue Mussels (*Mytilus edulis*) and Soft-Shell Clams (*Mya arenaria*) in Inuit settlements (Brice-Bennett 1977). Qualitative and spatial data gathered by the Nunatsiavut Government as part of its Imappivut knowledge collection study included semi-structured interviews (n=45) and Direct to Digital participatory mapping methodologies (Olson et al. 2016). Interview participants documented harvest locations for a variety of benthic invertebrate species as important wild food sources, including scallops (*Chlamys islandica*), sea snails (*Tachyrhynchus erosus*) (referred to locally as whelks or wrinkles), mussels, clams, and Green Sea Urchins. Interview participants described collecting benthic species while visiting cabin locations and as part of other fishing activities, particularly in spring, summer, and fall (Figure 7.1). Brice-Bennett (1977) described Inuit use of invertebrate species throughout Labrador including clams, snails, mussels, and sea urchins. Bivalves are particularly common as a food source for Inuit and are commonly distributed across inner shelf regions at depths ranging from 5–25 m (Carey 1991; Nunatsiavut Government 2018). Brice-Bennett (1977) noted that in the Nain and Hopedale regions in spring, “Along shallow, rocky shores on coastal islands or in the bays, clams and mussels were gathered at low tide” (p. 128). In addition to species utilized as wild food by Inuit, Table 7.2 presents a list of benthic species documented in both the study area and beyond the continental shelf (Sikumiut Environmental Management Ltd. 2008).

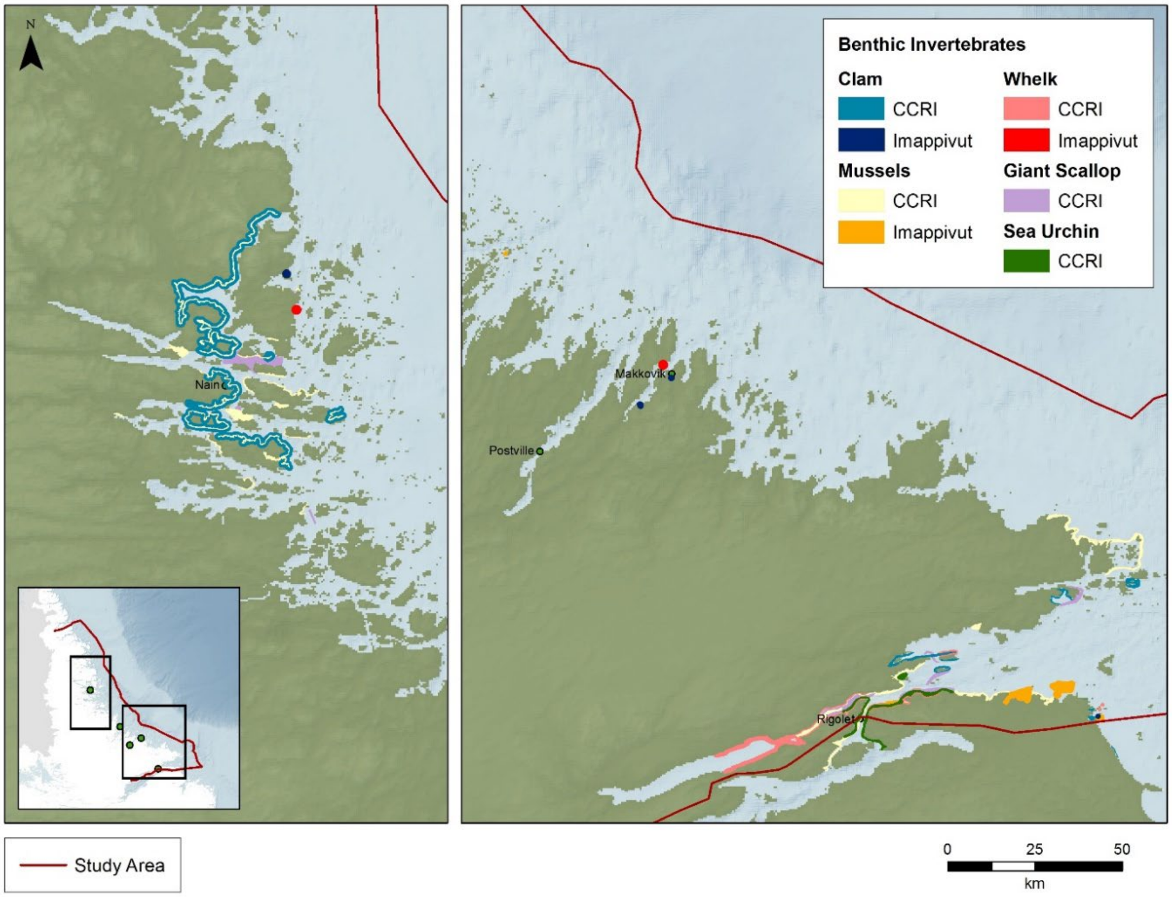


Figure 7.1: A sample of benthic invertebrate harvest locations identified by Labrador Inuit through local knowledge studies.

Table 7.2: List of macrobenthic invertebrate species in Labrador compiled by previous studies (Sikumiut Environmental Management Ltd. 2008).

Taxa	Species	Common Names (If Applicable)
Bivalves	*Tachyrhynchus erosus*	Eroded turretsnail, whelk, wrinkle, siutiguk
	Macoma calcarea	Clam
	Macoma loveni	Clam
	Turtonia minuta	-
	Serripes groenlandicus	Greenland cockle
	Mytilus edulis	Blue mussel, uviluk
	Hiatella arctica	Wrinkled rock-borer, clam
	*Limecola balthica**	Baltic clam

Taxa	Species	Common Names (If Applicable)
	Mya arenaria	Soft-shell clam, ammomajuk
	Ennucula delphinodonta	-
	Astarte borealis	Northern astarte
	Portlandia arctica	-
	Chlamys islandica	Icelandic scallop, matsojak
Polychaetes	*Rhodine gracilior*	-
	Maldane sarsi	Bambooworm
	Chaetozone setosa	-
	*Nothria conchylega**	-
	Scoloplos armiger	-
	Nephtys longosetosa	Catworm
	Ampharete arctica	-
	Prionospio steenstrupi	-
	*Cistenides granulata**	-
	Nephtys caeca	Catworm
Echinoderms	*Ophiura robusta*	-
	Stegophiura stuwitzi	-
	Strongylocentrotus droebachiensis	Sea urchin, itik
Crustaceans	*Unciola leucopis*	Crayfish
	Hyas araneus	Great spider crab
	Ampelisca eschrichtii	Crayfish
	Diastylis rathkei	-
	*Byblis gaimardii**	-
	*Semibalanus balanoides**	Barnacle
	Pandalus borealis	Northern shrimp, kinguppak

Taxa	Species	Common Names (If Applicable)
	Pandalus montagui	Striped shrimp, kinguppak
	Chionoecetes opilio	Snow Crab, putjoti

*Updated species names to reflect taxonomic changes since data used by the Strategic Environmental Assessment Labrador Shelf Offshore Area (Sikumiut Environmental Management Ltd. 2008).

Allard and Lemay (2012) report on data collected as part of the IRIS that conducted seafloor mapping using multibeam sonar techniques to interpolate habitat maps to estimate information about benthic communities in Nunatsiavut. Sampling took place in Nachvak Fjord, Saglek Fjord, and Okak Bay at depths ranging from 7–210 m (Allard and Lemay 2012). Okak Bay is within the study area and could be a starting point to help provide an indication of benthic community structure and habitat in other fjord areas. As an example of the results generated through these methods, Figure 7.2 shows an overview of benthic sampling locations and a multibeam bathymetric map in Okak Bay, with depths ranging from 5–200 m. Figure 7.3 shows a habitat map for Okak Bay generated through multibeam bathymetric studies. The results from Okak Bay reveal that its physiology and biology differ from the northern fjords (Nachvak and Saglek). As a fjard, Okak Bay is characterized as a generally shallow, low elevation estuary. Okak Bay contains flat sandy areas near freshwater inputs and coarse substrates on both sills and shallow basin features, which is a notable difference from more typical fjord systems which generally contain deep muddy basins. Benthic species assemblages found throughout the study areas were consistent and tended to show increasing biodiversity near the mouths of the fjords and fjards as salinity increased (Allard and Lemay 2012). Species found in the study areas included juvenile bivalve species on the sandy seafloor at the heads of all the arms, such as *Astarte borealis*, *Macoma calcarea*, *Ennucula delphinodonta*, and *Portlandia arctica*. Shallow areas of muddy substrates were associated with *Macoma calcarea, Cistenides granulata,* and *Maldane sarsi* (Allard and Lemay 2012).

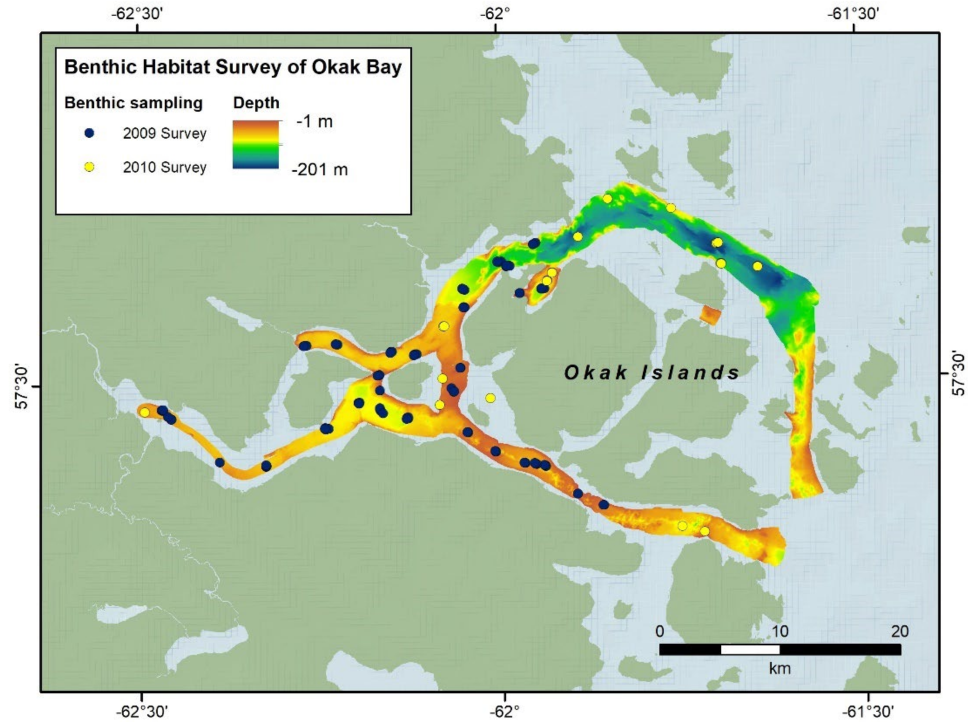


Figure 7.2: Multibeam bathymetric map of Okak Bay with benthic sampling stations (Allard and Lemay 2012).

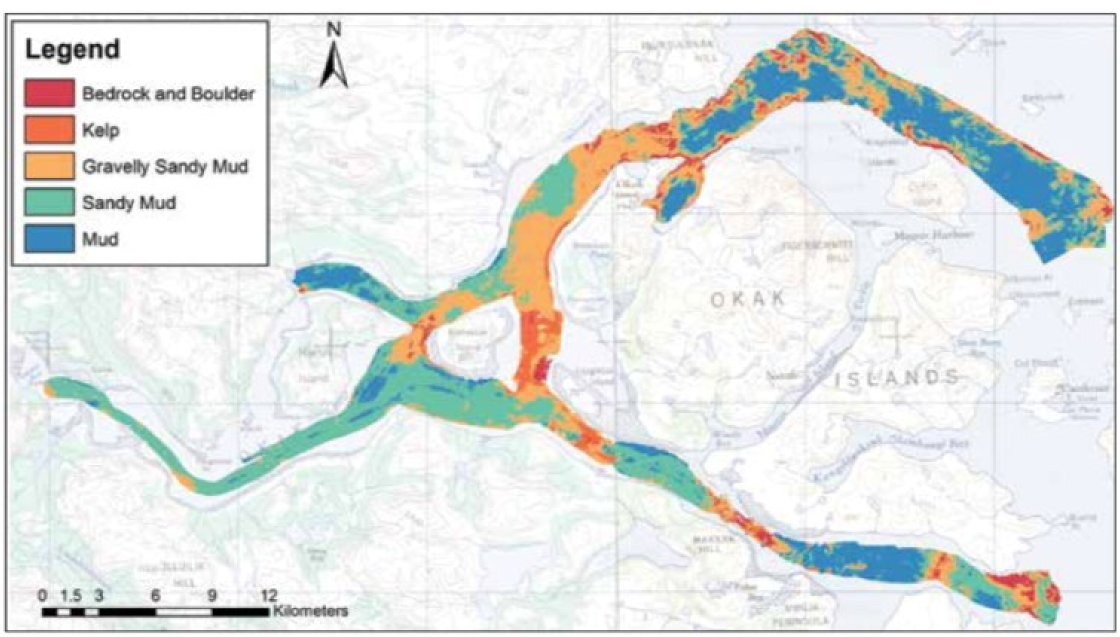


Figure 7.3: Habitat map of Okak Bay with habitat types distinguished on the basis of substrate type (bedrock and boulder, kelp, gravelly sand, gravelly mud, sand, sandy mud, and mud), benthic assemblage, backscatter and depth (Allard and Lemay 2012).

A range of biomass values have been documented for benthic macrofaunal invertebrates at coastal sites and on the shelf and slope regions of Labrador, though not all sampling locations of previous studies have been within the current study area. Barrie et al. (1980) collected baseline biological data in shallow nearshore benthic habitats and the littoral zone. Two of their four sites were located near Makkovik (Figure 7.4) and were selected based on wave exposure. The protected site had an exposure index of 1, while the exposed site had an exposure index of 6 (Barrie et al. 1980). Each site was a 1 km length of coastline that was sampled using grab, diver-operated airlift, and intertidal techniques from the estimated high water mark to the 50 m depth contour (Barrie et al. 1980). The mean biomass of benthic fauna ranged from 74.1 ± 64.6 g/m^2 to 470.6 ± 631.8 g/m^2 at the protected site and 40.8 ± 44.8 g/m^2 to 2,577.0 ± 2,825.9 g/m^2 at the exposed site (Table 7.3). When compared to other areas in North America, the mean biomass found at the Barrie et al. (1980) sites was high (Table 7.4). Gagnon and Haedrich (1991) report on data collected on a study of benthic polychaetes in the continental shelf and upper slope region at depths of 85–622 m and found a biomass range of 0.06–2,274.11 g/m^2 (Figure 7.4).

Table 7.3: Depth comparisons of mean biomass (g/m^2) of benthic fauna collected by airlift and grab at two sites in Makkovik Bay, Labrador during August and September 1979 (reproduced from Barrie et al. 1980).

Site	Variable	Depth Range (m)		
		2–5	**10–15**	**30–50**
Makkovik Bay, protected site	Substrate	Fine sand	Fine sand	Fine sand
	Mean biomass	470.6	88.8	74.1
	±S.D.	631.8	136.3	64.6
	Sample Size	15	18	11
Makkovik Bay, exposed site	Substrate	Bedrock	Cobble	Fine sand
	Mean biomass	2,577.0	1,486.1	40.8
	±S.D.	2,825.9	1,758.2	44.9
	Sample Size	8	11	8

Table 7.4: Comparison of mean biomass (g/m^2) of benthic fauna from Labrador and other areas in North America. Only depths 50 m and shallower are considered (reproduced from Barrie et al. 1980).

Location	Sample Size	Mean Biomass (g/m^2)	± S.D.	Source
Arctic Islands	71	212	212	Buchanan et al. 1977 Barrie et al 1980
Eastern High Arctic	81	231	353	Barrie et al 1980
West Greenland	29	374	D.U.	Vibe 1939

Location	Sample Size	Mean Biomass (g/m^2)	± S.D.	Source
Labrador	140	1,044	1,952	Barrie et al. 1980
Epifauna	35	2,390	2,285	Barrie et al. 1980
Infauna	105	504	941	Barrie et al. 1980
Grand Banks	5	1,455	D.U.	Nesis 1963
New Brunswick Estuaries	70	2–192	D.U.	Wildish and Kristmanson 1979

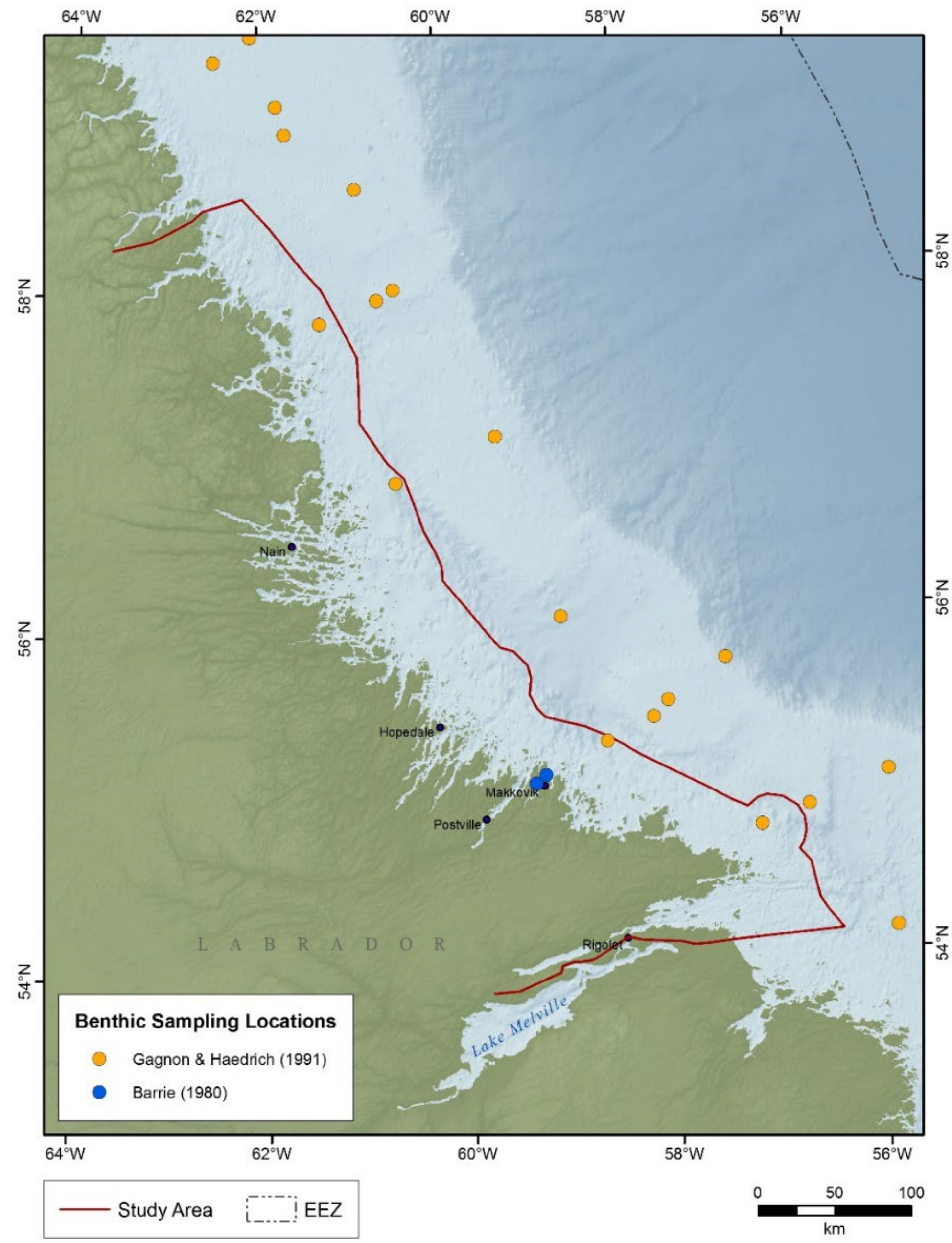


Figure 7.4: Locations of macrobenthic sampling stations on the Labrador coast and continental shelf used in Barrie et al. (1980) and Gagnon and Haedrich (1991).

DFO RV surveys are largely restricted to the seaward extent of the study area but have collected rich multispecies data since 1995 that includes information on benthic invertebrates. Much of the invertebrate data is still being cleaned and processed; however, a variety of taxa (e.g., echinoderms, decapods, and deep-water bivalve species) have been recorded along the Labrador shelf and slope. Quantitative RV survey data for commercially important taxa such as shrimp (*Pandalus* spp., Figure 7.5) and crab (*Chionoecetes opilio*, Figure 7.6) are available and provide an indication that these taxa can have patchy, heterogeneous distributions in offshore environments and that invertebrate species distributions may not necessarily extend across the full latitudinal extent of the study area. Such patterns suggest that oceanographic features and habitat play an important role in their distribution within the study area as has been found in other parts of the northwest Atlantic (Mullowney et al. 2012, 2017, 2018; Koeller 2000). Specifically, the most productive Snow Crab areas are found in shallow, cold waters so crab are only found in pockets in NAFO Division 2J and are not known to commonly occur north of 56 degrees latitude (Mullowney et al. 2017, 2018). With respect to shrimp, caution should be exercised when interpreting this species' distributions north of NAFO Division 2J (i.e., in NAFO Divisions 2GH; Figure 7.5), as the number of survey sets completed in these areas is much lower than in areas south (Rideout and Ings 2018). In fact, shrimp populations in more northern areas (i.e., shrimp fishing areas 4 and 5, which overlap with the study area) are doing much better than those further south (DFO 2018b).

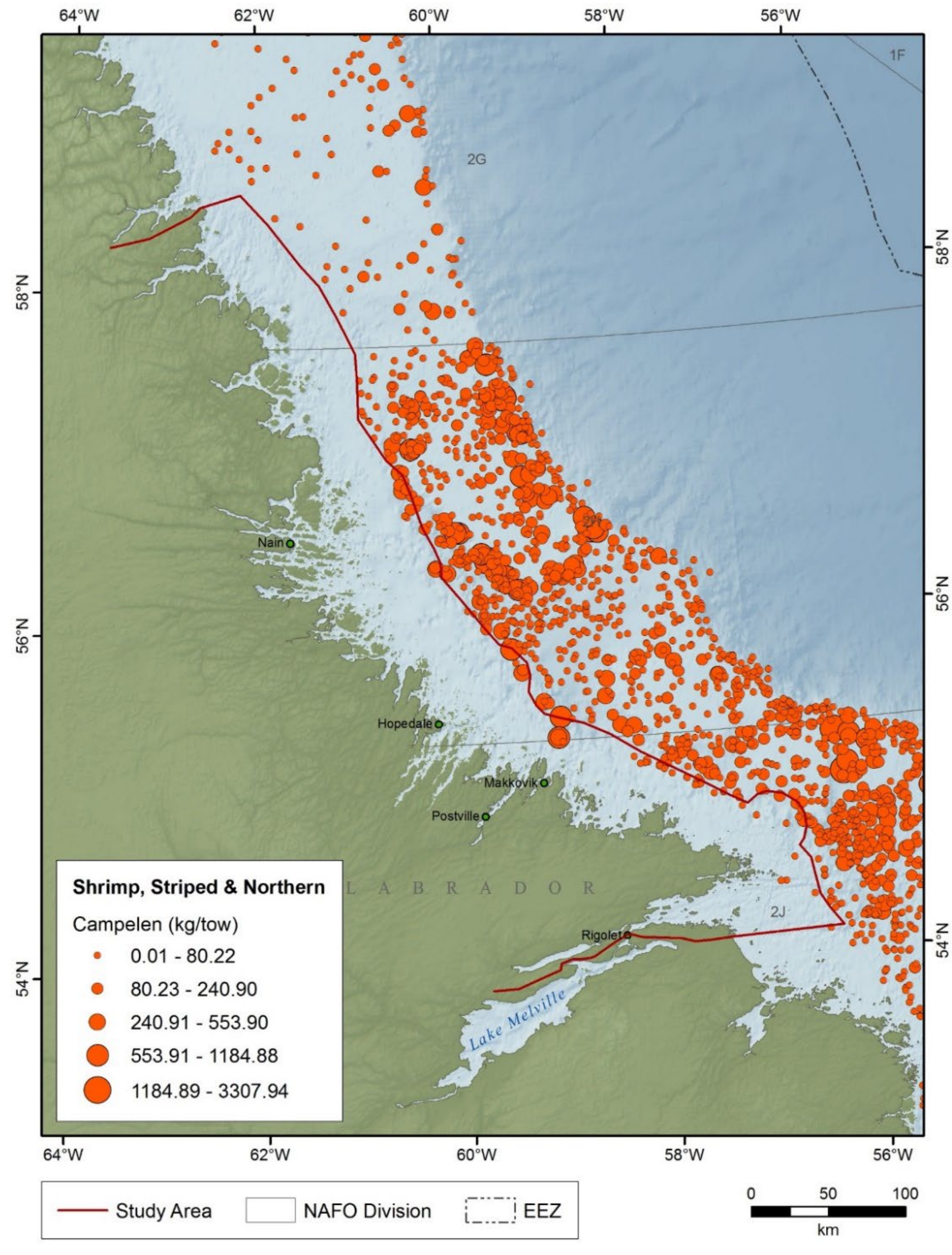


Figure 7.5: Data on total catch (kg/tow) for striped and northern shrimp from a Campelen trawl collected during DFO RV surveys (1996–2017).

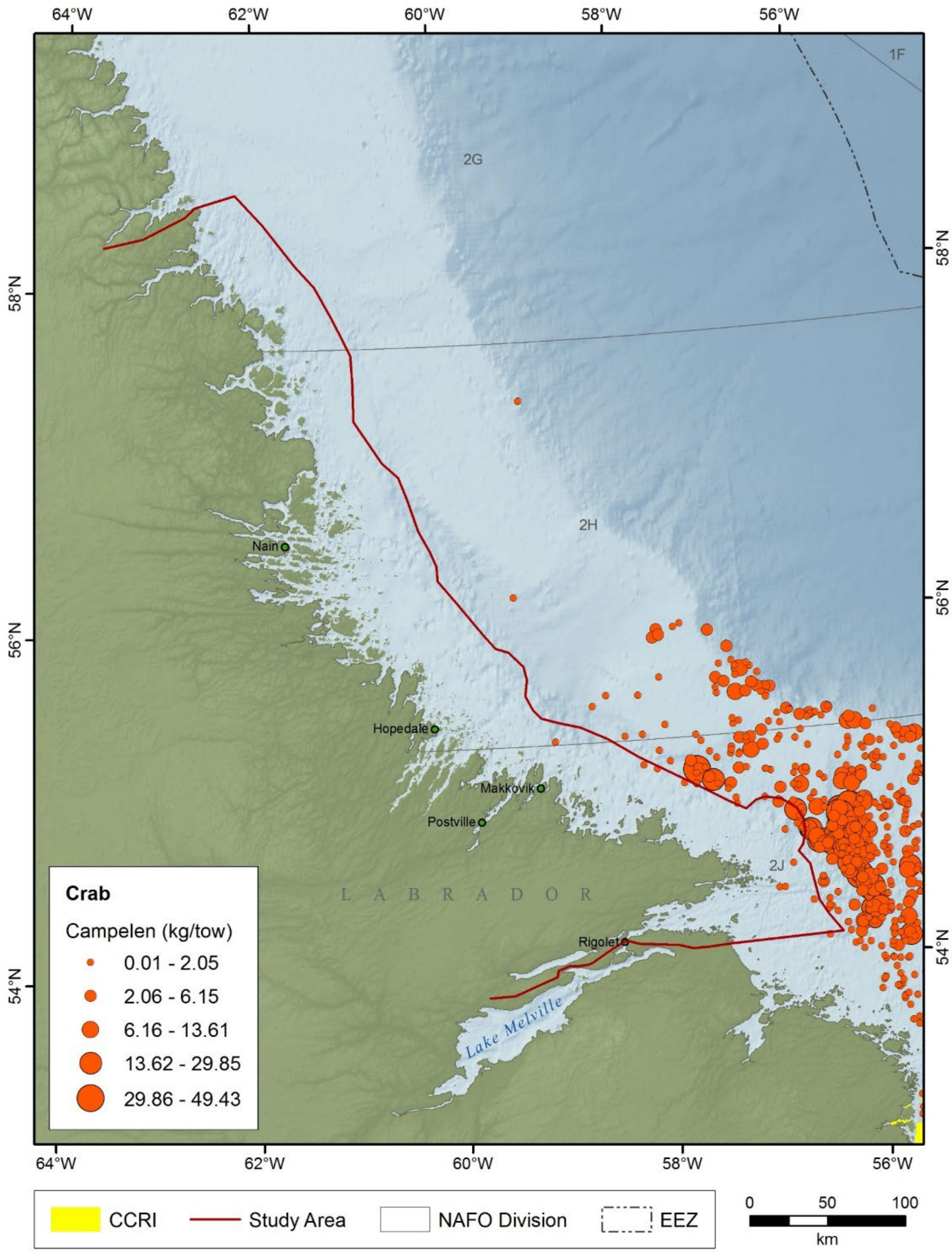


Figure 7.6: Data on total catch (kg/tow) for crab from a Campelen trawl collected during DFO RV surveys (1996–2017).

7.2. Sensitive Species and Habitats

The lack of extensive and recent data on the benthic community in the study area makes it difficult to identify potential sensitivities among species and their habitats. Coté et al. (2019) note that benthic species, in particular echinoderms, are likely to be key components of deep-sea ecosystems. Recent research conducted on echinoderms on the Scotian Shelf, including many of the same species found in the study area, indicates that these species dominate biomass in shallower marine ecosystems (Rosellon-Druker and Stokesbury 2019).

Studies in other Arctic regions have noted the reductions in ice algal contributions to primary production systems associated with climate change-mediated sea ice loss and questions remain about the potential impacts of these changes on benthic communities and diets (e.g. Mäkelä et al. 2017a, 2017b). Other studies have noted the potential negative impacts of increasing water temperatures on benthic communities in Arctic fjord ecosystems (Drewnik et al. 2017). Rising water temperatures and increased vessel traffic could improve colonization conditions for invasive species such as Green Crab.

Data collected from multispecies trawl surveys and other indices (e.g. fisheries logbook data, at-sea observers, vessel monitoring systems, the dockside monitoring program, and inshore and offshore trap surveys) have demonstrated fluctuations in Snow Crab populations over the past four decades (Mullowney et al. 2018). Since 2013, Snow Crab biomass has declined to its lowest observed level. While much of this data is focused outside the study area, declines in Snow Crab populations in particular areas may contribute to increased and more concentrated pressure on the resource in other areas, including potentially within the study area.

7.3. Data Gaps and Recommendations

The lack of recent benthic sampling efforts and targeted research on benthic species in the study area is the principal data gap. Research in the study area is difficult due to logistics challenges and environmental limitations as a result of seasonal ice cover in the study area. On a global level, there are efforts to better understand benthic assemblages in Arctic regions and identify the factors that contribute to their abundance and distribution. Additional studies to define community structures at various depth profiles will contribute to a better understanding of the ecological role of benthic species in the study area. It will also be important to continue to understand the likely impacts of climate change on benthic communities and the subsequent effects on other marine species. While studies in other regions, Arctic and otherwise, provide useful indicators of potential trends and community structures, focused research in the study area will be critical to understanding habitat characteristics and better defining the community composition.

At a species level, a more rigorous understanding of the particular species that comprise the benthic community in the study area will be critical to identifying potential sensitivities and future threats and developing appropriate conservation and other management measures (Gale et al. 2015). Coté et al. (2019) also recommend data collection efforts work to better understand species life history characteristics and basic ecology, including reproductive and feeding ecology. Understanding species characteristics is also necessary to develop a wider understanding of the study area’s ecosystem characteristics and functions (Coté et al. 2019).

The use of mixed methods research could generate unique possibilities to combine spatial data collected from Inuit resource users with scientific data (e.g., RV survey, bathymetric and habitat mapping) to develop a more rigorous picture of the benthic community, distribution, and biomass throughout the study area. Collection of additional qualitative and spatial data on Inuit use of benthic species to better understand the cultural and food security importance of these species is a priority. In addition, analysis of invertebrate data collected through DFO RV surveys should be prioritized and pursued. The combination of LK and RV survey data will provide an enhanced overview of the spatial distribution of benthic species throughout the study area. Additional bathymetric studies and habitat mapping throughout the study area would deepen understandings of benthic community distribution based on previous knowledge of depth and habitat preferences identified in Nachvak Fjord, Saglek Fjord, and Okak Bay by Allard and Lemay (2012). To date, invertebrate data (primarily LK) has been concentrated in coastal areas near communities and in the north of the study area (Allard and Lemay 2012), as well as along the seaward extent of the study area (RV surveys). Since it is known that species distributions will change along latitudinal gradients and across depth zones, additional efforts should be expanded to represent habitats intermediate to the coast and the RV surveys as well as coastal inshore surveys in the southern parts of the study area. Future analyses of RV datasets, which include non-commercial species, are expected to greatly increase understanding of benthic communities (i.e., diversity, habitat associations) along the outer parts of the study area.

8. Corals, Sponges and Bryozoans

Corals, sponges, and bryozoans are habitat-forming sessile benthic organisms (Probert et al. 1979; Krieger and Wing 2002). Their presence is important because of the habitats they create, modify, and maintain at various spatial scales. For instance, gorgonian corals resemble trees and can provide macro-habitats between the colonies, micro-habitats between the branches, and even nano-habitats within the tissue of the coral.

The functional roles that sessile megafauna play in benthic ecosystems have been well documented (Bell 2008; Buhl-Mortensen et al. 2010; Baillon et al. 2014) including; protection from predators (Wulff 2006), shelter from bottom currents (Zedel and Fowler 2009), forage areas (Buhl-Mortensen and Mortensen 2005; Neves et al. 2018), nurseries for young (Aldrich and Lu 1967; Mercer 1968; Baillon et al. 2012; Wareham-Hayes et al. 2017; Neves et al. 2018) and a source of food for other animals (e.g., Gale et al. 2013). Coral and sponge habitats are associated with elevated biodiversity (Cerrano et al. 2010; Hogg et al. 2010; Kenchington et al. 2013; Neves et al. 2018; Miatta and Snelgrove 2018). However, these valuable attributes (i.e., complex structure and associated fragility) also make them vulnerable to anthropogenic disturbances (Watling and Norse 1998; Fosså et al. 2002; Hall-Spencer et al. 2002; Thrush and Dayton 2002; Anderson and Clark 2003; Wareham-Hayes and Edinger 2007).

DFO has been documenting and mapping the occurrences of corals, sponges, and bryozoans since 2002 (Wareham-Hayes and Edinger 2007). The following is a general overview of the current information available on these groups within the study area. Other benthic invertebrates are addressed in Section 7 above.

8.1. Available Information

8.1.1. DFO RV Multispecies and Other Fisheries Surveys

Corals and sponges have been documented throughout the Northwest Atlantic, including the Labrador Shelf, with the majority of available data derived from scientific research surveys. Records are also available from sources such as the Fisheries Observer Program (FOP), museum records, and voluntary fisher reports. Additional survey data in the LISA Zone, collected during exploratory crab (2009, 2010, and 2013) and Greenland Halibut (2012) surveys, have been provided by the Torngat Wildlife, Plants and Fisheries Secretariat (Figure 8.1).

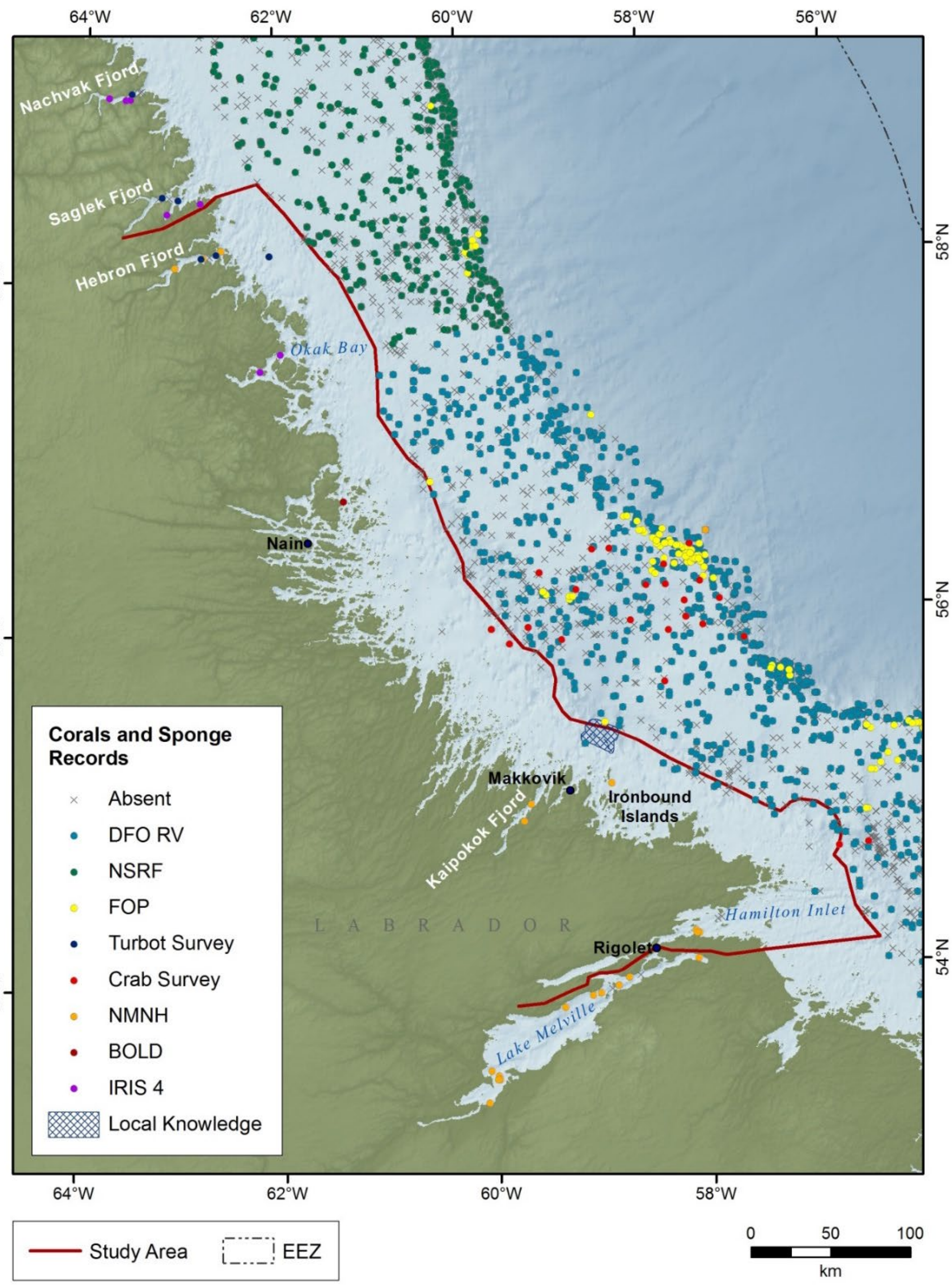


Figure 8.1: Records of corals and sponges from all sources, including; research surveys (DFO, NSRF, Greenland Halibut and Crab Surveys, ArcticNet Integrated Regional Impact Study-IRIS 4), Fisheries Observer Program (FOP), museum collections (NMNH, BOLD), and local knowledge.

These records indicate the presence of soft corals, gorgonians (small and large), sea pens, stony corals, black corals, and sponges in the Labrador Shelf region, ranging between depths of 34–1,495 m (Figure 8.2).

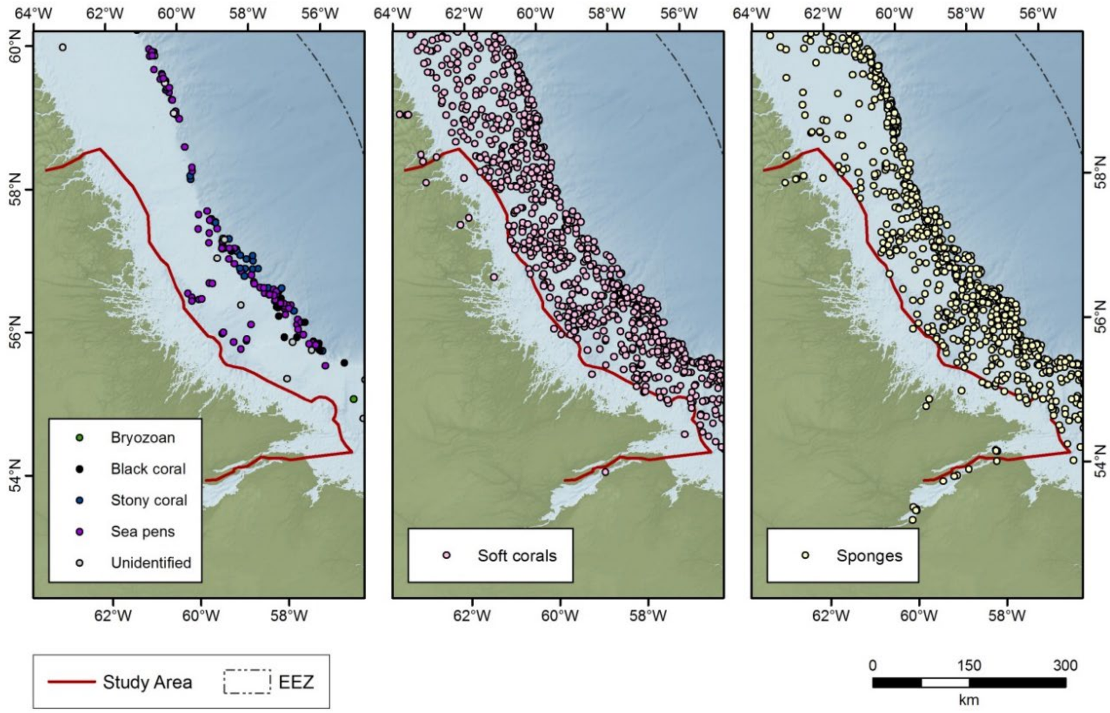


Figure 8.2: Benthic megafauna by groups; left panel: bryozoans, black coral (Order Anthipatharia), stony coral (Order Scleractinia), sea pens (Order Pennatulacea), and coral unidentified; middle panel: soft corals (Order Alcyonacea); right panel: sponges (Phylum Porifera).

Surveys from the Northern Shrimp Research Foundation (NSRF; comprised of offshore License holders with scientific guidance from DFO), cover northern portions of the Labrador Shelf (NAFO Division 2G) to a maximum depth of 750 m. Both NSRF and DFO RV survey stations are randomly selected and stratified by depth; however, they are biased by substrate (i.e., trawlable bottoms).

Records inside the study area are limited, as DFO/NSRF surveys are rarely conducted near the coast. DFO-NL RV database (2005–17) includes ten stations with occurrences of soft corals inside the boundaries of the study area in the Labrador Marginal Trough between Makkovik Bank and Harrison Bank (132–332 m, Figure 8.1 and Figure 8.2). The Marginal Trough separates the inner and outer parts of the Labrador Shelf and depths can reach up to 800 m locally but typically are limited to 300 m (Sikumiut Environmental Management Ltd. 2008). Corals recorded in this area include the soft corals *Gersemia* sp., *Drifa* sp., and other unidentified soft coral species, and included specimens associated with juvenile basket stars (*Gorgonocephalus* sp.), which have been shown to use soft corals as nurseries (Neves et al. 2018). DFO-NL RV surveys include 12 stations containing sponge records also in the Labrador Marginal Trough between Makkovik Bank and Harrison Bank (122–468 m, Figure 8.1 and Figure 8.2). One particular set recovered 5 kg of sponges. DFO historic survey data (1939–96), using a variety of gear types, also documented the presence of sea pens and sponges in the Labrador area adjacent to the study area (Wareham-Hayes, unpublished data).

8.1.2. Other Scientific Surveys

Additional fishery exploratory surveys were conducted by the Torngat Wildlife, Plants and Fisheries secretariat in the LISA Zone including Crab (2009–10, and 2013) and Greenland Halibut (2012) exploratory surveys.

The Crab Exploratory surveys yielded soft coral and sponge records from two stations inside the study area (2009) with one station noting many basket stars attached to the corals. The 2010 and 2013 Crab surveys also included stations inside the study area. The 2010 (n=45) and 2013 (n=4) stations were located in the southern inside portion of Nain Bank and Harrison Bank, respectively. Soft corals (one station) and sponges (two stations) were found in the 2013 survey at stations adjacent to the study area (see Whalen et al. 2013, page 44). Results from the 2010 survey are still pending.

The Greenland Halibut Exploratory survey, using gillnets and longlines, documented specimens of a small gorgonian and a soft coral in Hebron Fjord (also the basket star *Gorgonocephalus* sp.), *Acanella arbuscula* (a small bamboo coral) in Nachvak Fjord, and another soft coral (*Gersemia* cf. *fruticosa*) in Saglek Fjord (just north of the study area). Sponges were also found in the Saglek and Hebron Fjords during these surveys (Figure 8.1 and Figure 8.2).

8.1.3. Museum Records, Local Ecological Knowledge, and Other Databases

Examination of museum collections (e.g., Smithsonian National Museum of Natural History [NMNH] 2018) and other online databases (e.g., Barcode of Life Data System [BOLD] 2018) yielded records of the soft coral *Gersemia fruticosa* for the Hebron Fjord, collected at 91 m (National Museum of Natural History, NMNH collections, 1949 Labrador Expedition) and for the South Alutasivik Island area (SCUBA dive depths, BOLD). Examination of the NMNH collection database also yielded records of sponges collected during the 1949 Labrador Expedition, including the Hebron Fjord (3 stations, 91–225 m), Kaipokok Inlet (two stations, 82 m), Kidlialiut Island (Ironbound Harbor, SW End Kidlialiut Island, 7–13 m), and Hamilton Inlet (37, 82, and 88 m, Figure 8.1 and Figure 8.2).

Other information such as Fisher's Ecological Knowledge (FEK) is important for filling knowledge gaps in under-studied areas like the Coastal Labrador Sea and can provide knowledge on biological and ecological aspects of these areas (Johannes 1981; Johannes et al. 2000).

For example, Mr. Wilfred Bartlett, a retired gillnet fisherman who fished the Labrador Coast off Makkovik in the 1970s-80s, encountered many invertebrates as bycatch throughout his career (Figure 8.3). Examples of bycatch included a 3 m tall *Paragorgia arborea* (aka rubber tree; Figure 8.4a), and several pieces of *Primnoa* cf. *resedaeformis* (Figure 8.4b). These large gorgonian corals along with a dead solitary stony coral, *Desmophyllum dianthus* (Figure 8.4e-f) and several species of bryozoans (Figure 8.4c-d), were captured separately in an area north of the Ironbound Islands (Figure 8.3). Mr. Bartlett would set his gillnets on top of topographical high points, starting at shallow depths, and ending downslope along vertical walls. The 'tree' corals were caught along the vertical walls and the bryozoan 'meadows' were caught on top. Exact positions and depths of the bycatch are unknown due to the nature of the gear and how it was set in the water. He generalizes the benthic communities he encountered stating "some areas you find miles and miles of bottom with bryozoans on it [on high points] … others are in deep pockets where rubber trees and hard corals were captured on vertical walls".

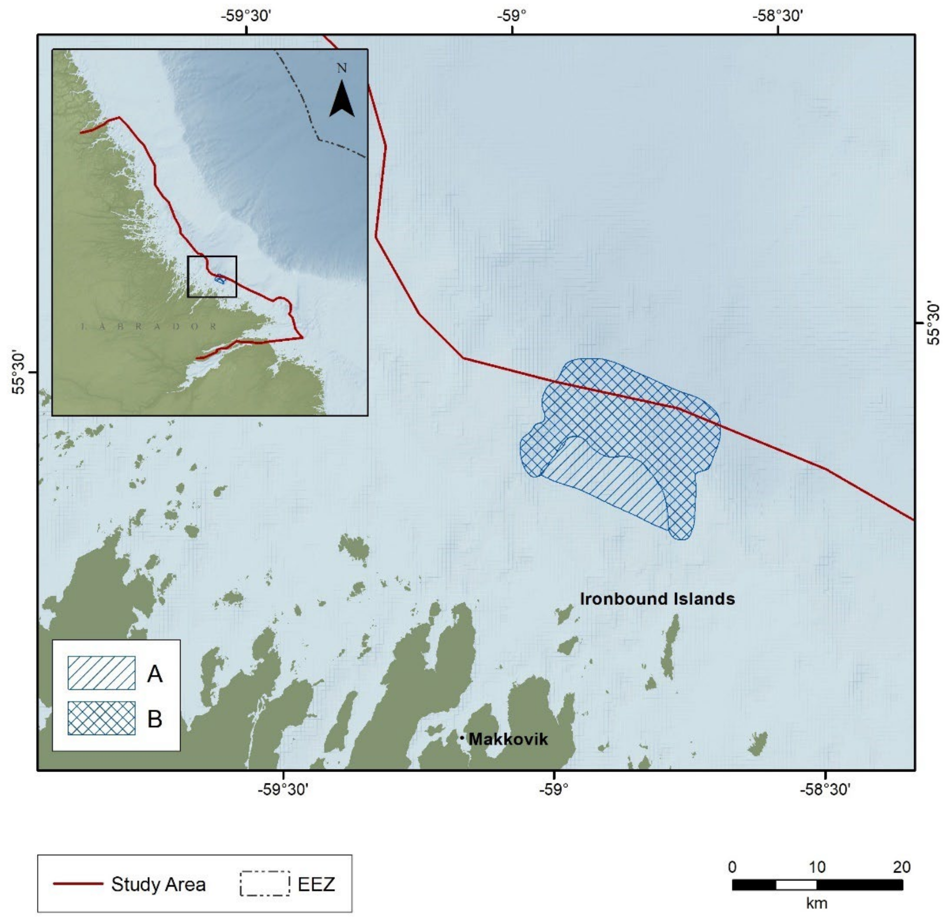


Figure 8.3: Generalized area where Mr. Bartlett encountered bycatch of corals (B) and bryozoans (A).

8.1.4. Predictive Modelling

Predictive modelling of coral suitability for the Labrador area by Gullage et al. (2017) covers only a small portion inside the study area. Yet, an area inside Makkovik Bank was shown to be particularly suitable for small and large gorgonians (Figure 8.5). Furthermore, the areas to the north of the study area, as well as the area near the Hopedale Saddle, and throughout the Labrador Marginal Trough (behind Harrison-Hamilton Banks) have high suitability for the soft coral *Gersemia*. The area adjacent to the majority of the coastal Labrador study area boundary is highly suitable for soft corals (*Nephtheidae* sp.) in general (Figure 8.5).

Bryozoans were not covered by Gullage et al. (2017); however, they have been modeled in order regions of the world (see Wood et al. 2013).

8.1.5. Reports

The IRIS surveyed four fjords in northern Labrador: Nachvak Fjord, Saglek Fjord, Okak Bay, and Anaktalak Bay (Figure 8.1). Brown et al. (2012) collected video data and used box-cores to sample substrate and biota, at depths ranging from 7–210 m. The IRIS document reported general results on the benthic macrofauna diversity and abundance in those fjords (e.g., bivalves and polychaete worms). Data on corals were not included, but will be published separately (Brown et al., pers. comm.).

Figure 8.4: Invertebrate samples from Mr. Wilfred Bartlett's private collection; a. Paragorgia arborea with basket stars attached, b. Primnoa cf. resedaeformis, c-d. bryozoans, e-f Desmophyllum dianthus. Scale bar = 5 cm.

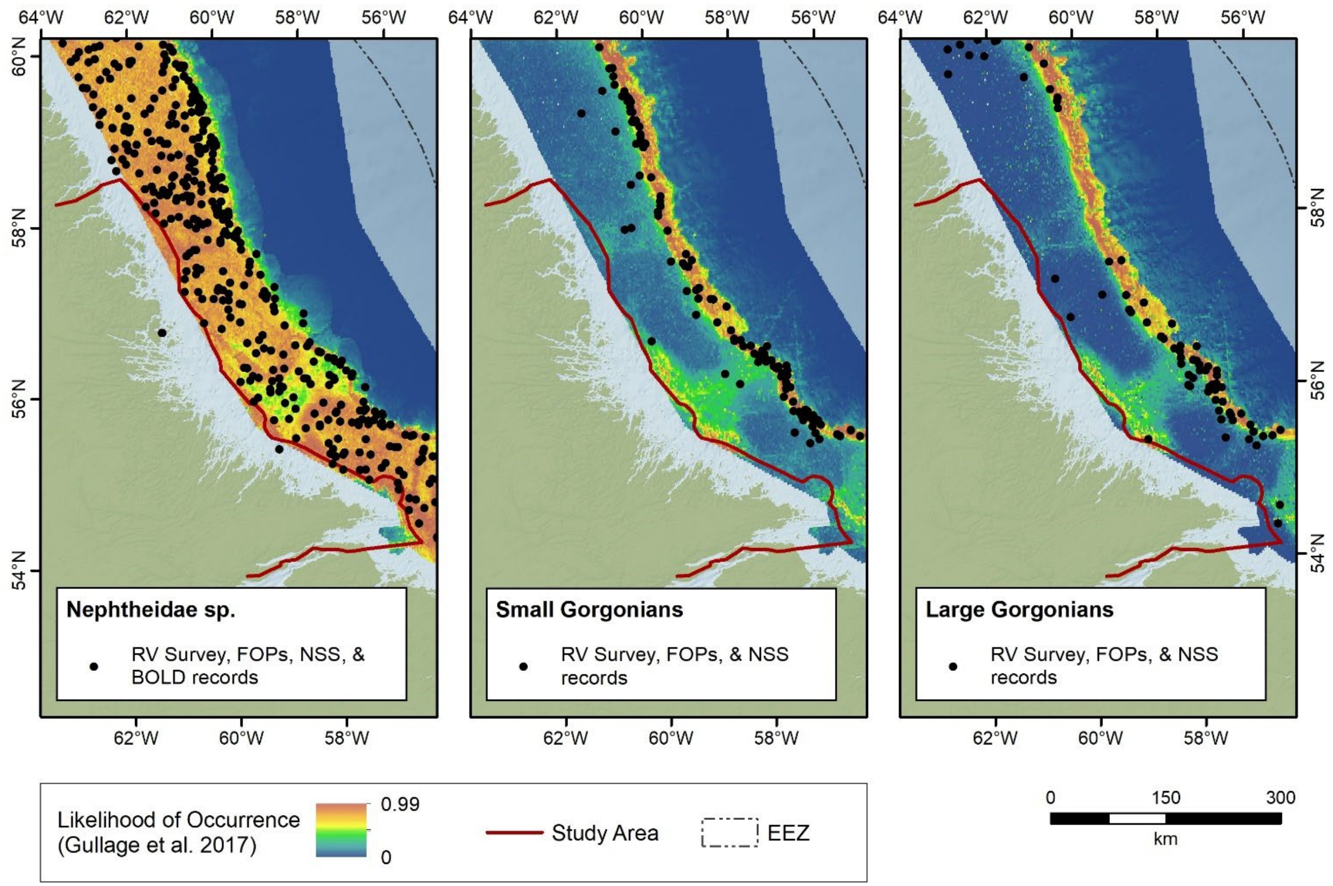


Figure 8.5: Model results of the likelihood of occurrence of soft corals (Nephtheidae), small and large gorgonians from Gullage et al. (2017).

8.2. Sensitive Species and Habitats

Corals and sponges have been recognized by NAFO as Vulnerable Marine Ecosystems (Fuller et al. 2008) and by DFO as Significant Benthic Areas (DFO 2013). Sessile benthic taxa like corals and sponges are known to be vulnerable to impacts by fishing gear, by direct damage from physical contact and indirect damage from smothering (Koen-Alonso et al. 2018). Their life history characteristics also make them slow to recover from these types of disturbances (Sherwood and Edinger 2009, Boutillier et al. 2010, DFO 2010b, Buhl-Mortensen et al. 2016). For these reasons, corals and sponges in general should be considered as sensitive habitats.

Other taxa, like bryozoans and sea squirts also possess life history characteristics that make them valid Significant Benthic Area taxa from an ecological perspective. Information on these taxa is scarce but increasing. These and other taxa with similar ecological characteristics are conceptually equivalent (i.e., habitat forming, and vulnerable to fishing impacts) (DFO 2017a).

8.3. Data Gaps and Recommendations

The main gap for corals, sponges, and bryozoans within the study area is the lack of baseline data, including benthic assemblages, bathymetric distributions, and general life history traits. Currently DFO and NSRF Research surveys do not cover the coast due to the extremely rough nature of the benthic environment found in this region. Models are now being used to predict suitable habitats for corals and sponges (see Gullage et al. 2017) and can be expanded to included bryozoans and other non-traditional data sources (i.e., museum collections, local knowledge, etc.).

Models can address knowledge gaps but require ground-truthing to test each model’s performance. Information from Fisheries Observers has been used to do this but is limited to fished areas. Further ground-truthing utilizing non-destructive methods (e.g., video footage collected by Remotely Operated Vehicles) is required in order to strengthen the performance of habitat suitability models within the study area.

Speciation of sponges is another large gap that exists not only within the study area but for the Newfoundland and Labrador Region as a whole. Sponge taxonomy is extremely challenging and time consuming and requires dedicated resources.

Recommendations:

- Utilize non-invasive, non-destructive sampling methods to gather information on benthic communities including drop camera for large spatial coverage and Remotely Operated Vehicles (ROV) for fine scale (i.e., ‘hotspots’) coverage.
- Utilize models to generate habitat suitability inside the study area, include other benthic species like bryozoans, and explore the plausibility of using non-traditional data in areas where RV survey coverage is minimal.
- Ground-truth (drop camera and/or ROV) locations currently identified by LEK (i.e., North of Ironbound Islands).

9. Fish

Fish are a diverse taxonomic group that form an important part of the study area’s ecosystem as they transfer energy through the benthic and pelagic food chain to higher trophic levels that include marine mammals, seabirds, and humans. As such, many species in the study area are also of great cultural and commercial importance to the Labrador Inuit.

9.1. Available Information

Two fish assemblages will be discussed in the following sections: nearshore/coastal and offshore fishes. Nearshore/coastal fishes places focus on fish species that are found in coastal or estuarine environments for at least part of their life cycle (including anadromous species) while offshore fishes focus on the dominant and sensitive offshore fish species which are known to occur within or directly adjacent to the deeper extents of the study area. Emphasis is placed on fish species that are important for commercial, recreational, and/or subsistence fisheries in coastal Labrador, as well as key forage species.

9.1.1. Nearshore/Coastal Fishes

Coastal Labrador is largely considered data deficient in terms of DFO RV survey data for marine coastal fish species; surveys have been primarily conducted on the continental shelf and slope just outside the study area. Therefore, information on nearshore and coastal fish species in the study area was obtained from several studies conducted within the study area as well as data gathered from LK.

Within the study area there is a mixture of anadromous fish species that undertake migrations between freshwater overwintering/spawning areas and marine feeding habitats, and obligate marine species that inhabit nearshore, shelf, and offshore habitats. The life history and ecology of species prevalent in the study area are summarized in Table D-1 in Appendix D. The dominant anadromous fish species within the study area include: Arctic Char, Atlantic Salmon, Brook Trout (*Salvelinus fontinalis*), and Smelt (*Osmerus mordax*), with anecdotal records also indicating a limited presence of Rainbow Trout (*Oncorhynchus mykiss*). Black et al. (1986) also notes the presence of Lake Whitefish (*Coregonus clupeaformis*), Round Whitefish (*Prosopium cylindraceum*), Northern Pike (*Esox lucius*), Burbot (*Lota lota*), Threespine Stickleback (*Gasterosteus aculeatus*), Ninespine Stickleback (*Pungitius pungitius*) and Slimy Sculpin (*Cottus cognatus*) that are mainly freshwater species but are known to inhabit brackish waters within coastal Labrador, including the study area. American Shad (*Alosa sapidissima*) is known to occasionally occupy estuaries and has previously been observed in the Nain area (Dempson et al. 1983). Daubed Shanny (*Leptoclinus maculatus*) have been found within the stomachs of Arctic Char captured within the study area (Dempson et al. 2002; 2008). Rock Cod (i.e., Greenland Cod-*Gadus ogac*; however, more recently characterized as *Gadus microcephalus*, Mecklenburg et al. 2018) and Capelin are also important species, found in both coastal and offshore habitats in this region.

Several coastal Labrador fishes were documented by Backus (1957) (Table 9.1) within the study area during the Blue Dolphin Labrador Expeditions from 1949–51. Marine fishes were primarily captured using beam and otter trawls in coastal regions while freshwater collections were conducted using seines or gill nets principally in the lower tributaries of the Hamilton Inlet/Lake Melville Estuary. Some species not caught during the expeditions but noted by the author to occur in the study area from previous studies include: Lake Char (*Salvelinus namaycush*), Atlantic Sturgeon (*Acipenser oxyrhynchus*), Sleeper Shark (*Somniosus microcephalus*), and Fish Doctor (*Gymnelis viridis*) (Backus 1957).

Table 9.1: Fish species collected from the Blue Dolphin Labrador Expeditions from 1949–51 (Backus 1957).

Family (Latin/Inuktitut)	Common Name (Inuktitut/English)	Scientific Name
Agonidae	Atlantic Poacher	*Agonus decagonus*
	Alligatorfish	*Aspidophoroides monopterygius*
	Arctic Alligatorfish	*Aspidophoroides olrikii*
Ammodytidae / Amajak	Tâgganit Amajak / American Sand Lance	*Ammodytes americanus*
Catostomidae	Longnose Sucker	*Catostomus catostomus*
Cottidae / Kanajut	Arctic Hookear Sculpin	*Artediellus uncinatus*
	Arctic Staghorn Sculpin	*Gymnocanthus tricuspis*
	Sea Raven	*Hemitripterus americanus*
	Fourhorn Sculpin	*Myoxocephalus quadricornis*
	Arctic Sculpin	*Myoxocephalus scorpioides*
	Shorthorn Sculpin	*Myoxocephalus scorpius*
	Ribbed Sculpin	*Triglops pingeli*
	Spatulate Sculpin	*Icelus spatula*
Cyclopteridae / Nipisait	Nipisak / Lumpfish	*Cyclopterus lumpus*
	Kakillautilik Nipisak / Atlantic Spiny Lumpsucker	*Eumicrotremus spinosus*
	KikKuamiutak sukkaituk ogak / Kelp Snailfish	*Liparis tunicatus*
	Sukkait ogait / Snailfishes	*Liparis* sp.
Gadidae / Ogak	Arctic Ogak / Arctic Cod	*Boreogadus saida*
	Atlantic Ogak / Atlantic Cod	*Gadus morhua*
	Karâllimiuk / Rock Cod	*Gadus ogac*
Gasterosteidae	Threespine Stickleback	*Gasterosteus aculeatus*
	Ninespine Stickleback	*Pungitius pungitius*
Osmeridae / Autsituk	Kuleligak / Capelin	*Mallotus villosus*

Family (Latin/Inuktitut)	Common Name (Inuktitut/English)	Scientific Name
	TauttuKutulik Autsituk / Smelt	*Osmerus mordax*
Pholidae	Banded Gunnel	*Pholis fasciatus*
	Rock Gunnel	*Pholis gunnellus*
Pleuronectidae / Talippiani ijilet natânnak)	American Plaice	*Hippoglossoides platessoides*
	Atlantic Halibut	*Hippoglossus hippoglossus*
	Ukiutsiutik natânnak / Winter Flounder	*Pseudopleuronectes americanus*
	Manittuk natânnak / Smooth Flounder	*Liopsetta putnami*
Salmonidae / Ânâtlik ammalu kavisilik	Atlantic kavisilik / Atlantic Salmon	*Salmo salar*
	IKaluk, IKalutuinnak / Arctic Char	*Salvelinus alpinus*
	Ânâtlikuluk / Brook Trout	*Salvelinus fontinalis*
Stichaeidae	Fourline Snakeblenny	*Eumesogrammus praecisus*
	Ukiuttattuk shanny / Arctic Shanny	*Stichaeus punctatus*
	Daubed Shanny	*Leptoclinus maculatus*
	Snakeblenny	*Lumpenus lumpretaeformis*
Rajidae	Atlantic Prickly Skate	*Raja radiata*
Zoarcidae / Kudjuanait	Ukiuttattumiutak Kudjuanak / Arctic Eelpout	*Lycodes reticulatus*
	Newfoundland Kudjuanak / Newfoundland Eelpout	*Lycodes lavalaei*
	Canadian Kudjuanak / Canadian Eelpout	*Lycodes polaris*

Seasonal ice coverage and the cost of sampling in these remote areas limit the opportunity to conduct surveys and studies in coastal Labrador. Within the study area; however, some recent studies have characterized coastal marine fish assemblages and habitats. One such study was conducted by Devine (2017) using baited cameras within the inshore fiords and offshore regions of the northern Labrador Sea. Camera deployments within inshore fiord systems were conducted during fall in shallow water (~10 m depth) in Kangalaksiorvik, Nachvak, Saglek, and Okak in the Nunatsiavut region of northern Labrador. Of these, only Okak falls within the boundaries of the study area. Substrates recorded in the Okak sets (both the inner and outer fiord) were a mixture of fine sediments and rocky substrates with some macroalgae cover. Relative to the more northern sampling fiords, Okak was found to have the highest fish species richness. Species observed included Rock Cod, Sculpin (*Myoxocephalus sp.* and small Cottidae), Arctic Shanny, and Eelpout. (Figure 9.1). The low overall richness observed in this study could have partially been a reflection of the late season and the reliance on bait to attract fish.

Most recently, in August 2018, Seiden et al. (unpublished data) set traps to check for the presence of the invasive species Green Crab (*Carcinus maenas*) within Nain Harbour, Anaktalak, and Webb Bay Estuary. Traps were set for 12 to 21 hour soak times. There was bycatch of Rock Cod and Sculpin in a portion of the trap sets. Overall, Webb Bay Estuary had no bycatch in its four trap sets, Anaktalak had juvenile Rock Cod in five out of 10 sets, and a juvenile Sculpin in one set, and Nain Harbour had only two Rock Cod captured in eight trap sets.

Within the Fraser River-Nain Bay system, Dempson and Green (1985) noted that Arctic Char were abundant, however Brook Trout (*Salvelinus fontinalis*), Lake Char, Threespine Stickleback, and Mottled Sculpin (*Cottus bairdi*) were also noted to occur within the area. Beddow et al. (1998) also found that the most common fish species in the river systems draining into Voisey's Bay were Arctic Char, followed by Threespine Stickleback, Ninespine Stickleback, Atlantic Salmon, Brook Trout, Lake Char, and Lake Whitefish. Of these species, Arctic Char, Brook Trout, Atlantic Salmon, Threespine Stickleback, Ninespine Stickleback, and Lake Whitefish are found in freshwater and estuarine/marine areas. Arctic Char, Brook Char/Trout, and Atlantic Salmon have both freshwater resident and anadromous forms. Anadromous populations undertake migrations from freshwater to estuarine and marine habitats in the study area to feed before returning to natal freshwater habitats to spawn and/or overwinter.

Other research undertaken within the study area was conducted in support of environmental baseline studies prior to the construction of a nickel mine in Voisey's Bay (VBNC 1997). Baseline studies were conducted from 1995–96 to characterize the existing freshwater and marine fish assemblages and habitats in the surrounding area which included portions of Anaktalak Bay, Kangeklukuluk Bay, Kangeklualuk Bay, Throat Bay, and Voisey's Bay. Many of the fish found within the bays are also believed to have widespread distribution along the Labrador coast and/or circumpolar distributions (VBNC 1997). Overall, in the marine baseline studies, 32 fish species were encountered comprising 11 taxonomic families (Table 9.2) (JWEL 1997b). Of these fish species, Sculpins [including Arctic Staghorn (*Gymnocanthis tricuspis*), Longhorn (*Myoxocephalus octodecemspinosus*), Shorthorn (*Myoxocephalus scorpius*), Moustache (*Triglops murrayi*), Grubby (*Myoxocephalus aenaeus*) and Twohorn Sculpin (*Icelus bicornis*)] were the most common fishes observed with five other fish species observed in all assessed bays (inclusive of the current study area): Snakeblenny (*Lumpenus lampretaeformis*), Banded Gunnel (*Pholis fasciata*), Grubby Sculpin, Sandlance/Amajak (*Ammodytes sp.*), and Winter Flounder (*Pseudopleuronectes americanus*) (VBNC 1997). Additionally, these reports suggest that Sculpins may play an important ecological role to nearshore fish and marine mammal species due to the abundance and diversity of Sculpins within the region as well as the number of known species that feed on them (JWEL 1997b). For example, Sculpins are known to be important prey for Arctic Char (Dempson et al. 2002). For the freshwater fish baseline studies, fish species commonly encountered within watersheds (consisting of ponds, streams, and wetlands) included: Arctic Char (landlocked and anadromous populations), Brook Trout (landlocked and anadromous populations), Lake Char, Threespine Stickleback, Ninespine Stickleback, and Round Whitefish (VBNC 1997). Arctic Char and Atlantic Salmon were found to migrate from freshwater into the study area in the summer. Tagged Atlantic Salmon from as far away as New Brunswick were also found in the area (VBNC 1997).

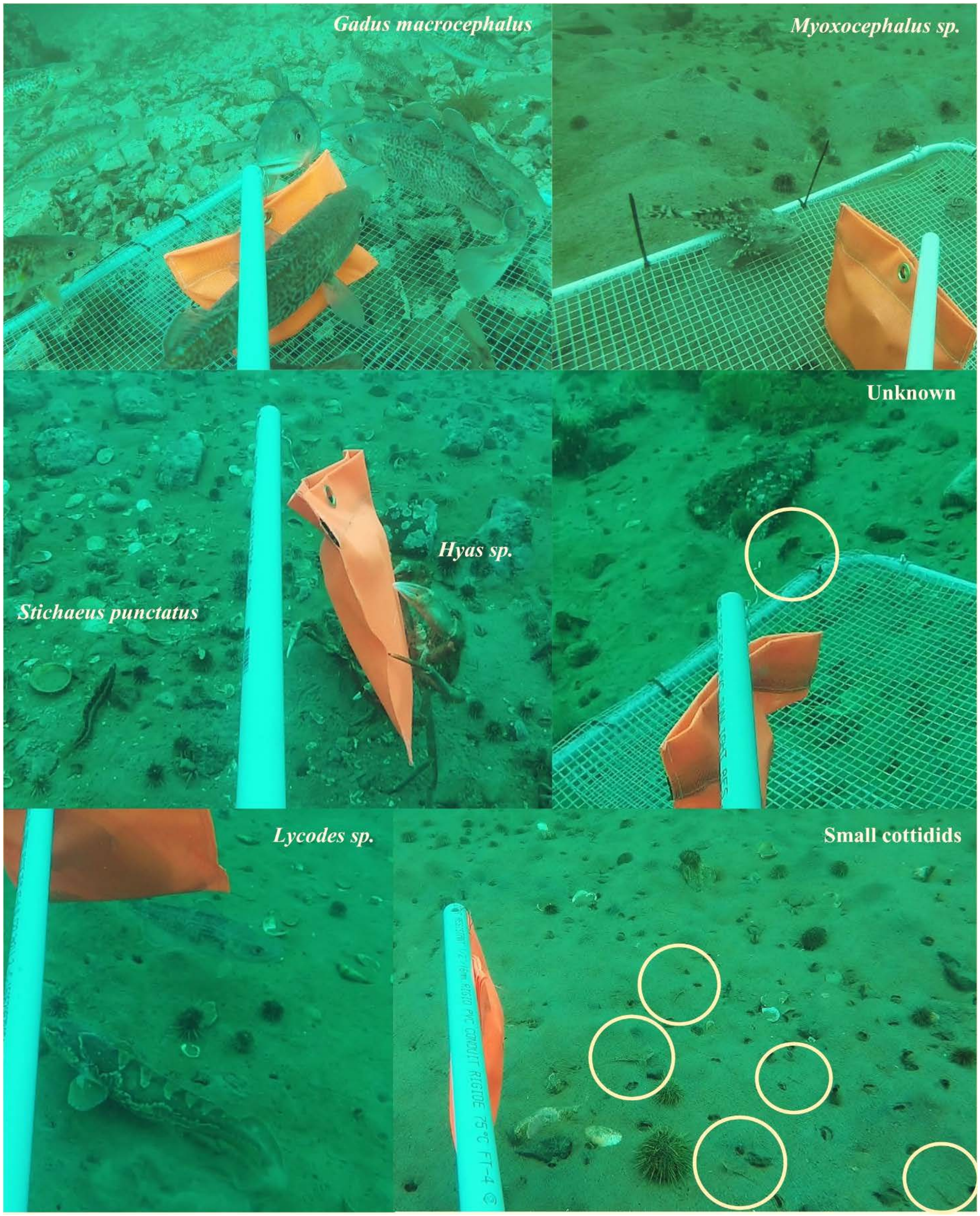


Figure 9.1: Species observed in shallow inshore camera deployment sets conducted in northern Labrador by Devine (2017). Figure obtained from Devine (2017).

Table 9.2: Fish species observed in the Voisey's Bay Marine Fauna Baseline Surveys 1995–96 (JWEL 1997b).

Family (Latin/Inuktitut)	Common Name (Inuktitut/English)	Scientific Name
Agonidae	Alligator fish	*Aspidophoroides monopterygius*
Ammodytidae / Amajak	Northern Sandlance	*Ammodytes dubius*
	S Tâgganit Amajak / Sand Lance	*Ammodytes* sp.
Cottidae	Shorthorn Sculpin	*Myoxocephalus scorpius*
	Arctic Staghorn Sculpin	*Gymnocanthis tricuspis*
	Atlantic Hookear Sculpin	*Artediellus atlanticus*
	Moustache Sculpin	*Triglops murrayi*
	Longhorn Sculpin	*Myoxocephalus octodecemspinosus*
	Twohorn Sculpin	*Icelus bicornis*
	Grubby	*Myoxocephalus aenaeus*
Cyclopteridae	Nipisak / Lumpfish	*Cyclopterus lumpus*
	Dusky Snailfish	*Liparis gibbus*
	KikKuamiutak sukkaituk ogak / Atlantic Snailfish	*Liparis atlanticus*
	Kakillautilik Nipisak / Atlantic Spiny Lumpsucker	*Eumicrotremus spinosis*
	Gelatinous Seasnail	*Liparis koefoedi*
Gadidae	Polar Cod	*Boreogadus saida*
	Atlantic Ogak / Atlantic Cod	*Gadus morhua*
	Arctic Ogak / Arctic Cod	*Arctogadus glacialis*
	Karâllimiuk / Rock Cod	*Gadus ogac*
Gasterosteidae	Threespine Stickleback	*Gasterosteus aculeatus*
	Ninespine Stickleback	*Pungitius pungitius*
Pholidae	Banded Gunnel	*Pholis fasciata*
	Rock Gunnel	*Pholis Gunnellus*

Family (Latin/Inuktitut)	Common Name (Inuktitut/English)	Scientific Name
Pleuronectidae	Manittuk natânnak / Smooth Flounder	Liopsetta putnami
	Ukiutsiutik natânnak / Winter Flounder	*Pseudopleuronectes americanus*
Salmonidae	Ânâtlikuluk / Brook Trout	*Salvelinus fontinalis*
	IKaluk, IKalutuinnak / Arctic Char	*Salvelinus alpinus*
Stichaeidae	Ukiuttattuk shanny / Arctic Shanny	*Stichaeus punctatus*
	Snakeblenny	*Lumpenus lumpretaeformis*
	Atlantic Warbonnet	*Chirolophis ascanii*
Zoarcidae	Kudjuanak / Fish Doctor	*Gymnelus viridus*
	Canadian Kudjuanak / Canadian Eelpout	*Lycodes polaris*

Three primary sources of LK were used to map regions of fish distribution within the study area including: *Our Footprints Are Everywhere* (Brice-Bennett 1977), the CCRI data (O'Brien et al. 1998, DFO 2007) and most recently, Nunatsiavut Government *Imappivut* data collections (Nunatsiavut Government 2018). Much of these data were collected through interviews and consultations with Labrador Inuit and were gathered from traditional fishing areas for particular species or areas where it was indicated that fish were captured. In addition, OFAE provided a general synopsis of primary and secondary nearshore fish species of importance in four regions of Labrador: Nain, Hopedale, Postville, Makkovik, and Rigolet (Table 9.3).

In general Arctic Char appear to be of primary importance in the Nain and Hopedale region whereas Atlantic Salmon appear to be important in communities further south (Postville, Makkovik, and Rigolet). Brook Trout were also of high importance in the Rigolet region (Table 9.2). Arctic Char have historically been encountered along the coast of the entire study area (Figure 9.2). CCRI data shows that Arctic Char have been harvested primarily around the communities of Nain, Hopedale, Postville, Makkovik, and Rigolet while OFAE data indicates Arctic Char are distributed among the many fiord systems north of Nain, in addition to those observations of char near all of the aforementioned communities. Collectively, LK data show observations of char primarily around Makkovik, Postville, Rigolet, and inner Lake Melville but also some north of Nain (Figure 9.2). Atlantic Salmon are reported in the area of Hopedale and regions to the south, however CCRI and OFAE data indicate observations of salmon in the Nain region as well as north of Nain (Figure 9.3). Brook Trout appear to be distributed from Hopedale to Rigolet in the study area with very few cases of Trout caught around Nain (Figure 9.4). It should be noted that all observational data is limited locations used by Labrador communities for fishing. Earlier studies (MacCrimmon and Campbell 1969) indicated that Brook Trout are not found north of Nain; however more recent studies have reported observations from areas as far north as Hebron Fiord (Black et al. 1986). There are few LK references to Smelt in the study area with observations of Smelt restricted to the Postville region as well as Rigolet (Figure 9.5).

Table 9.3: Primary and secondary fish species utilized by Inuit in four regions of Labrador. Obtained from Brice-Bennett (1977).

Region	Primary Emphasis Fish Species	Secondary Emphasis Fish Species
Nain and Hopedale	Arctic Char (in Spring; and in Summer-Hopedale to Hebron) Salmon (in Summer-Hopedale to Okak)	Tom Cod, Cod, Brook and Lake Trout, Capelin, Arctic Char
Postville	Salmon	Smelts, Capelin, Freshwater Trout (Spotted Trout), Saltwater Trout (Arctic Char), Rock Cod, Cod
Makkovik	Salmon	Cod, Arctic Char, Capelin, Smelt
Rigolet	Salmon, Brook Trout	Capelin, Smelts, Arctic Char, Rock Cod

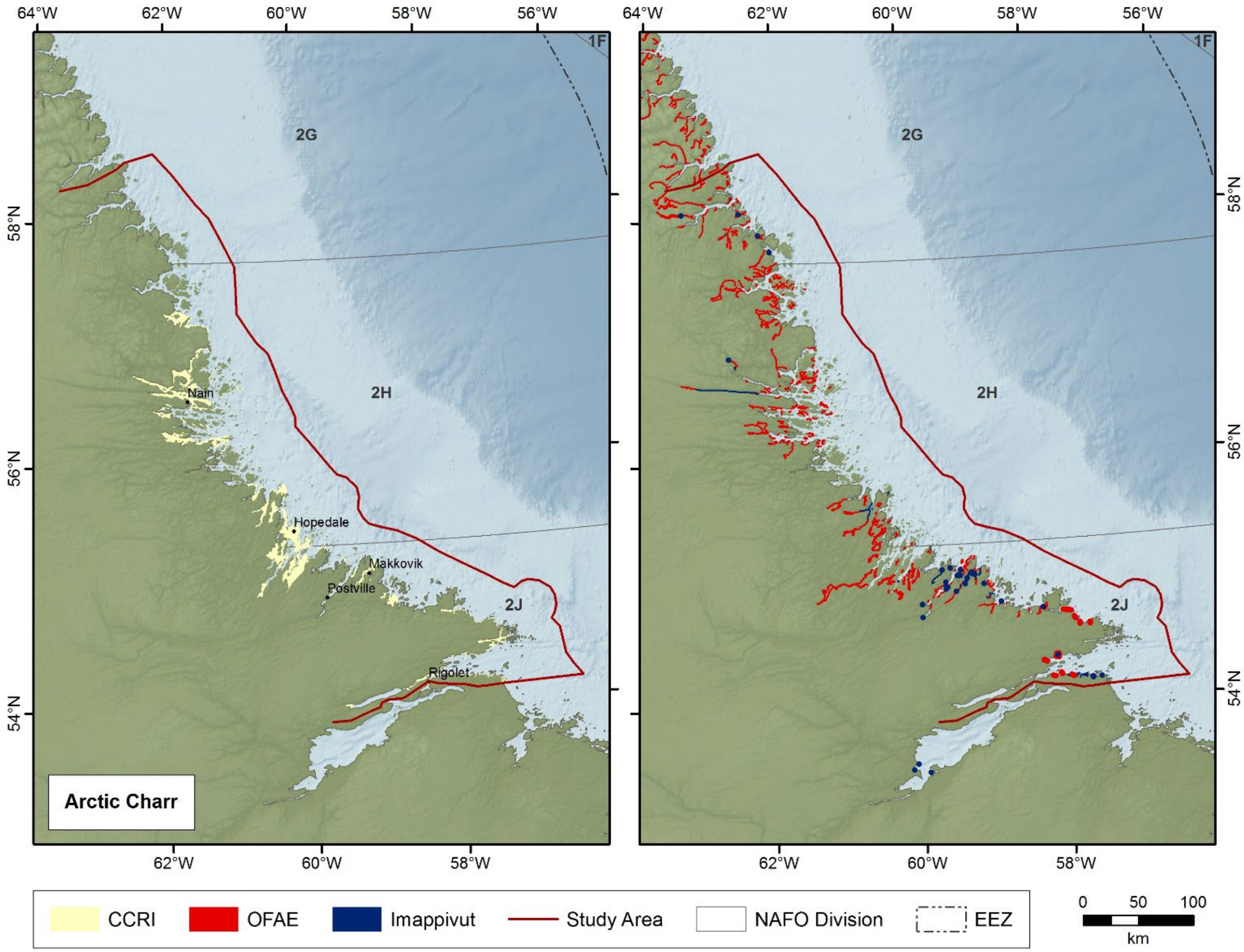


Figure 9.2: Arctic Char distribution in northern Labrador study area collected from local knowledge sources: CCRI, Our Footprints Are Everywhere (Brice-Bennett 1977), Imappivut (Nunatsiavut Government 2018). Distribution records are indicative of char harvesting locations in regional fisheries, char spawning rivers, and general observations of char.

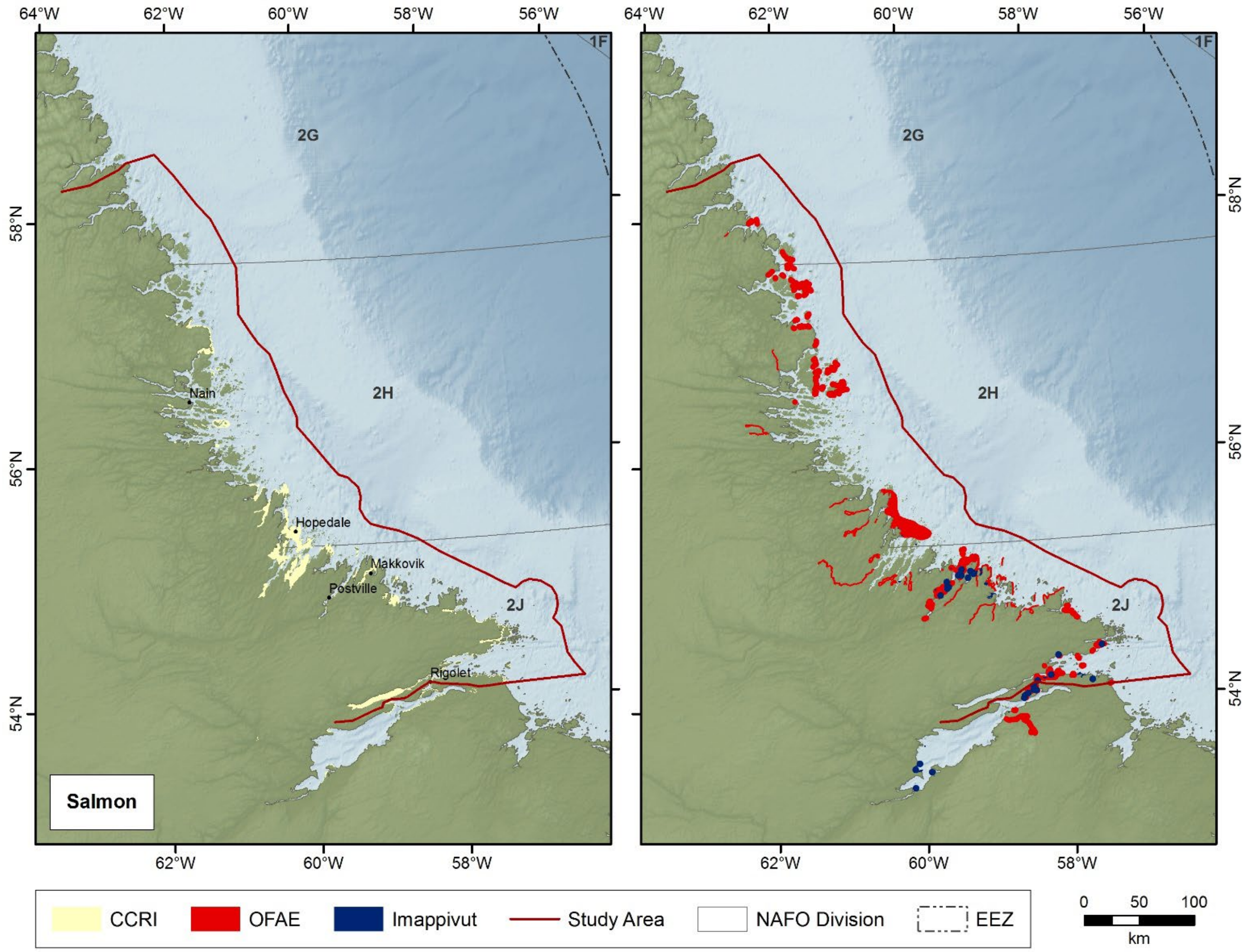


Figure 9.3: Atlantic Salmon distribution in northern Labrador study area from local knowledge sources: CCRI, Our Footprints Are Everywhere (Brice-Bennett 1977), Imappivut (Nunatsiavut Government 2018). Distribution records are indicative of salmon harvesting locations in regional fisheries, salmon spawning rivers, and general observations of salmon.

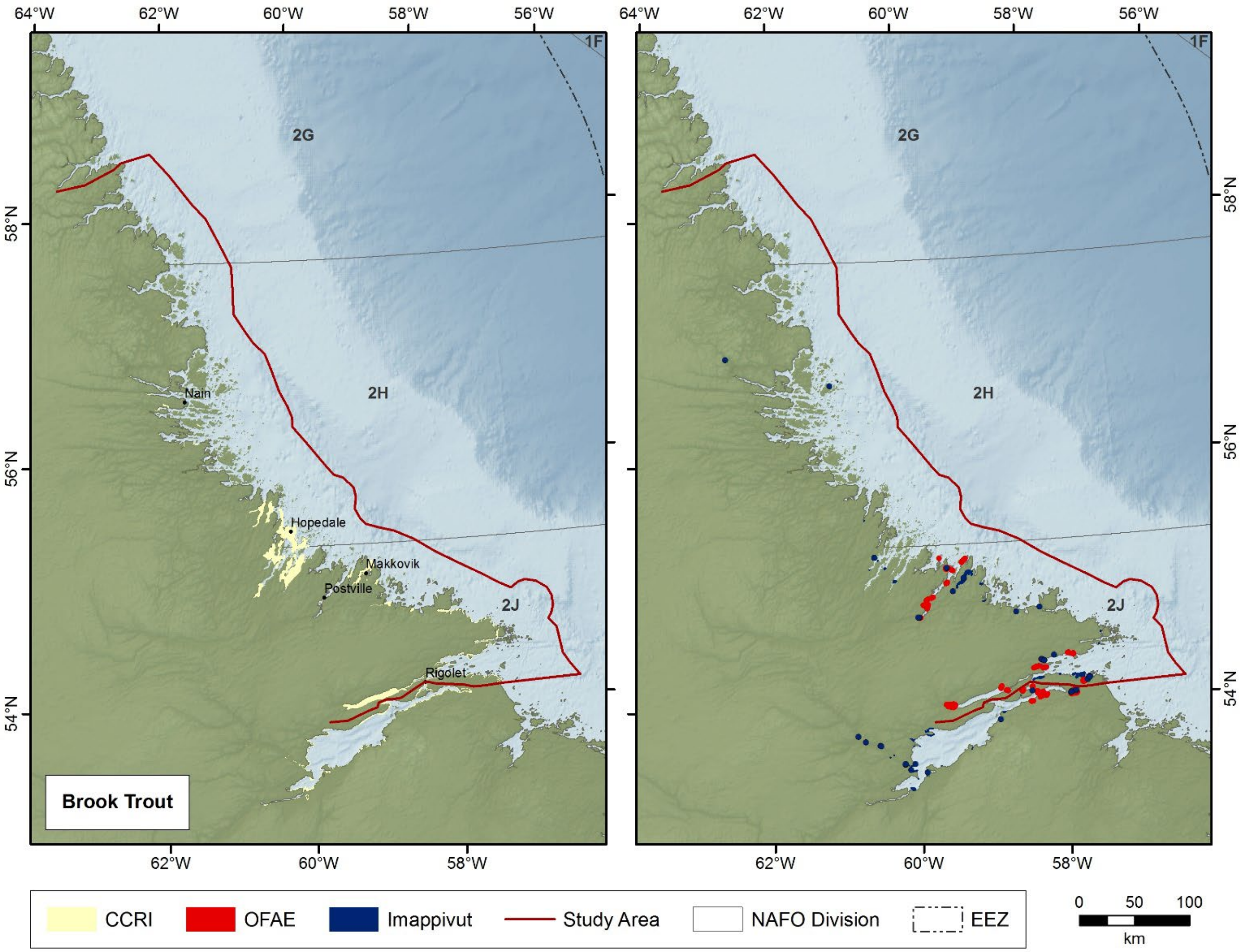


Figure 9.4: Brook Trout distribution in northern Labrador study area collected from local knowledge sources: CCRI, Our Footprints Are Everywhere (Brice-Bennett 1977), Imappivut (Nunatsiavut Government 2018). Distribution records are indicative of Trout harvesting locations in regional fisheries, Trout spawning rivers, and general observations of Trout.

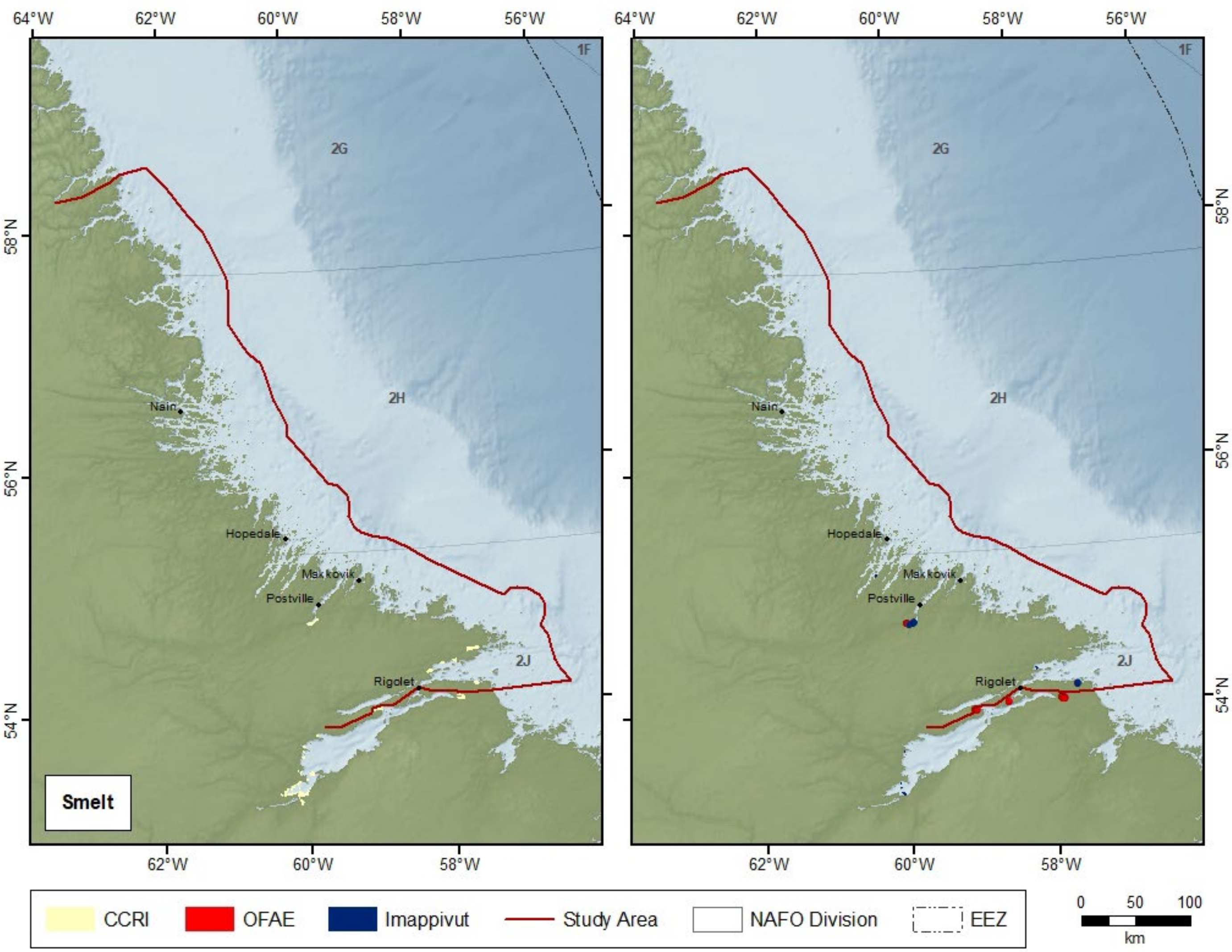


Figure 9.5: Smelt distribution in northern Labrador study area collected from local knowledge sources: CCRI, Our Footprints Are Everywhere (Brice-Bennett 1977), Imappivut (Nunatsiavut Government 2018). Distribution records are indicative of Smelt harvesting locations in regional fisheries, smelt spawning rivers, and general observations of Smelt.

Within the study area, Arctic Char and Atlantic Salmon are considered two very important fish species for commercial and/or recreational and subsistence fisheries. In Labrador, Arctic Char tend to be more abundant north of Hamilton Inlet with Brook Trout and Atlantic Salmon dominating coastal areas and rivers further south (Dempson and Green 1985; Reddin and Dempson 1986; DFO 2001).

9.1.2. Arctic Char

The last review and status of Arctic Char in Northern Labrador was completed by Dempson et al. (2004). In the review, a list of studies that were completed on northern Labrador char were provided, including general life history and ecology (Dempson and Green 1985; Dempson 1993), distribution, homing, ocean migration patterns, age at first migration (Black and Dempson 1986; Dempson and Kristofferson 1987), and genetic investigations (Dempson et al. 1988; Bernatchez et al. 1998). Catch statistics suggest that Arctic Char are commonly encountered in the more northern regions of Labrador (Dempson and Shears 2001). Arctic Char are harvested year-round in northern Labrador and historically have been fished quite heavily in the commercial fishery within the study area. However, char stocks have demonstrated tolerance and stability to periods of high levels of fishing over the last several decades (Dempson 1995; Dempson et al. 2008). This is encouraging, as it indicates that char stocks within the region may be capable of maintaining sustainable fisheries for the Inuit.

Arctic Char returns are counted at English River, which is the only counting fence within the study area. However, char numbers have not been published in assessments of this river since 2000. In 2000, 1,454 char were counted; this was a large increase from 1999 when only 296 char were counted (Reddin et al. 2001).

Previous studies have identified discrete anadromous Arctic Char stock complexes for the northern Labrador coastal region from information obtained from long term tagging studies of char distribution and migration as well as morphometric and meristic analyses (Dempson and Kristofferson 1987; Dempson 1984, Dempson and Misra 1984 *in* Dempson et al. 2004). Biological characteristics of note in determining the separation of stocks were growth rate, longevity, age and size at maturation, and distribution patterns of tagged fish. Meristic characteristics including pectoral fin ray and upper gill raker counts for individual fish were also important for differentiating stocks (Dempson and Misra 1984). Dempson and Misra (1984) noted little mixing of stocks between inner bays and fiords with the exception of some offshore areas that had mixtures of a few inner bay char populations. This suggests that Arctic Char do not conduct extensive at-sea migrations. This is confirmed by other studies, including a tag-recapture study of Arctic Char conducted by Dempson and Green (1985) who found that char from the Fraser River did not undertake large-scale migrations over an eight year period (from 1976–83); most char recaptured were those that had returned to the Fraser River, Nain Bay, or adjacent Tikkoatokak Bay. Similarly, results from other tag-recapture studies in northern Labrador from 1974–99 have shown that char do not typically make extensive at-sea migrations. The majority of recovered char (87–93%) from these studies that had been tagged and released in each of their respective stock complexes (Voisey, Nain, and Okak) were recaptured within their stock complexes. In general, it was noted that there were few char recaptured more than 100 km from their tag/release location (Dempson and Kristofferson 1987; Dempson and Shears 2001, Figure 9.6).

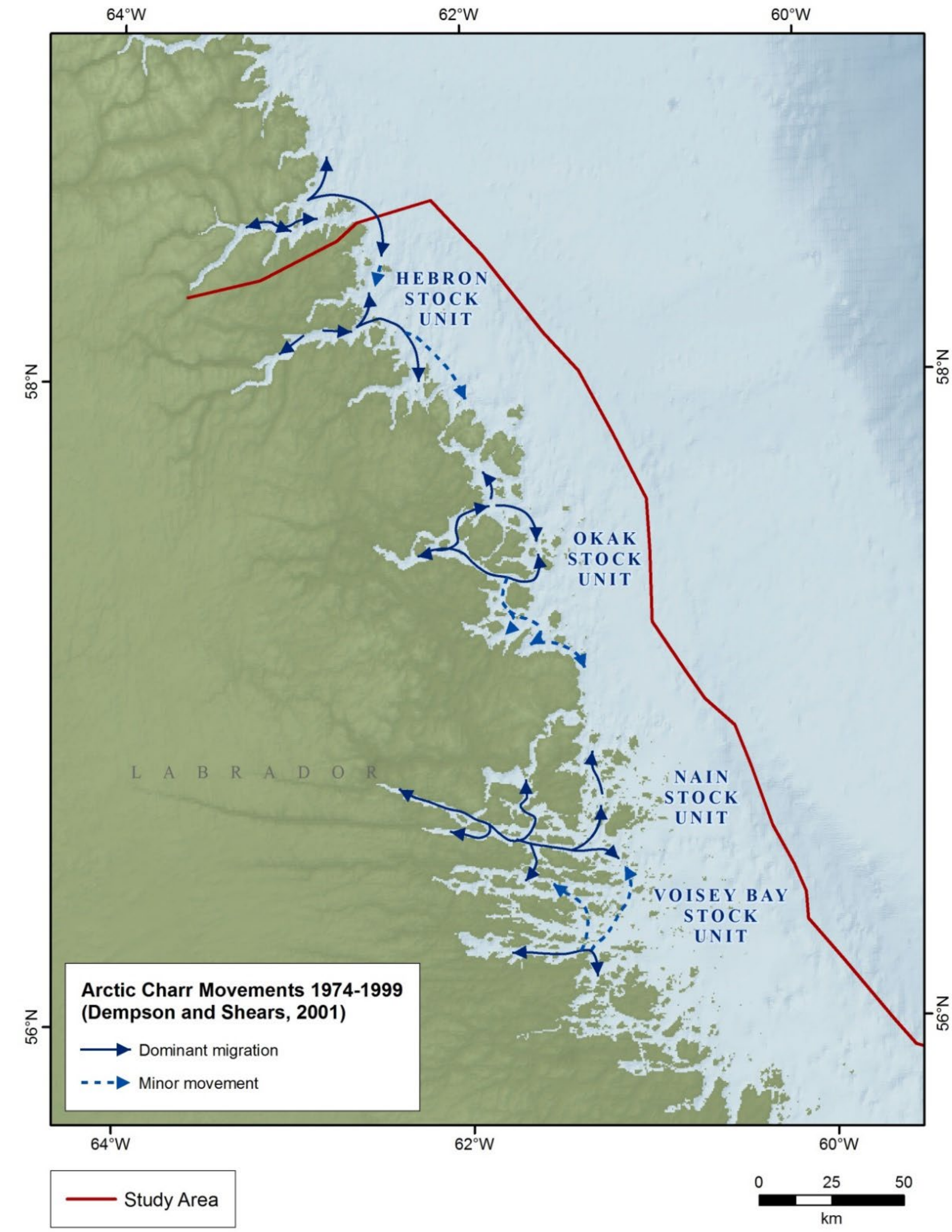


Figure 9.6: General at-sea migration patterns of anadromous Arctic Char stocks from northern Labrador. Solid lines indicate dominant migration routes while broken lines indicate minor migration routes. Data obtained from 1974 to 1999 tag-recapture studies. Reproduced from Dempson and Shears (2001).

In Voisey's Bay, Beddow et al. (1998) conducted a radio-telemetry study in the Reid Brook and Ikadlivik Brook systems. They provided evidence that Arctic Char occasionally overwinter in neighboring or adjacent rivers (known as "straying") in contrast to returning every year to overwinter in their natal rivers. Moore et al. (2017) suggested that straying may be a life history strategy to minimize the energetic costs by taking shorter migration routes to overwinter in nearby rivers as opposed to taking longer migration routes to natal rivers, especially in non-breeding years. Bernatchez et al. (1998) also provided evidence of char straying to nearby rivers (e.g., Reid Brook, Ikadlivik Brook, and Kongluktokluk Brook that flow into Voisey's Bay) through genetic analysis of population structure and mixing. This further supports the observation of limited marine migrations of char (i.e., Dempson and Kristofferson 1987; Spares et al. 2015; Moore et al. 2016). Char stock mixing at sea has been observed in commercial fishing areas, but this primarily occurs in outer coastal or offshore islands (Dempson and Kristofferson 1987; Moore et al. 2016; 2017). Important overwintering areas for anadromous Arctic Char tend to be their natal rivers or river systems within close proximity to their natal rivers. For example, Arctic Char from the Nain stock unit primarily overwinter in the Fraser River and other areas within this region (including Anaktalak Brook, Kingurutik River, Webb Brook, etc.) whereas char from the Voisey's Bay stock unit primarily inhabit the three river systems that drain into the Bay: Kogluktokoluk Brook, Ikadlivik Brook, and Reid Brook (JWEL 1997a).

Char have been sampled within the study area to determine contaminant loads based on age structure and size class by the Nunatsiavut Government. Preliminary results indicate that even older, larger char from Saglek (former PCB contaminant site) carry low contaminant loads, which is promising news for the communities who rely on this important food source.

9.1.3. Atlantic Salmon

Designated management areas for Atlantic Salmon throughout Newfoundland and Labrador are termed Salmon Fishing Areas (SFAs). SFAs differentiate salmon stocks based on differences in life history traits such as freshwater residency time, timing of return migration, age at first spawning, and the extent of ocean migration (DFO 2018c). There are 89 rivers that Atlantic Salmon are known to inhabit in Labrador. Of these, 35 are located within the study area (Figure 9.7). The drainage area of these rivers are 24,956 km^2 and represent 29% of the accessible habitat for salmon (Reddin et al. 2010). The most northerly salmon rivers known to contain reproducing populations of salmon are Webb Brook, located in Webb Bay, north of Nain, and Siugak Brook within Okak Bay (Reddin et al. 2010; J.B. Dempson, pers. comm.). However, there is the possibility that other reproducing populations have not yet been identified.

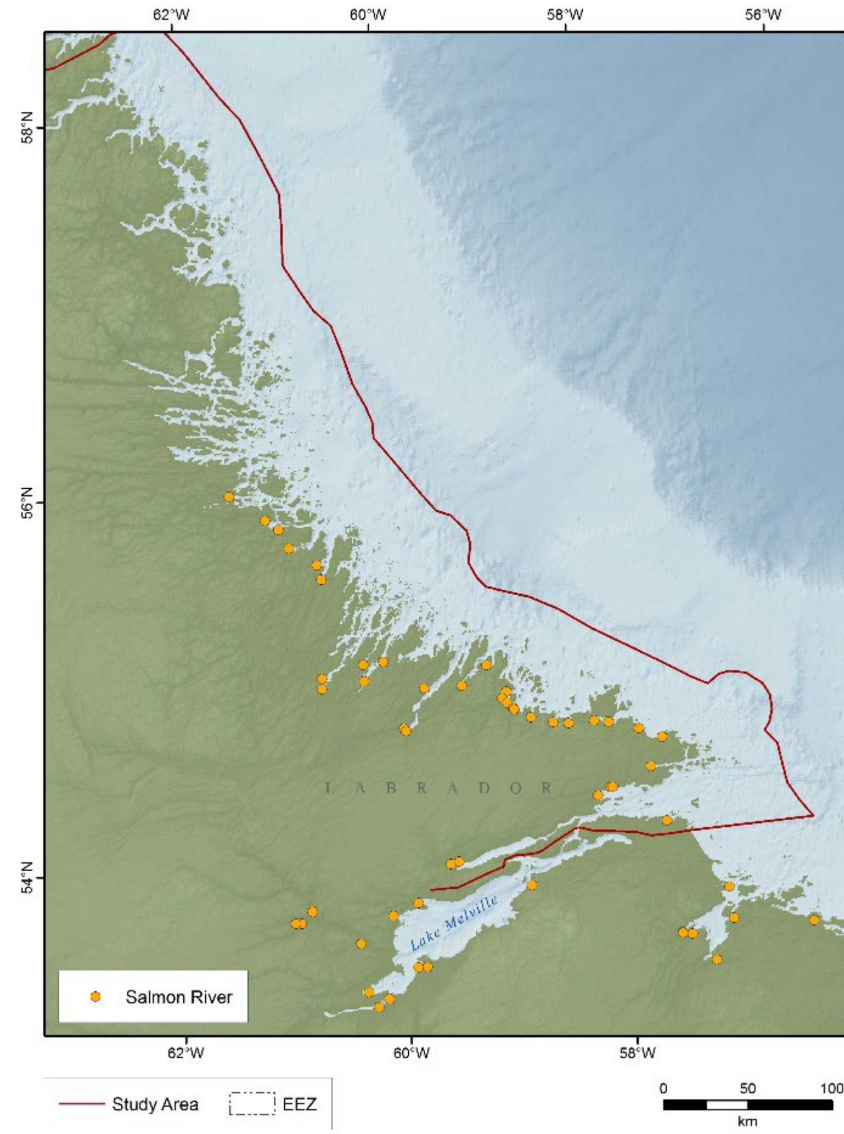


Figure 9.7: Location of known salmon rivers within the study area.

Total returns of small (<63 cm fork length) and large (>63 cm) salmon to the SFA1 English River counting facility have been counted since 1999. Returns have increased since 2004 (Figure 9.8). Overall, 744 salmon were counted returning to the river in 2017, which was 3% less than the previous six year mean (2011–16); furthermore, there was a 13% decrease in the number of small salmon and a 41% increase in the number of large salmon from the previous year (Figure 9.8; DFO 2018c). Overall, salmon returns in recent years have been above the post-moratorium time series (1998–2016) average (Figure 9.8) and recent LK interviews have indicated increases in salmon abundance and size of salmon within the Postville and Rigolet regions compared to prior years (P. McCarney, pers. comm.).

The most recent stock assessment for Atlantic Salmon in Newfoundland and Labrador reports declining returns for all 15 monitored salmon rivers and three of the four Labrador rivers were found to be below river-specific limit reference points for egg production (DFO 2018c).

Also, salmon harvested in subsistence fisheries within SFA1 (inclusive of the study area) from 2000–16 have generally shown steady increases in total biomass of salmon harvested from year to year, perhaps owing to more larger salmon being harvested (Veinott et al. 2018).

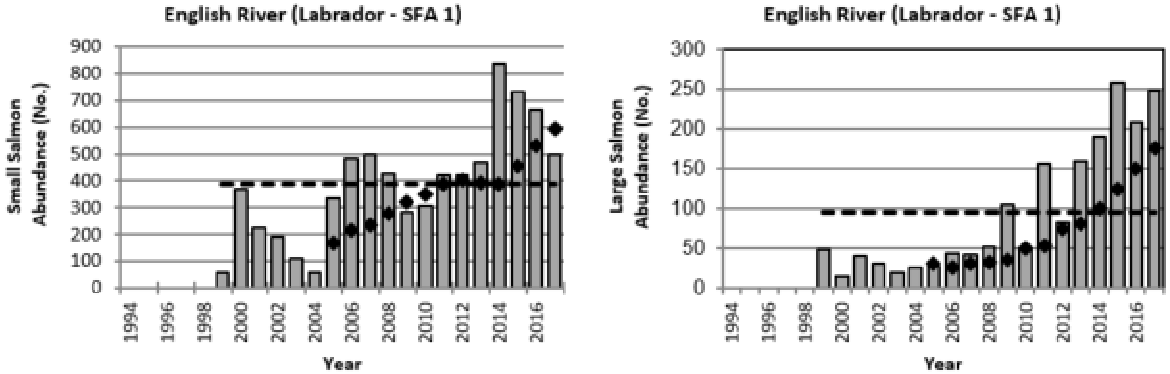


Figure 9.8: Total abundance of small (<63 cm fork length) and large (>63 cm) salmon returns from 1999–2017 for English River, Labrador (SFA1). The dashed line indicates the average of the post-moratorium time series (1998–2016). The black diamonds are the previous generation average (six years) for each year. Reproduced from DFO (2018c).

Coastal Labrador is known as an essential migration route for salmon populations migrating from the south. The Labrador Sea is believed to be an important nursery area for post-smolt Atlantic Salmon and an important overwintering area for salmon (Reddin 2006). Many Atlantic Salmon stocks are known to mix during their marine migrations in this area, including stocks from the island of Newfoundland, the Gulf of St. Lawrence and the Maritimes, as well as northern Quebec (Ungava Bay), USA (Maine), and Europe (England and Scotland) (Reddin and Dempson 1986; Bradbury et al. 2015) (Figure 9.9). Many of these are listed as species of conservation concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2010c). The Labrador Population (inclusive of the study area) was designated as Not at Risk in 2010. Although numerous salmon stocks may mix in the study area, Bradbury et al. (2015) reported genetic results that less than 3% of all salmon caught in coastal subsistence fisheries (n=1,772 salmon) from 2006–11 in Labrador (ranging from Nain in the north to Lodge Bay in southern Labrador) were of non-Labrador origin. Additional research in Labrador has been to obtain information regarding stock structure of Atlantic Salmon and Arctic Char and exploitation of specific stocks in various fisheries (I. Bradbury, pers. comm.). This has been conducted using genome-wide scans to characterize population structure and to disentangle the composition of mixed stock harvests (Bradbury et al. 2015; 2018) and explore climate associations (Jeffery et al. 2017; Sylvester et al. 2018).

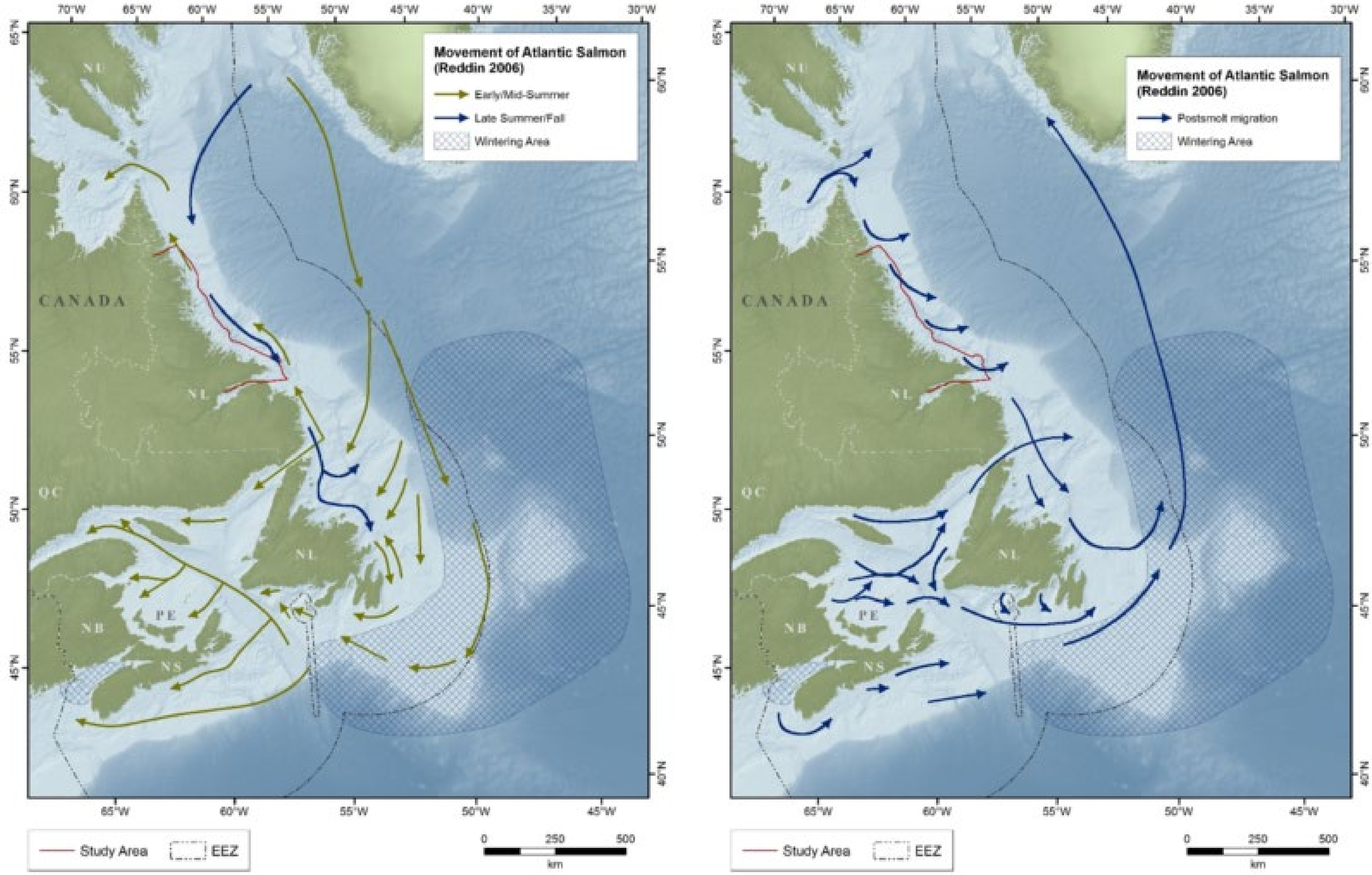


Figure 9.9: General migration routes of Atlantic Salmon in the Northwest Atlantic from the Labrador Sea and Greenland to home rivers. Reproduced from Reddin (2006).

9.1.4. *Other Species*

Fish assemblages in nearshore/coastal environments tended to be different from offshore (see below). However, two species were found in both nearshore and coastal habitats. CCRI data indicates that Rock Cod were captured in fiord systems around Hopedale and Postville, while LK data indicates that Rock Cod were captured in fiords near Makkovik, Rigolet and Nain (Figure 9.10). Offshore collections of this species were collected by DFO RV surveys (see below), but biomass of this species was relatively low (5.50 kg or less per tow; Figure 9.10). Similarly, CCRI and OFAE data show Capelin spawning beaches in the Hopedale, Makkovik, Rigolet and Postville (CCRI only) regions (Figure 9.11) and DFO RV survey data also include Capelin at low biomass (up to 33 kg per tow; Figure 9.11).

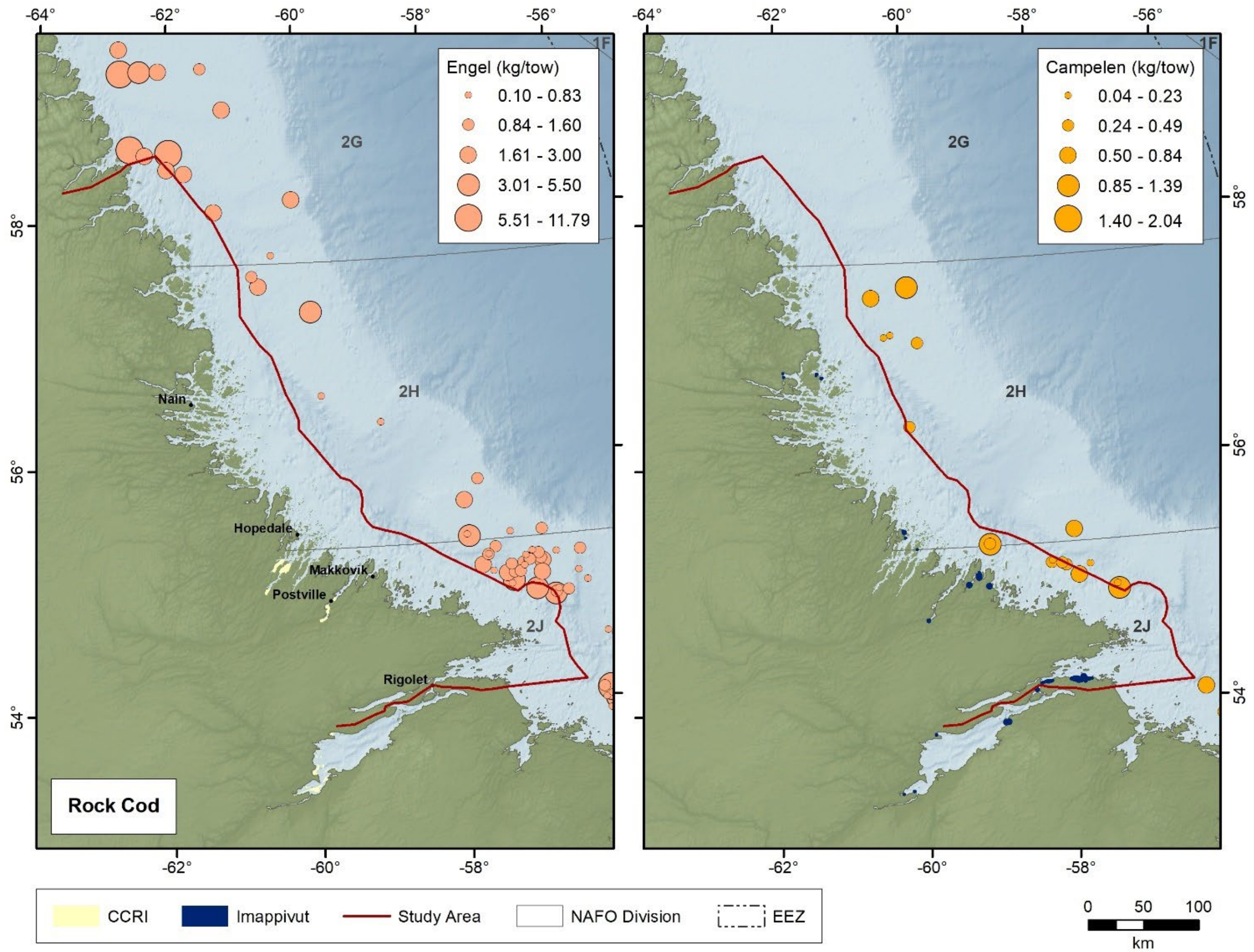


Figure 9.10: Rock Cod distribution in northern Labrador study area collected from DFO Engel and Campelen RV Survey Data and from local knowledge sources: CCRI, Our Footprints Are Everywhere (Brice-Bennett 1977), Imappivut (Nunatsiavut Government 2018). Campelen and Engel records are indicative of Rock Cod captured in RV surveys; local knowledge sources are indicative of Cod harvesting locations in regional fisheries, and general observations of Cod.

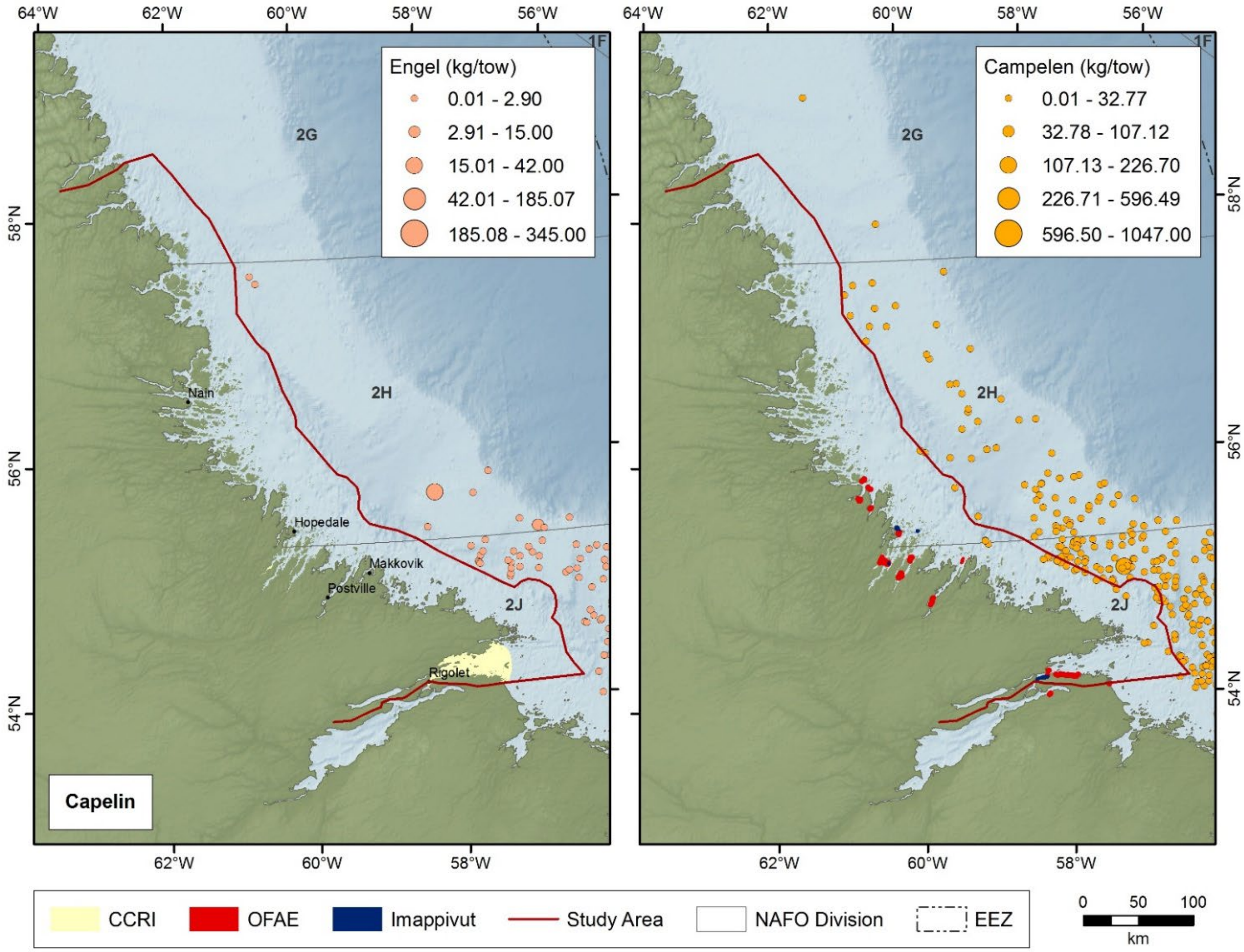


Figure 9.11: Capelin distribution in the northern Labrador study area collected from DFO Engel and Campelen RV Survey Data and from local knowledge sources: CCRI, Our Footprints Are Everywhere (Brice-Bennett 1977), Imappivut (Nunatsiavut Government 2018). Distribution records are indicative of Capelin captured in RV surveys; local knowledge sources are indicative of Capelin harvesting locations in regional fisheries, Capelin spawning beaches, and general observations of Capelin.

9.1.5. Offshore Fishes

Dominant and sensitive offshore fish species present within and adjacent to the study area were identified from the DFO RV multispecies bottom trawl survey database. In the NL region, RV trawl surveys have been performed in the spring and fall of each year since the early 1970s throughout NAFO subareas two and three at depths from 32–1,500 m (Rideout and Ings 2018; Figure 9.12). Division 2G has not been surveyed since 1999 and, due to the presence of spring ice, Divisions 2HJ3K are only surveyed in the fall (Rideout and Ings 2018).

An Engel Hi-Lift Otter Trawl was used to conduct surveys until spring 1995, after which the gear was switched to a Campelen shrimp trawl (McCallum and Walsh 1996). These two gear types differ in their characteristics (i.e., catchability) and conversion factors only exist for a small group of commercial species (Stansbury 1996, 1997; Warren 1996; Warren et al. 1997). Therefore, Engel data cannot be scaled to comparable Campelen catches and all analyses using the RV data treat the two datasets separately.

The study area spans portions of NAFO Divisions 2GHJ (Figure 9.12) but, because of its water depths and untrawlable substrate types, just 66 trawl sets have been performed within the boundaries of the study area since 1971. To ensure the selection of key and sensitive species was robust, all RV trawls in NAFO Divisions 2GHJ that were: within the study area, within a 10 km buffer adjacent to the study area, or on the continental shelf at a depth ≤160 m (mean depth of the study area plus one standard deviation) were included in the analysis (Figure 9.12).

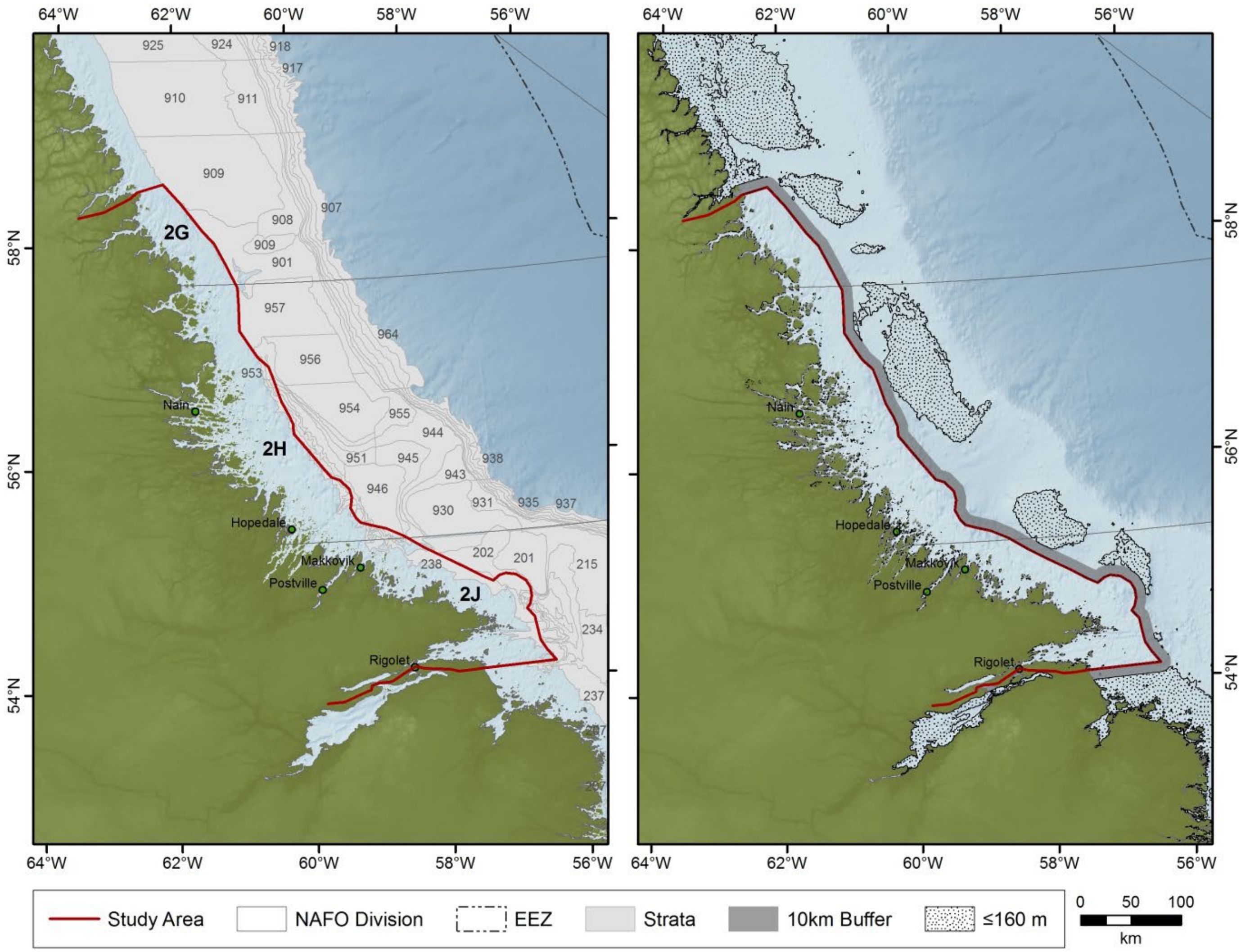


Figure 9.12: Map indicating NAFO Divisions and DFO RV trawl survey strata (Left), as well as the locations adjacent to the study area from which RV trawls were extracted (Right).

In total, 951 trawls were included in the analysis. Of these, 30.6% were collected using the Engel trawl (1977–94), while the remaining 69.4% were collected using the Campelen trawl (1995–2017). Key species of interest were divided into two categories: dominant species and sensitive species. Dominant species were identified by ranking species' mean biomass (kg/trawl) and mean abundance (individuals/trawl) during the Engel and Campelen time series and retaining those which were found within the top 20 of both rankings (Table 9.3). Initially, this list was then refined to include the top 10 dominant species. However, there was debate over the dominance of Deepwater Redfish relative to areas outside the study area with greater depths. To address this, the 11th most dominant species (Lumpfish [NS]) was also included. Although Rock Cod was not identified as a dominant species, it was included as it is also commonly found in nearshore waters where it is targeted in subsistence fisheries.

Sensitive species were identified as any COSEWIC and/or SARA listed species found within or near the study area (Table 9.4). Species whose depth distribution or latitudinal range did not overlap the study area were excluded. For example, Roundnose Grenadier, which occurs along the coast of Labrador, but is most abundant at depths of 800–1,000 m (COSEWIC 2008a), and Winter Skate, which rarely extends as far north as Labrador (COSEWIC 2015; Froese and Pauly 2016) were excluded.

Where available, species-specific information on biology, ecology, distribution, biomass, abundance, and temporal trends was collected from a variety of sources including, but not limited to: DFO CSAS Advisory Reports and Research Documents, COSEWIC Status Reports, NAFO Scientific Council Research (SCR) Documents, published scientific literature, and relevant online databases. The information and associated references gathered are available in Table D-1 in Appendix D.

In general, the 17 species described as dominant and/or sensitive (Table 9.4 and Table 9.5, Figure 9.13 to Figure 9.28) can be grouped into three communities based on the shelf environment of the study area. Greenland Halibut, Deepwater Redfish, Eelpout (NS), Atlantic Wolffish, Northern Wolffish, Smooth Skate, and Roughhead Grenadier were found in highest densities within basins, shelf valleys, and glacial troughs. In contrast, Arctic Cod, Mailed Sculpin (NS), American Plaice, Daubed Shanny, Lumpfish (NS), Rock Cod, and Spotted Wolffish were more common along medium to high relief areas of the continental shelf.

Table 9.4: Dominant species located within or near the study area.

Rank	Associated Figure	Common Name	Scientific Name	Mean Biomass (Campelen) (kg/trawl)	Mean Abundance (Campelen) (individuals/trawl)
1	Figure 9.13	Greenland Halibut	*Reinhardtius hippoglossoides*	17.72	111.11
2	Figure 9.14	Arctic Cod	*Boreogadus saida*	7.75	577.99
3	Figure 9.15	Capelin	*Mallotus villosus*	3.65	240.51
4	Figure 9.16	Atlantic Cod	*Gadus morhua*	2.77	6.23
5	Figure 9.17	Mailed Sculpin (NS)	*Triglops* sp.	1.31	162.40
6	Figure 9.18	American Plaice	*Hippoglossoides platessoides*	1.18	13.94
7	Figure 9.19	Deepwater Redfish	*Sebastes mentella*	1.18	21.37
8	Figure 9.20	Thorny Skate	*Amblyraja radiata*	1.15	8.27
9	Figure 9.21	Eelpout (NS)	*Lycodes* sp.	0.58	25.16
10	Figure 9.22	Daubed Shanny	*Leptoclinus maculatus*	0.50	89.77
11	Figure 9.23	Lumpfish (NS)	*Eumictrotremus* sp.	0.28	15.73
12	Figure 9.10	Rock Cod	*Gadus ogac*	0.04	0.26

Table 9.5: Sensitive species located within or near the study area.

Associated Figure	Common Name	Scientific Name	COSEWIC Status (In or Near Study Area)	SARA Status	Mean Biomass (Campelen) (kg/trawl)	Mean Abundance (Campelen) (individuals/trawl)
Figure 9.16	Atlantic Cod	*Gadus morhua*	Endangered	-	2.77	6.23
Figure 9.18	American Plaice	*Hippoglossoides platessoides*	Threatened	-	1.18	13.94
Figure 9.24	Atlantic Wolffish	*Anarhichas lupus*	Special Concern	Special Concern	0.06	0.38
Figure 9.25	Northern Wolffish	*Anarhichas denticulatus*	Threatened	Threatened	0.16	0.03
Figure 9.26	Spotted Wolffish	*Anarhichas minor*	Threatened	Threatened	0.90	0.17
Figure 9.20	Thorny Skate	*Amblyraja radiata*	Special Concern	-	1.15	8.27
Figure 9.27	Smooth Skate	*Malacoraja senta*	Hopedale Saddle=Data Deficient Funk Island Deep=Endangered	-	0.06	0.78
Figure 9.19	Deepwater Redfish	*Sebastes mentella*	Threatened	-	1.18	21.37
Figure 9.28	Roughhead Grenadier	*Macrourus berglax*	Special Concern	-	0.05	0.29
Figure 9.29	Porbeagle	*Lamna nasus*	Endangered	-	-	-

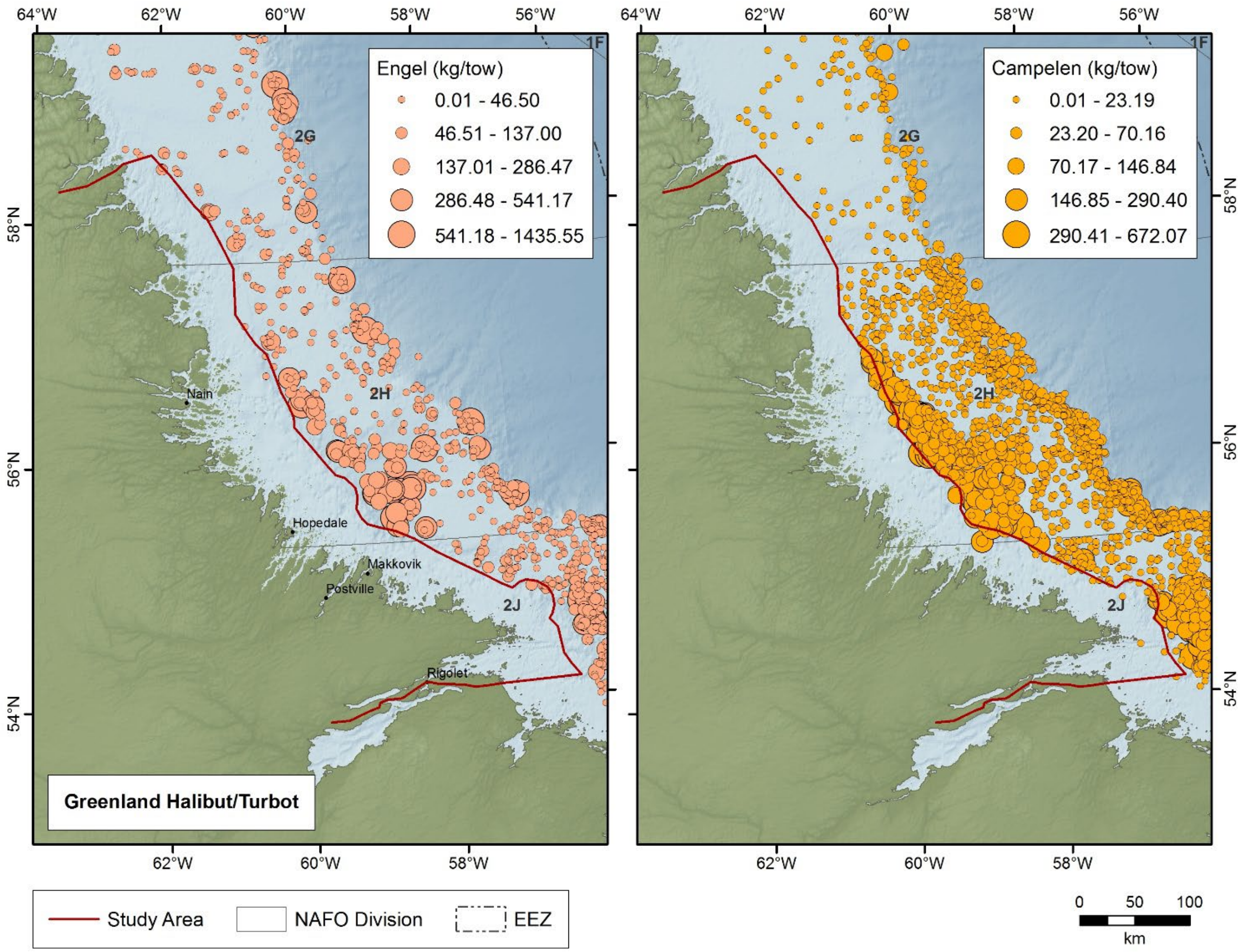


Figure 9.13: Distribution of Greenland Halibut (Reinhardtius hippoglossoides) as observed in RV multispecies trawl surveys (1977–2017) in NAFO Divisions 2GHJ.

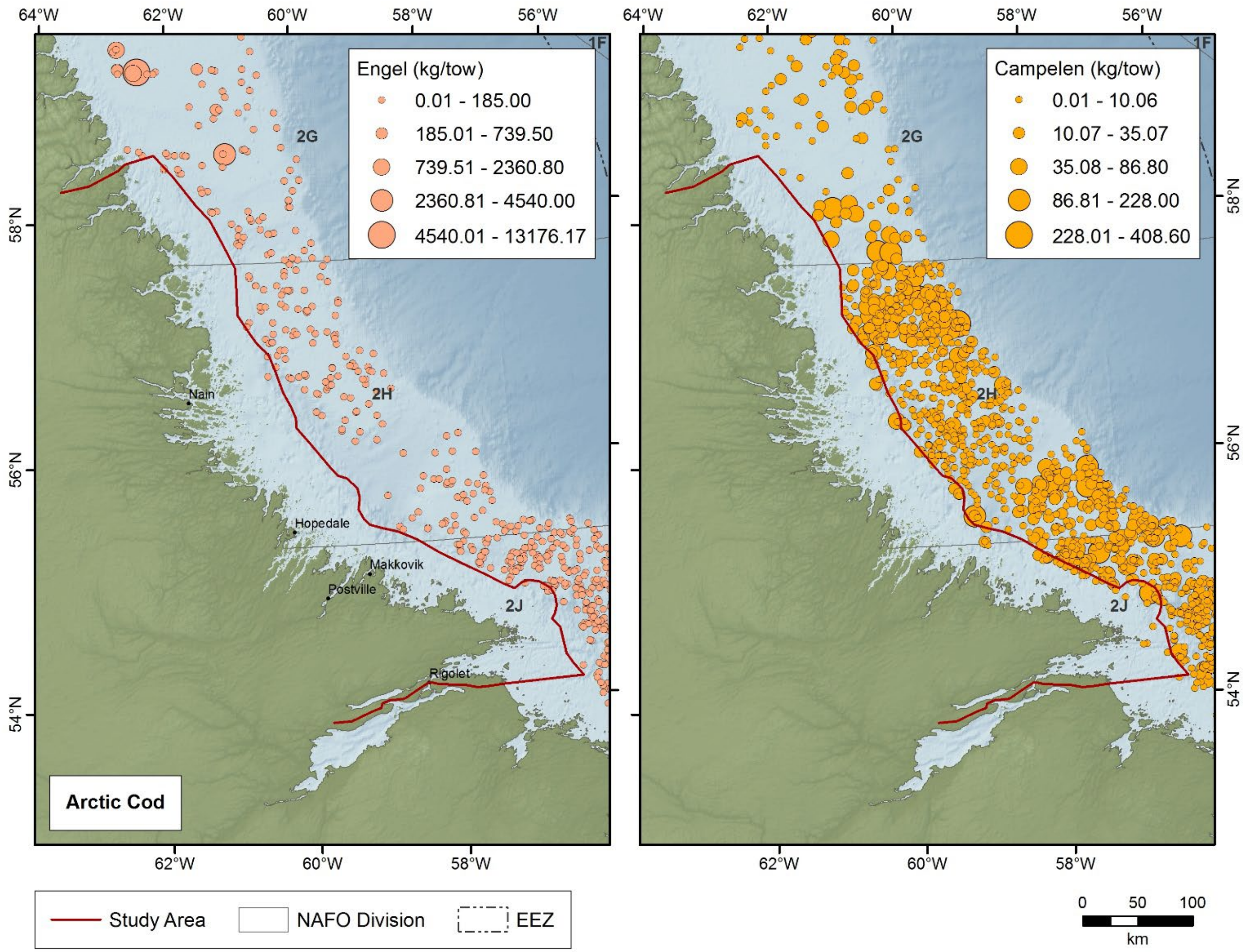


Figure 9.14: Distribution of Arctic Cod (Boreogadus saida) as observed in RV multispecies trawl surveys (1977–2017) in NAFO Divisions 2GHJ.

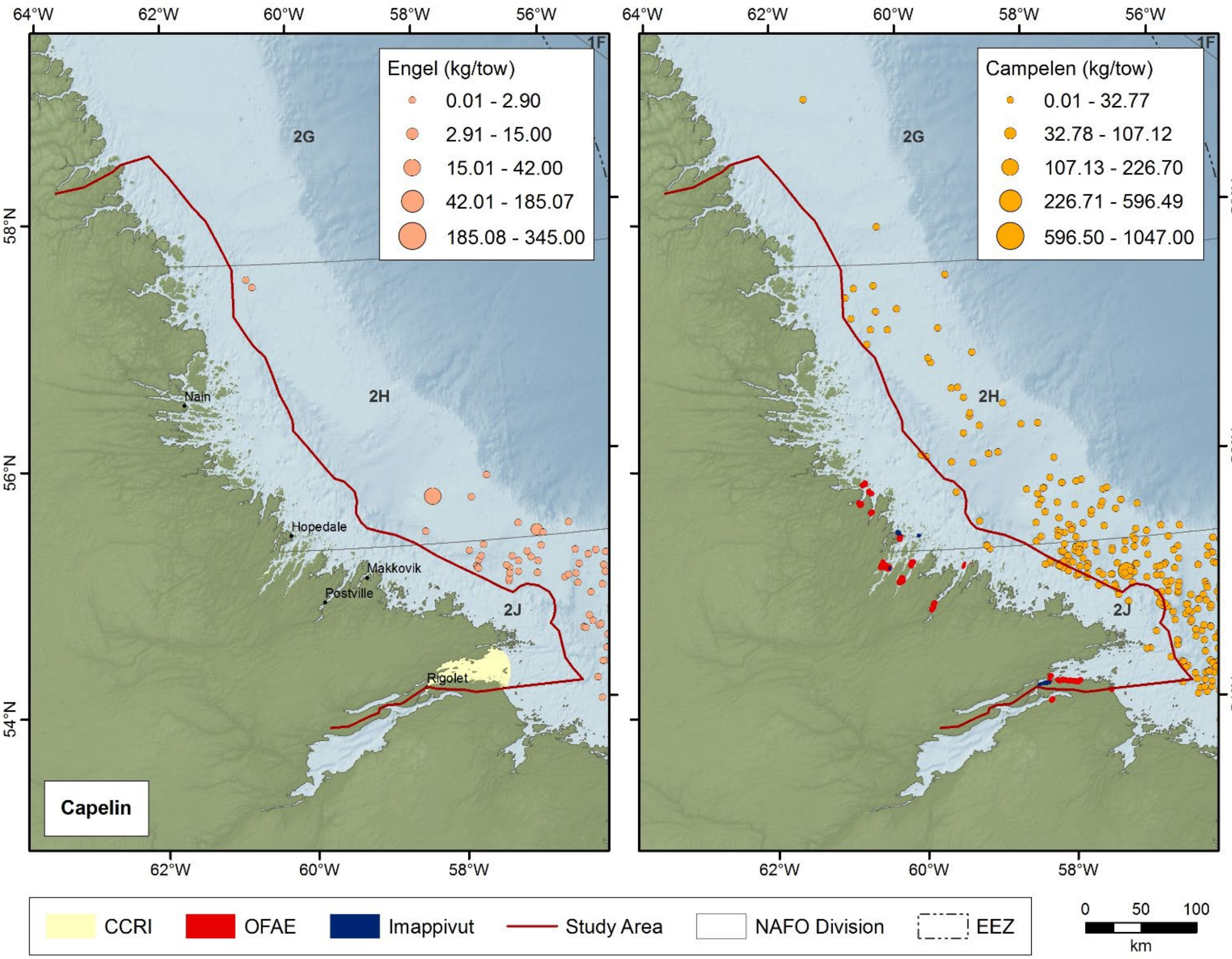


Figure 9.15: Distribution of Capelin (Mallotus villosus) as observed in RV multispecies trawl surveys (1977–2017), the CCRI, Our Footprints are Everywhere (Brice-Bennet 1977), and Nunatsiavut Government Imappivut data collections (Nunatsiavut Government 2018) in NAFO Divisions 2GHJ.

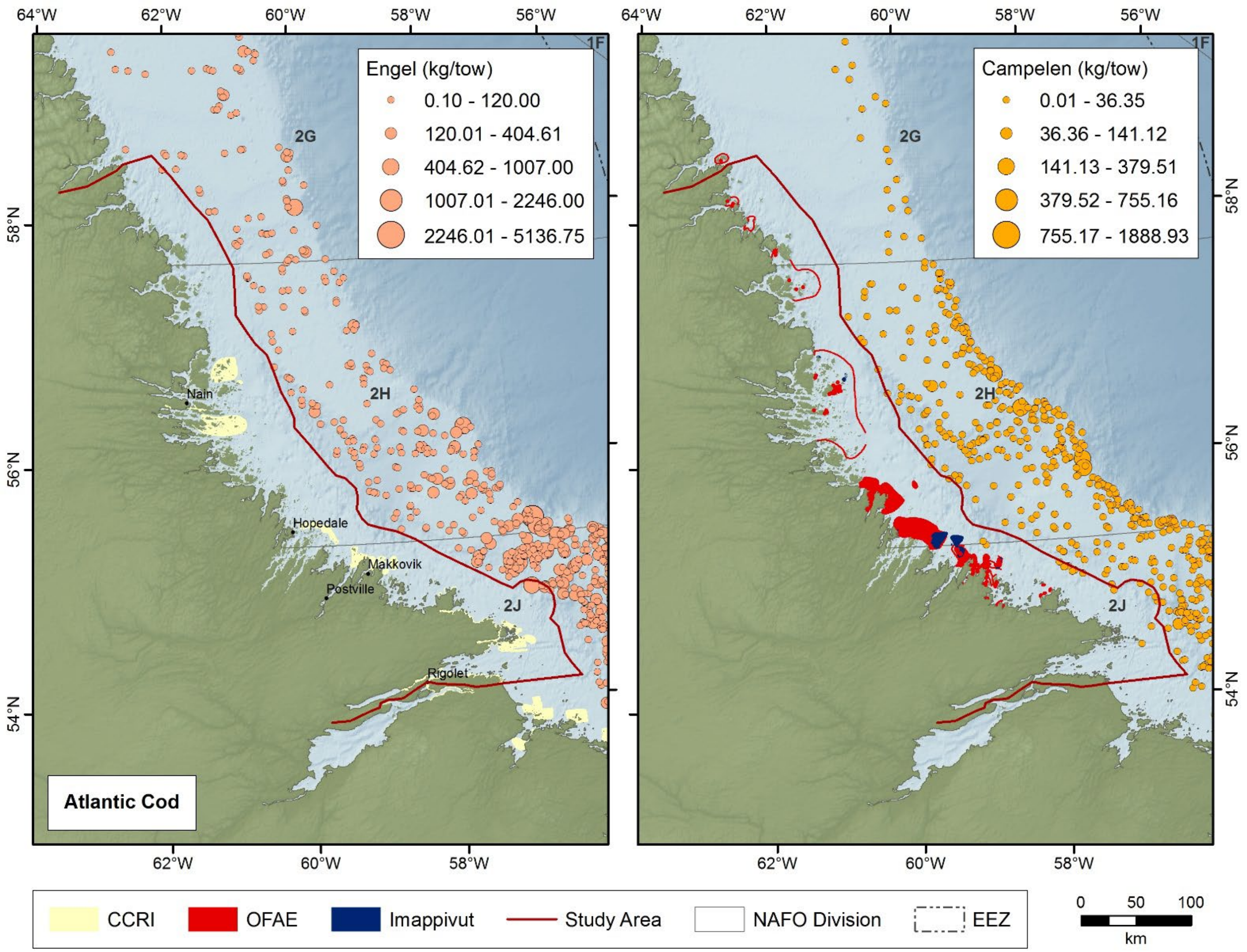


Figure 9.16: Distribution of Atlantic Cod (Gadus morhua) as observed in RV multispecies trawl surveys (1977–2017), the CCRI, Our Footprints are Everywhere (Brice-Bennet 1977), and Nunatsiavut Government Imappivut data collections (Nunatsiavut Government 2018) in NAFO Divisions 2GHJ.

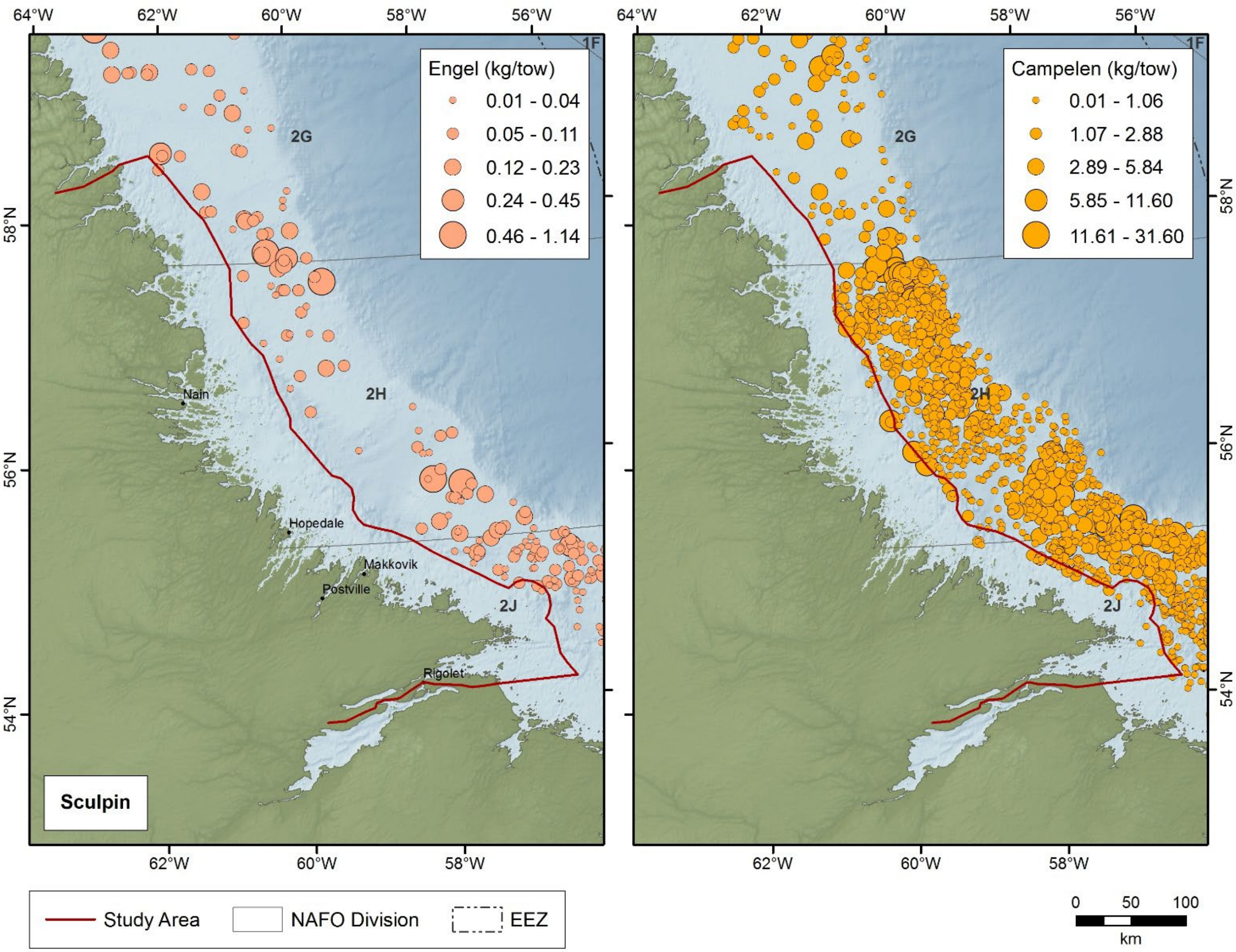


Figure 9.17: Distribution of Mailed Sculpin (Triglops sp.) as observed in RV multispecies trawl surveys (1977–2017) in NAFO Divisions 2GHJ.

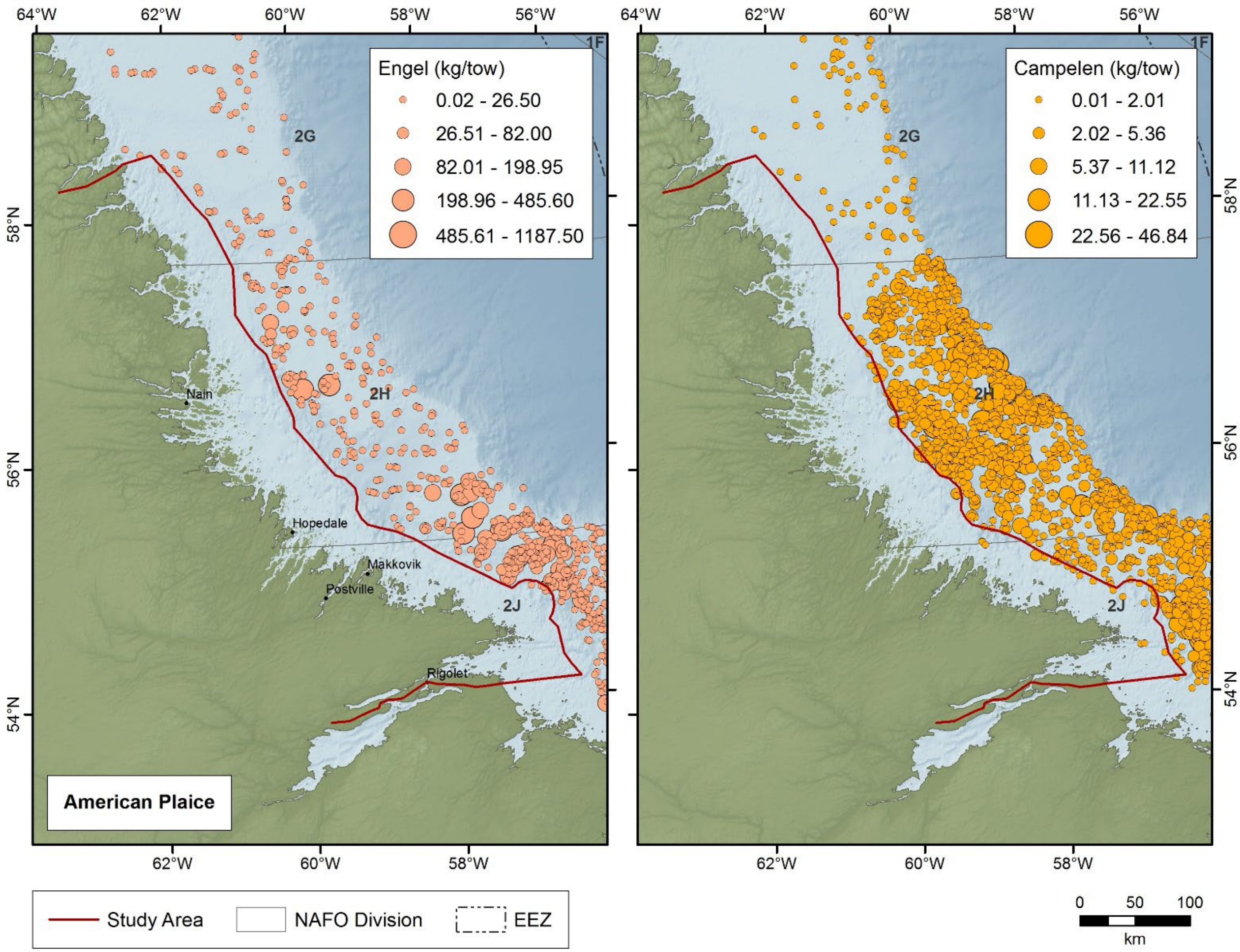


Figure 9.18: Distribution of American Plaice (Hippoglossoides platessoides) as observed in RV multispecies trawl surveys (1977–2017) in NAFO Divisions 2GHJ.

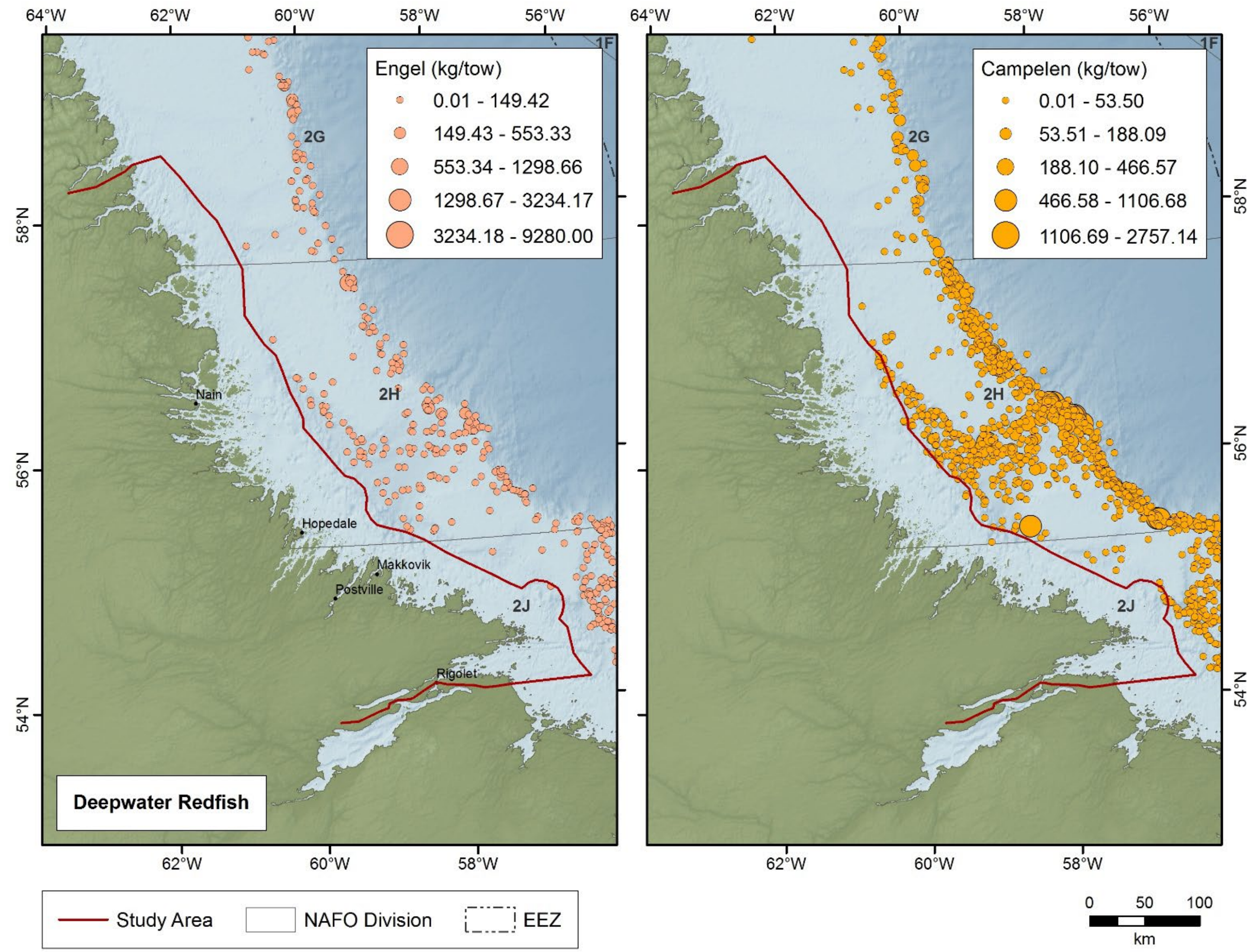


Figure 9.19: Distribution of Deepwater Redfish (Sebastes mentella) as observed in RV multispecies trawl surveys (1977–2017) in NAFO Divisions 2GHJ.

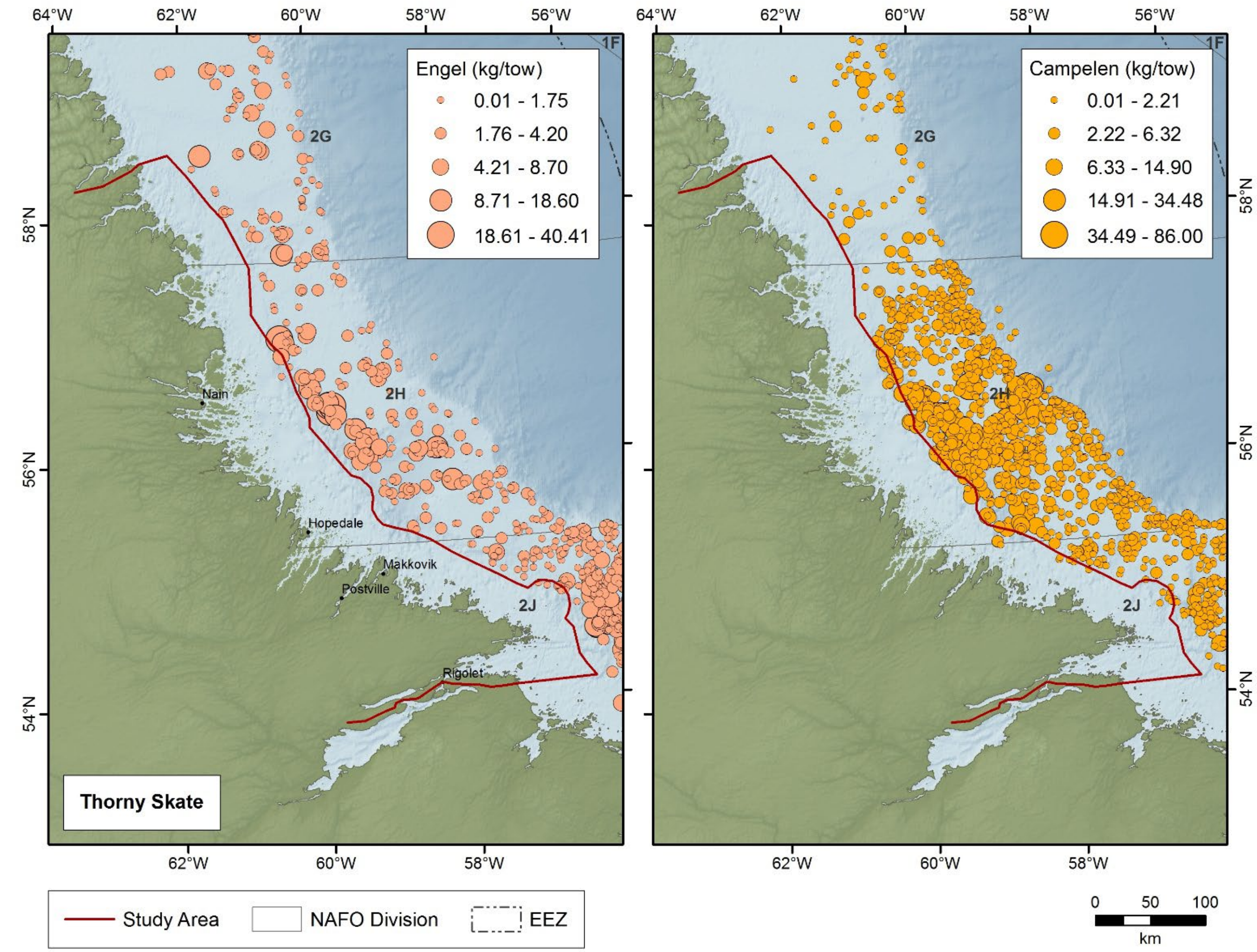


Figure 9.20: Distribution of Thorny Skate (Amblyraja radiata) as observed in RV multispecies trawl surveys (1977–2017) in NAFO Divisions 2GHJ.

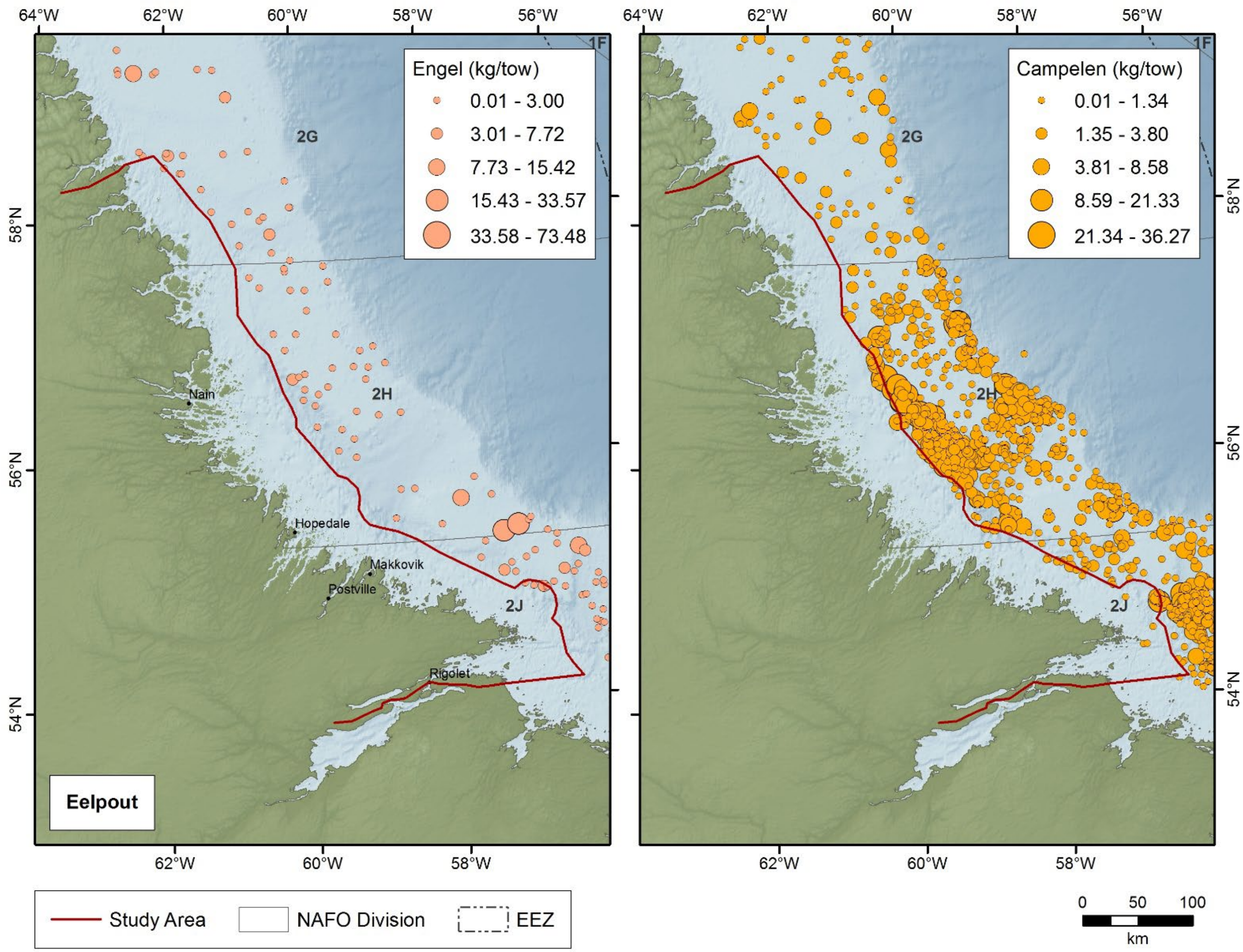


Figure 9.21: Distribution of Eelpout (Lycodes sp.) as observed in RV multispecies trawl surveys (1977–2017) in NAFO Divisions 2GHJ.

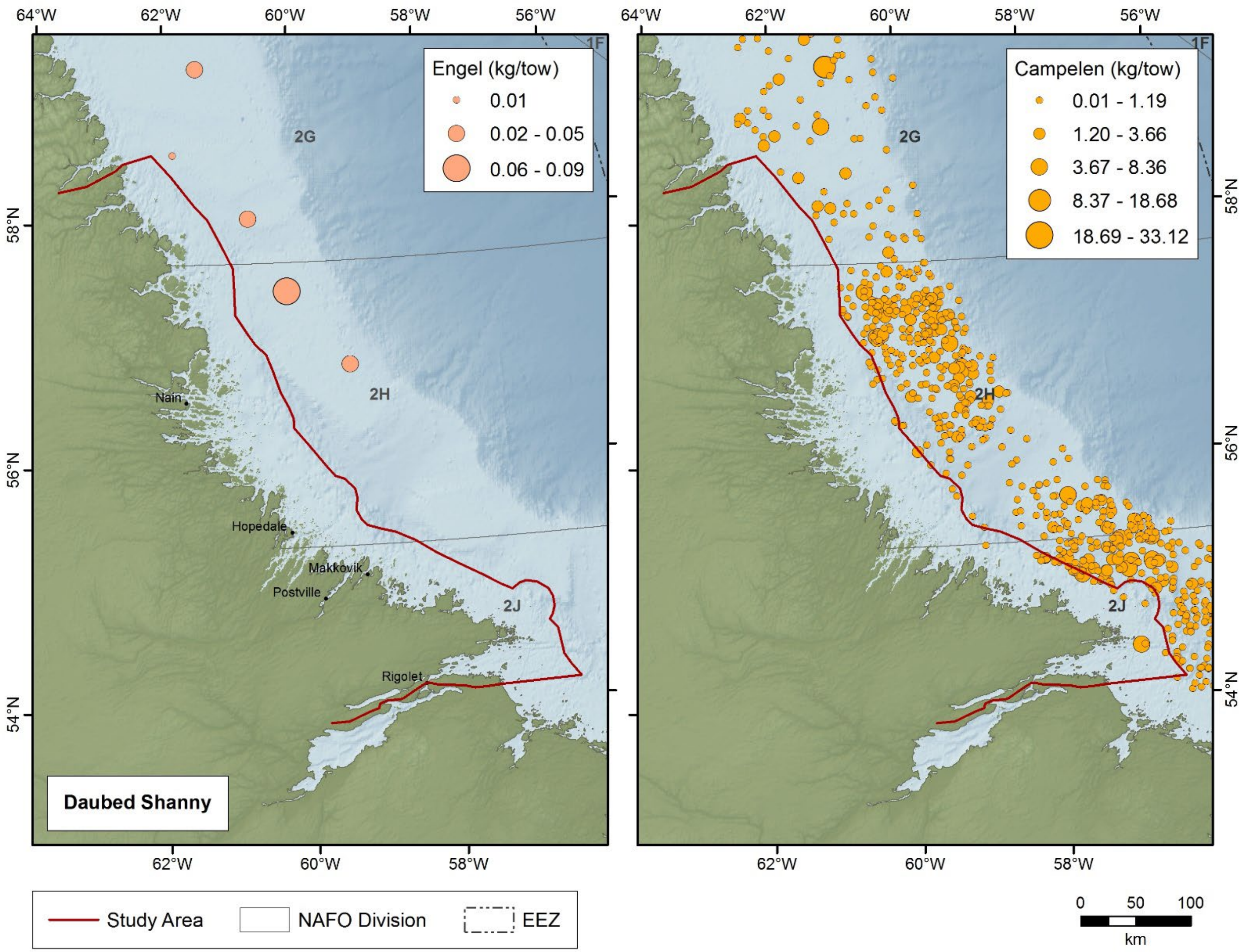


Figure 9.22: Distribution of Daubed Shanny (Leptoclinus maculatus) as observed in RV multispecies trawl surveys (1977–2017) in NAFO Divisions 2GHJ.

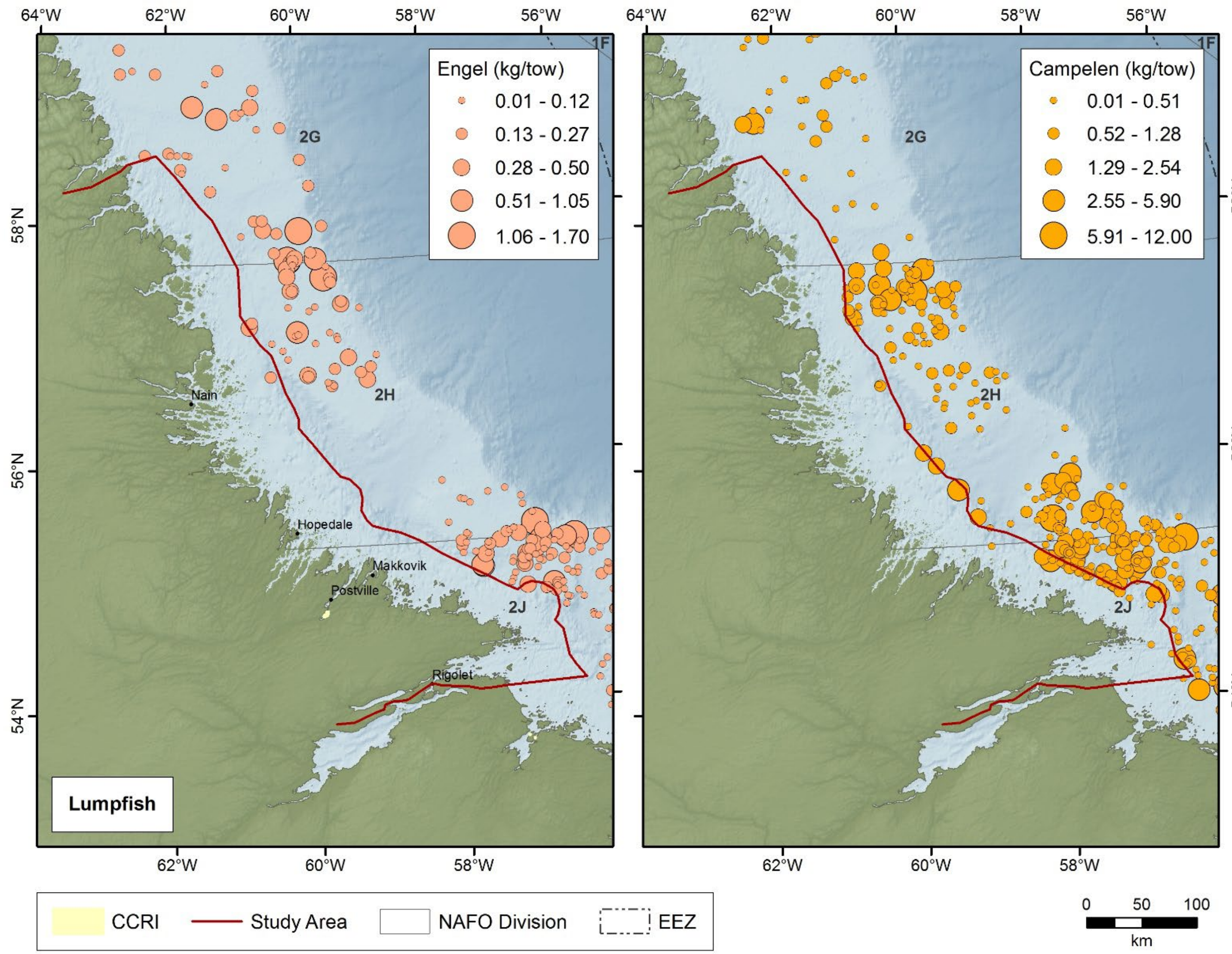


Figure 9.23: Distribution of Lumpfish (Eumictrotremus sp.) as observed in RV multispecies trawl surveys (1977–2017) and the CCRI in NAFO Divisions 2GHJ.

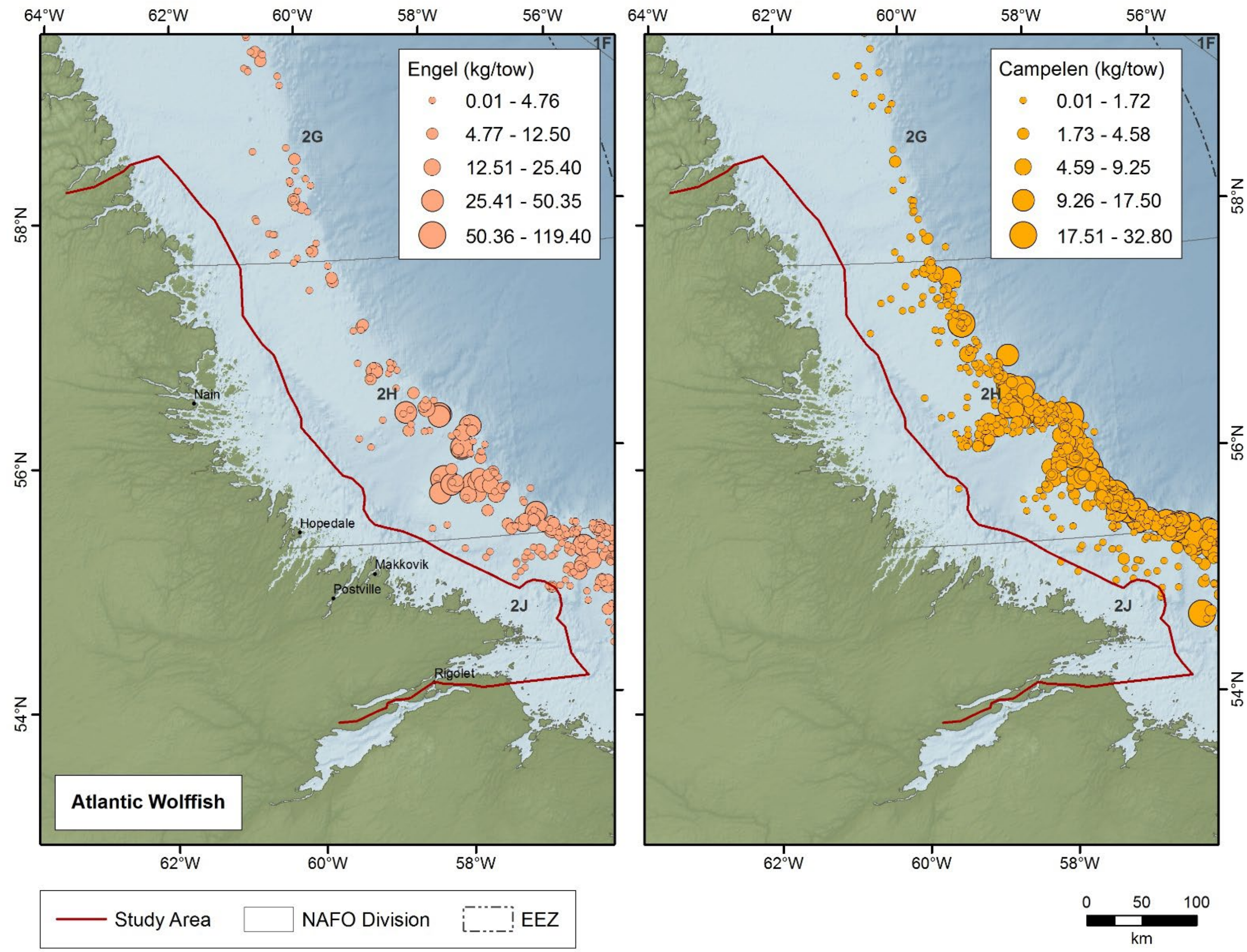


Figure 9.24: Distribution of Atlantic Wolffish (Anarhichas lupus) as observed in RV multispecies trawl surveys (1977–2017) in NAFO Divisions 2GHJ.

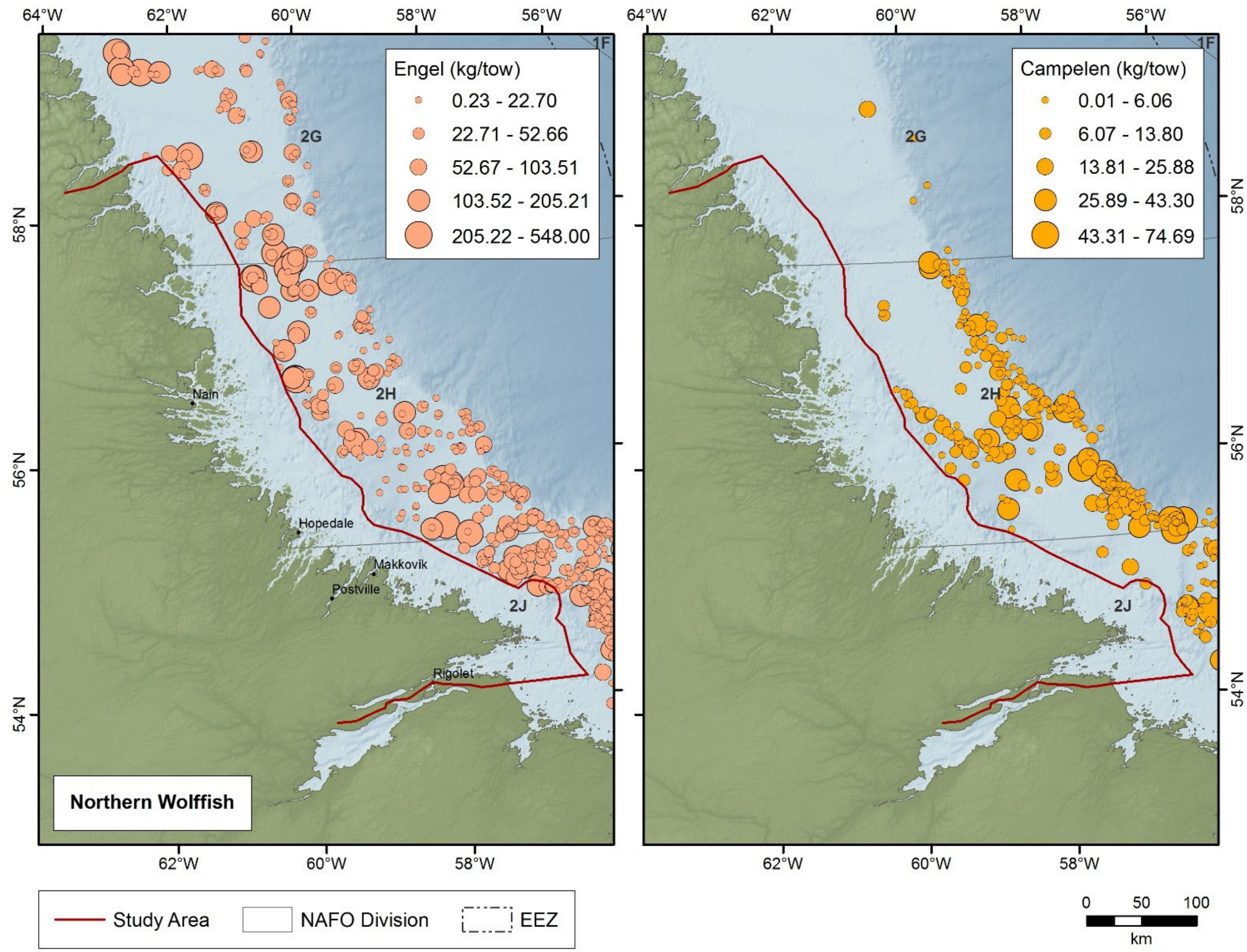


Figure 9.25: Distribution of Northern Wolffish (Anarhichas denticulatus) as observed in RV multispecies trawl surveys (1977–2017) in NAFO Divisions 2GHJ.

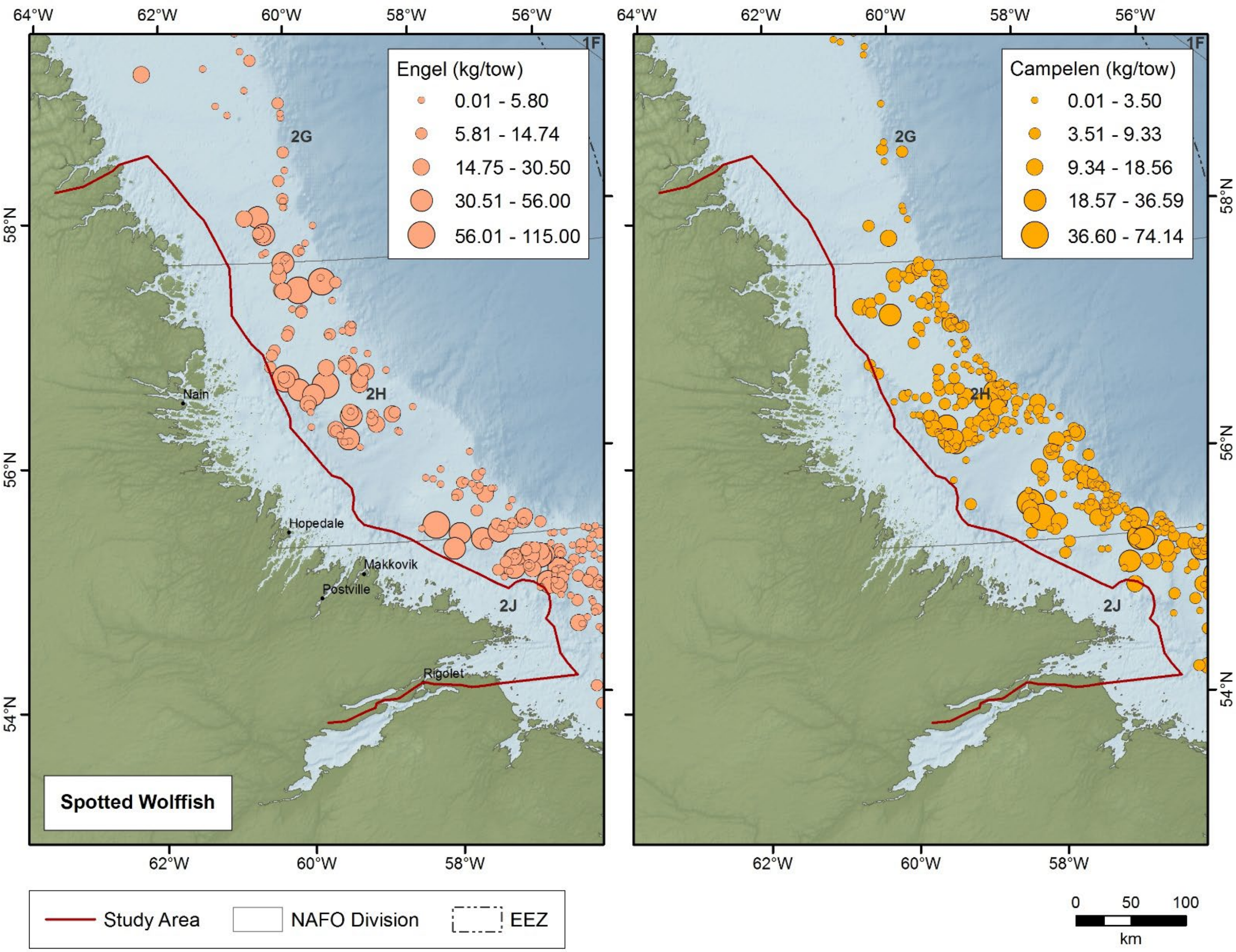


Figure 9.26: Distribution of Spotted Wolffish (Anarhichas minor) as observed in RV multispecies trawl surveys (1977–2017) in NAFO Divisions 2GHJ.

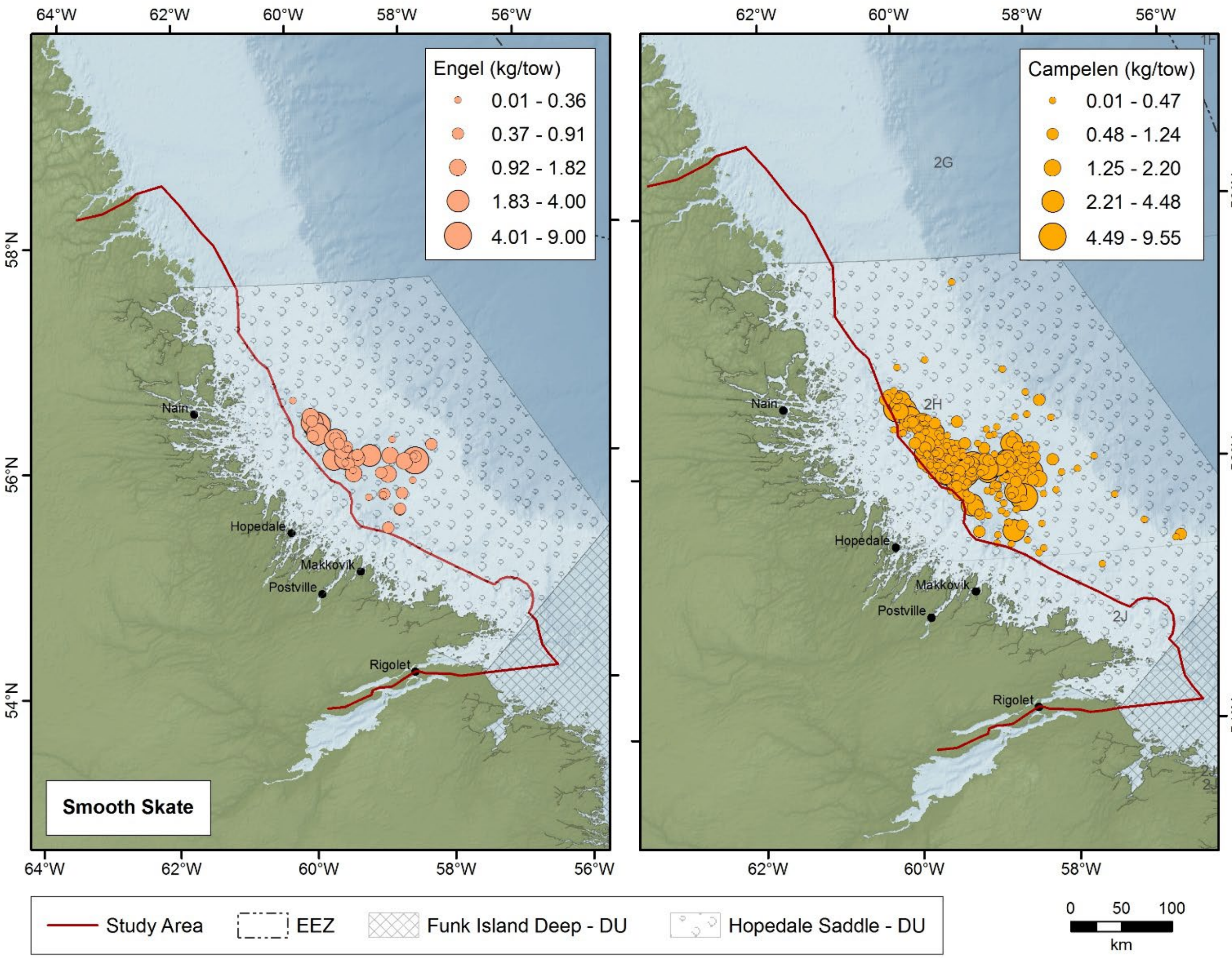


Figure 9.27: Distribution of Smooth Skate (Malacoraja senta) as observed in RV multispecies trawl surveys (1977–2017) in NAFO Divisions 2GHJ. Designatable Units (DU) depicted on the map are adapted from COSEWIC (2012e).

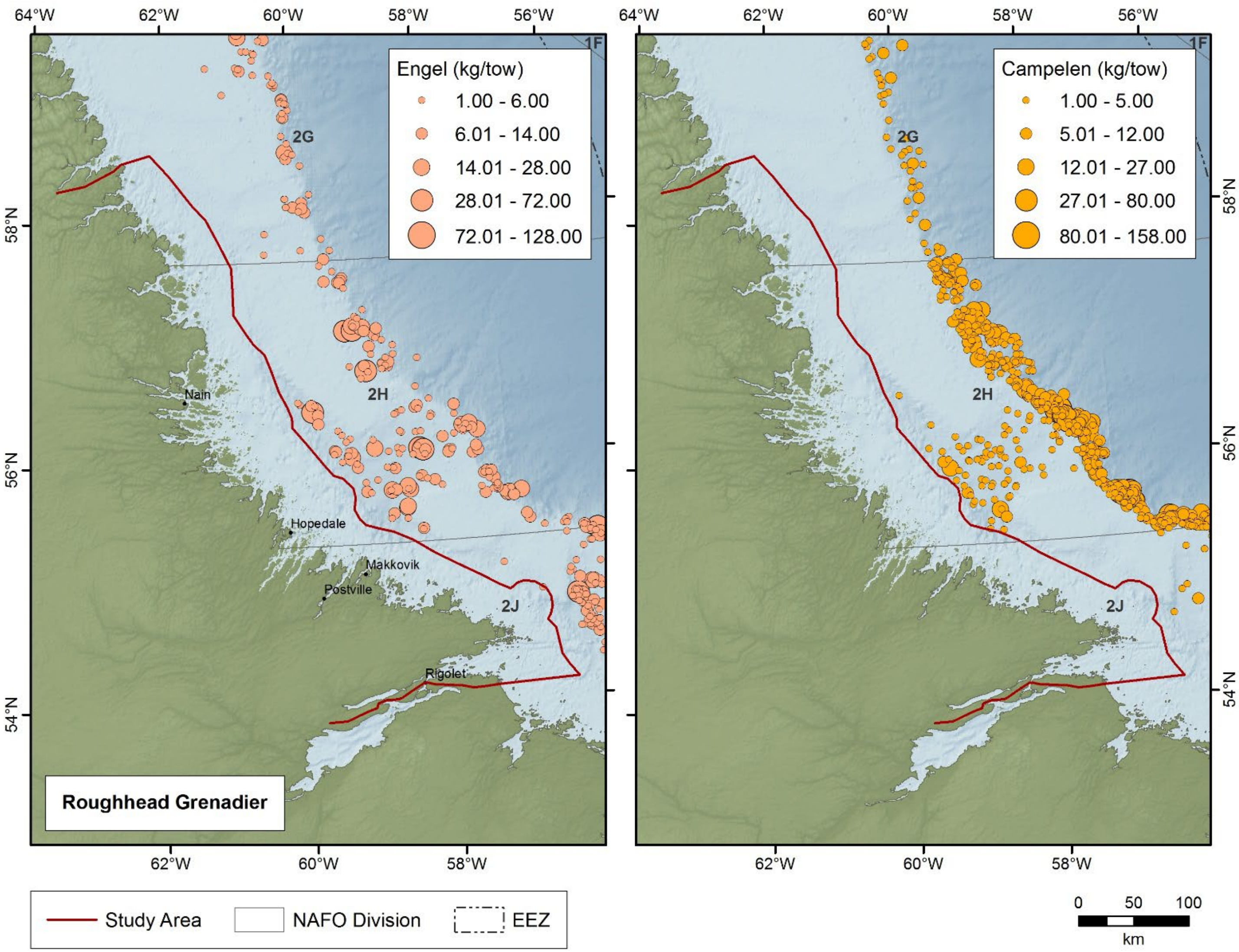


Figure 9.28: Distribution of Roughhead Grenadier (Macrourus berglax) as observed in RV multispecies trawl surveys (1977–2017) in NAFO Divisions 2GHJ.

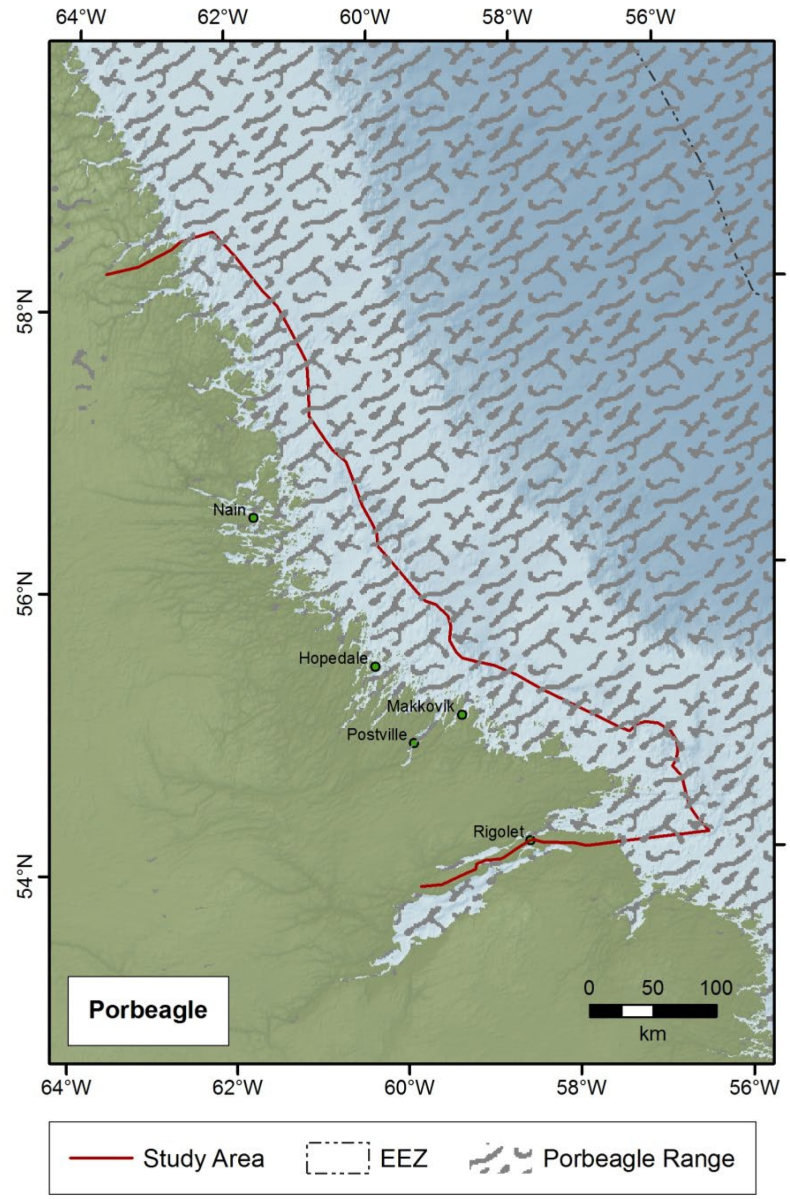


Figure 9.29: Range of Porbeagle (Lamna nasus) within and adjacent to the study area.

9.2. Sensitive Species and Habitats

There are several species and habitats within the study area that may be sensitive to natural and/or anthropogenic stressors or threats. Sensitive species include those that have been assessed by COSEWIC as being Special Concern, Threatened, or Endangered, or species that are considered vulnerable to impacts due to their particular life history traits.

9.2.1. Nearshore/Coastal Fishes

Arctic Char and Atlantic Salmon are fish species that have cultural, ecological, subsistence, and commercial importance to the Labrador Inuit. COSEWIC has yet to assess Arctic Char. Atlantic Salmon originating from the Labrador Coast have been assessed as “Not at Risk”. There are; however, other COSEWIC-listed salmon populations within Atlantic Canada that are known to migrate through the study area en route to winter feeding grounds in the Labrador Sea (COSEWIC 2010c).

Arctic Char and Atlantic Salmon may be useful umbrella species (i.e., conservation of these species may indirectly protect many others) due to their preference for cold water habitats and their reliance on a variety of habitats including freshwater rivers, lakes, estuaries, and marine environments (Reist et al. 2006). The stressors and sensitivities that impact char and salmon may also apply to other anadromous fish species, such as Brook Trout and Smelt, that are targeted by a subsistence fishery in the study area.

Arctic Char occupy the study area during their marine feeding phase, which begins after ice break up (typically May and early-June) and extends to early-July through mid-September (Dempson and Green 1985; Dempson and Kristofferson 1987; Beddow et al. 1998). However, some char may return to local rivers as late as September, depending on age of char and geographic location (Dempson and Kristofferson 1987). In contrast, Atlantic Salmon migrate from within and beyond the study area during more extensive marine migrations to feeding grounds off Labrador and western Greenland (COSEWIC 2010c; Coad and Reist 2018). Poor environmental conditions during these migrations could have negative impacts for both of these species. Poor ocean survival is considered the primary cause of the observed widespread decline of Atlantic Salmon (COSEWIC 2010c). The marine feeding phase for Arctic Char is also critical to build up food reserves to survive the winter, when feeding largely ceases (Mulder et al. 2018a, 2018b).

Climate change may have several implications for Arctic Char and Atlantic Salmon. First, the cold-adapted physiology of Arctic Char and Atlantic Salmon can make them vulnerable to a warming climate in freshwater and marine environments. Like many fish species (Perry et al. 2005; Fossheim et al. 2015; Morley et al. 2018), this may result in northward shifting distributions for Arctic Char and Atlantic Salmon and potentially expose them to competition from encroaching southern species (Hassol, 2004; Power et al. 2012; Reist et al. 2006). Fish communities may be altered by moderate warming (increases in 1–3°C), for example cod and Capelin productivity off central Labrador are expected to increase with elevated sea temperatures (Hassol, 2004). Second, prey densities and communities can shift with climate, which could in turn have implications to growth, reproductive potential, survival, and degree of anadromy for these species that rely heavily on the marine phase of feeding (Michaud et al. 2010; Power et al. 2012). Third, resistance to disease is an adaptation that is specific to latitudinal clines (e.g., Dionne et al. 2007). Changes in climate conditions may alter the available disease assemblage and leave locally adapted species like Arctic Char and Atlantic Salmon at risk. Collectively, such changes could have large impacts on the study area's ecosystem and on the Labrador Inuit who depend on these species.

Estuaries are likely the most sensitive habitats for Atlantic Salmon and Arctic Char as they are important staging areas for anadromous fish species during migrations to and from freshwater, aiding in osmoregulation processes and serving as feeding areas for juvenile and adult fishes (Bouillon and Dempson 1989; Spares et al. 2015).

9.2.2. Offshore Fishes

While depths within the study area range from 0–730 m, the majority (98.9%) of habitat is between 0–360 m deep. As a result, seabed features associated with depths greater than 360 m represent unique habitats within the boundaries of the study area. Species most commonly associated with deep water are typically found concentrated along the seaward edges of the study area boundary where shelf valleys, basins, and glacial troughs extend into the area (Harris et al. 2014). In Labrador, Hopedale, Cartwright, and Hawke Saddles constitute particularly important habitats for Deepwater Redfish, Atlantic Wolffish, Northern Wolffish, Smooth Skate, Roundnose Grenadier, Greenland Halibut, and Eelpout (NS). Alternatively, Arctic Cod, Mailed Sculpin (NS), American Plaice, Daubed Shanny, Lumpfish (NS), Rock Cod, and Spotted Wolffish, which are typically associated with medium to high relief areas on the continental shelf, were observed in the highest densities across Nain, Makkovik, and Hamilton Banks. Of the species whose preferred depth range overlaps much of the study area, Arctic Cod, Capelin, and Daubed Shanny play significant ecological roles as key forage species for fish, birds, and marine mammals (Meyer Ottesen et al. 2011; Wienerroither et al. 2011; DFO 2018d).

Of the dominant and sensitive species listed in Table 9.3 and Table 9.4, Atlantic Cod, Greenland Halibut, American Plaice, Capelin, Deepwater Redfish, Northern Wolffish, Spotted Wolffish, and Smooth Skate (Funk Island Deep population), and Porbeagle have undergone significant declines in abundance and biomass relative to the 1980s. Recently, Atlantic Cod, American Plaice, Capelin, Northern Wolffish, Spotted Wolffish, and Smooth Skate have experienced increasing trends, but abundance and biomass have not returned to historical levels. Greenland Halibut biomass continues to decline, while Deepwater Redfish stocks have remained steady since the mid-1990s. Porbeagle numbers have remained low but stable for the past decade. Northern Thorny Skate populations saw declines, but abundances have recovered to levels near the 1970s. Atlantic Wolffish and Roughhead Grenadier populations declined until approximately 1994, after which they experienced increasing trends. However, because no conversion factors exist for Engel time series for these species, the specific abundance and biomass estimates for Engel and Campelen periods cannot be directly compared (COSEWIC 2012a, Simpson et al. 2017). Refer to Appendix D for specific information on the abundance and biomass estimates, where available, as well as references for each species listed in Table 9.3 and Table 9.4.

9.3. Data Gaps and Recommendations

Coastal Labrador is largely considered data deficient for many fish species in comparison to more intensively studied areas further south (e.g., Newfoundland, Gulf of St. Lawrence, etc.). The dominant nearshore/coastal fishes that have been studied within the study area are anadromous fish species that are important to commercial, subsistence, and recreational fisheries in the region. Many of the anadromous fishes collected in these studies were from freshwater systems such as rivers, streams, lakes, and ponds, as well as nearshore marine areas including estuarine and fiord systems.

9.3.1. Nearshore/Coastal Fishes

Seasonal ice coverage, harsh environmental conditions, and high sampling costs are some of the primary factors which limit the opportunity to conduct surveys and studies in coastal Labrador. Accordingly, there is limited availability of specific data on distributions and abundance of coastal fish species, as well as the habitats that they occupy within the study area.

Future research within the study area could target more baseline studies, as well as studies directed towards obtaining more information on species abundance. Additional surveys of coastal, nearshore, and anadromous fish species is recommended, especially in coastal and inshore areas where little sampling has been completed. This would provide greater insight into fish habitats, associated fish communities, and ecological processes occurring within the region. For example, there is little known about Rock Cod within the region, even though it has become an increasingly important subsistence fish for Labrador Inuit. However, as previously mentioned, a tagging-telemetry study examining the coastal movements of Rock Cod and Arctic Char is underway.

Even species that have been the subject of considerable scientific investigations have significant data gaps within the study area. Much of the quantitative work on Arctic Char and Atlantic Salmon are restricted to the area extending from Voisey's Bay to Hebron, whereas for Atlantic Salmon, monitoring is restricted to the counting fence on the English River. Arctic Char are commonly encountered at this counting fence as well during salmon enumeration however their numbers are not routinely published in stock assessments. Qualitative data obtained from LK complement quantitative scientific baseline surveys well, but such information also has limits to its temporal and spatial scope as it is primarily based on observations from typical harvesting areas and seasons. Beyond these regions there is limited data on these species within the study area (Reddin et al. 2010). It is recommended that LK be utilized to address spatial and temporal variability of fish distributions and populations within the study area through targeted questions in future LK interviews. Sustainable fisheries management for both char and salmon is a priority for Labrador Inuit; however, a stock assessment has not been conducted for Arctic Char since 2003. Furthermore, there are few data sources on subsistence and recreational landings for either char or salmon (Dempson et al. 2004; Dempson et al. 2008). During the marine phase, both char and salmon can be found in mixed stocks and therefore, it is difficult to determine the source of harvested fish for monitoring (Moore et al. 2017). Moore et al. (2017) proposed integrating telemetry and genomic datasets as a means of obtaining a greater understanding of Arctic Char migrations. Accordingly, research has now been directed towards doing this for Arctic Char populations in Labrador. The development of new genetics techniques has also provided greater resolution of Atlantic Salmon populations in coastal Labrador fisheries and could be applied to other anadromous fish populations (Bradbury et al. 2018). This could aid in projecting the effects of climate change and associated geographical shifts of different fish populations in response to climate change (Jeffery et al. 2017; Sylvester et al. 2018). Environmental effects are particularly important for understanding Arctic Char stock dynamics and variation in stock characteristics (i.e., stock age, weight and length, and timing of downstream migrations) for Arctic Char stocks from year to year (Power et al. 2000; Power et al. 2005).

A greater understanding of how coastal Labrador is ecologically connected to other regions, including how coastal areas support offshore areas and vice versa through the provision of nutrients, critical stage-specific habitats, larvae, etc. will help establish the benefits of conservation both within and beyond the study area as well as determine the potential for external influences (e.g., overharvesting beyond the study area).

Time series data, which currently do not exist for sensitive and important coastal fish in this region, are critical to our understanding of how fish species are responding to climate-related and anthropogenic disturbances over time. For example, diet shifts have been reported in Arctic Char in response to broad ocean changes (Dempson and Shears 2001; Dempson et al. 2008). Ecological changes are likely to occur across a variety of fish species as the marine environment off Labrador continues to change.

9.3.2. Offshore fishes

The lack of RV trawls within the study area boundaries creates a primary gap in information on offshore fish species distribution and abundance in this area. Furthermore, of the trawls that have been performed, only 16 were conducted in the past 10 years. Data are particularly sparse within Division 2G, where survey trawl sets have not been collected there since 1999 (Rideout and Ings 2018). These spatial and temporal data gaps limit the ability to identify species and habitats requiring protection. Additional trawls within the shallower strata of Divisions 2GHJ could be used to bridge this information gap; however, bottom topography within the study area contains many features (e.g., cliffs and peaks) which make it unsuitable for trawl surveys. Other methods (e.g., modified trawling approaches, video surveys, etc.) better suited to shallow water environments are recommended to characterize and monitor fish species of importance in this predominantly coastal environment. Benthic habitats of the study area have been largely preserved due to limited access by trawls, a unique condition on the NL shelf. As such, future research should be conducted in a way that minimizes impacts, through the use of non-invasive survey techniques (e.g., ROVs, BRUVs, drop cameras). The presence of sea ice also inhibits RV surveys from being completed in northern areas of the region during the spring (Rideout and Ings 2018), meaning there is a limited ability to capture potential seasonal movements of the species along the coast of Labrador.

Another major gap exists for pelagic species (e.g., Porbeagle, Capelin), which are not targeted by RV trawl surveys. Such species likely play important roles in the study area but are more difficult to sample due to gear-specific biases. Acoustic surveys, such as those performed for Capelin (DFO 2018d), could provide valuable insight into pelagic species distribution, and could also be used to potentially generate biomass and abundance estimates within the study area (Handegard et al. 2013; Davidson et al. 2015). Species distribution modelling (SDM) could also provide information on important areas for pelagic fish (Juntunen et al. 2012; Phillips et al. 2017). Unfortunately, information on habitat types, as well as the environmental variables which drive species distributions, is sparse along the Labrador Coast and would need to be collected prior to the development of such models.

Current research is being conducted through the Marine Institute to collect local knowledge of Capelin along the coast of Labrador and the Eastern Quebec Lower North Shore. It is anticipated that the results of this project will lead to a deeper understanding of Capelin and its relationship with fisheries and communities, as well as contribute to ecological understanding of life-history traits of this critical forage fish. This project will provide a basis for future research and decision-making by guiding acoustic surveys in the area and directing conservation efforts.

10. Marine Mammals

Seven species of cetaceans and five species of pinnipeds have been identified as important to the study area based on local and scientific knowledge (see Table 10.1). Polar bears will also be discussed in this section. Each of these species has ecological, cultural and, for some, commercial importance to the area. Other marine mammal species are known to occur here (Lawson and Gosselin 2009, 2018; Brice-Bennett 1978) but are less common and/or have less ecological and cultural significance.

Table 10.1: List of all marine mammal species that have been observed within the study area or within 50 km of the study area.

Cetaceans	Pinnipeds	Other
Killer Whale*	Harp Seal*	Polar Bear*
Humpback Whale*	Harbour Seal*	-
Minke Whale*	Ringed Seal*	-
White-beaked Dolphin*	Bearded Seal*	-
Long-finned Pilot Whale	Grey Seal*	-
Fin Whale*	Atlantic Walrus	-

Cetaceans	Pinnipeds	Other
Common Dolphin	Hooded Seal	-
Atlantic White-sided Dolphin	-	-
Beluga Whale†	-	-
Harbour Porpoise*	-	-
Sei Whale	-	-
Northern Bottlenose Whale	-	-
Fin/Sei Whale†	-	-
Sperm Whale	-	-
Blue Whale	-	-
Risso's Dolphin	-	-
Bowhead Whale	-	-

** Those marked with an asterisk are discussed in this chapter because of their ecological, commercial, or cultural significance.*

† Those marked with a cross are discussed in this chapter because of conservation concerns.

Collectively, marine mammals are consumers of production at most trophic levels. Because of their large body size and abundance, they are thought to have a major influence on the structure and function of some marine communities (Bowen 1997). Pinnipeds, although smaller in body size than many cetaceans, can be significant consumers if their abundance is very high (e.g., Harp Seals) but their influence on prey dynamics is highly debated (Trites 1997). For example, Buren et al. (2014b) found that biomass dynamics of Northern cod were best explained by a combination of fisheries removals and capelin availability, whereas seal consumption was not found to be an important driver of the Northern cod biomass. In addition to their role as apex predators, seal and cetacean carcasses can provide important food for terrestrial and benthic scavengers, as well as polar bears (e.g., Galicia et al. 2016, McKinney et al. 2017). Seabirds and some fishes also benefit from feeding associations with cetaceans (Katona and Whitehead 1988). Marine mammals in general have been shown to enhance primary productivity in feeding areas by concentrating nitrogen near the surface through the release of flocculent fecal plumes (Roman and McCarthy 2010).

10.1. Available Information

10.1.1. Cetaceans

In addition to their ecological value, cetaceans have historically provided important cultural and subsistence value to Inuit. For example, an extensive review of the history of whaling in Labrador (Brice-Bennett 1978) provides context on the value that has been placed on these species for centuries.

Cetaceans sighting records have been collected by DFO in the Newfoundland and Labrador region dating back to the mid-1800s. There are also records of whales spotted, killed, or found dead along the Labrador Coast from the 1700s and 1800s (Brice-Bennett 1978). Most sightings in the Labrador area were recorded during a multi-year survey in support of potential oil and gas development in the 1980s and during recent large scale surveys of Canadian waters. Sources of opportunistic sightings include LK and fish harvesters, whaling records kept by the International Whaling Commission, and fisheries observer records. Two systematic aerial surveys were flown in recent years that included the study area. The Trans North Atlantic Sightings Survey (TNASS) covered all Newfoundland and Labrador waters in 2007 (Lawson and Gosselin 2009), followed nine years later by the Northwest Atlantic International Sightings Survey (NAISS) in 2016 (Lawson and Gosselin 2018).

All species of cetaceans found in the study area have much broader distributions, with most species being found throughout all major oceans (e.g., Fin Whales, Humpback Whales, Killer Whales, and Minke Whales). The Beluga Whale is an exception; this species is only found in Arctic and Subarctic waters but migrates south to the study area during the winter months. The most common dolphin species in the area, the White-beaked Dolphin, is found only in the North Atlantic, in temperate and subarctic waters. The Atlantic White-sided Dolphin is also observed fairly commonly in the study area, particularly in the nearshore waters off the coast of Hopedale. These two species are often identified as “dolphins”, “jumpers” or “squidhounds” locally. The Harbour Porpoise (known locally as “porpoise”) tends to be sighted on continental shelves in cold temperate and sub-polar waters of the Northern Hemisphere and is also a fairly common occurrence near Hopedale.

The biology and ecology of the seven cetacean species, as well as abiotic and biotic factors that influence them can be found in Appendix E. General patterns of distribution within and adjacent to the study area can be derived from the sightings database; however, caution is advised as many of these records were collected opportunistically and may not accurately represent preferred habitats, population size or trends. TNASS and NAISS survey information has been used to estimate regional population size for most species (see Appendix E); however, population size or information on trends is not available at the scale of the study area. LK collected through the Nunatsiavut Government’s Imappivut initiative, as well as digitized records from *Our Footprints are Everywhere* (Brice-Bennett 1977) and the Community Based Coastal Resource Inventory (O’Brien et al. 1998) have been mapped to indicate general distributions for whales, dolphins and porpoises (see Figure 10.1 and Figure 10.2). As seen on these maps, whales, dolphins and porpoises have been observed along much of the coast. It is worth noting that interview participants have observed whales and dolphins throughout the coastal region of the study area, but LK maps presented here are based primarily on harvest locations, so recorded observations do not extend far from shore.

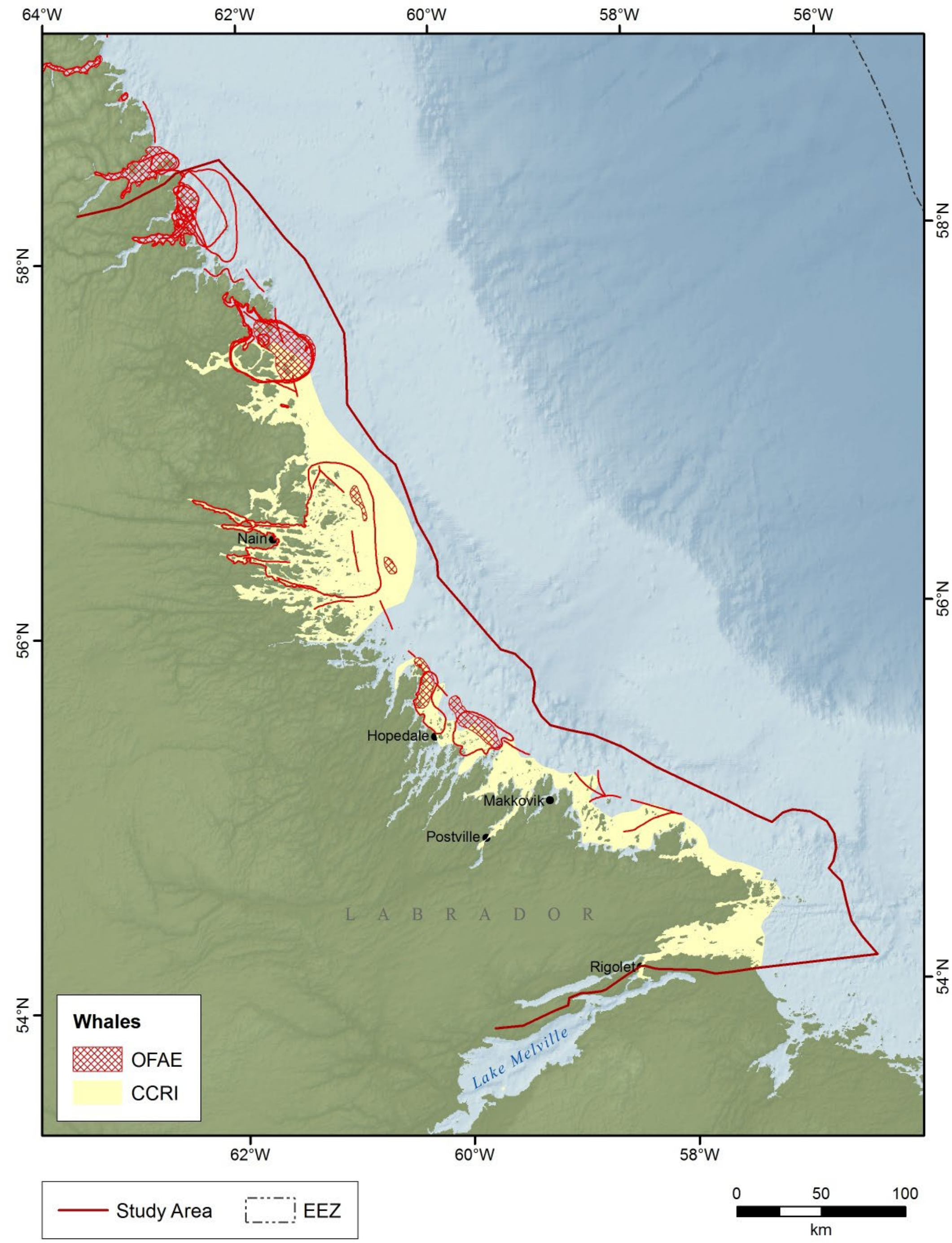


Figure 10.1: Distribution of whales based on Local Knowledge recorded in OFAE and CCRI.

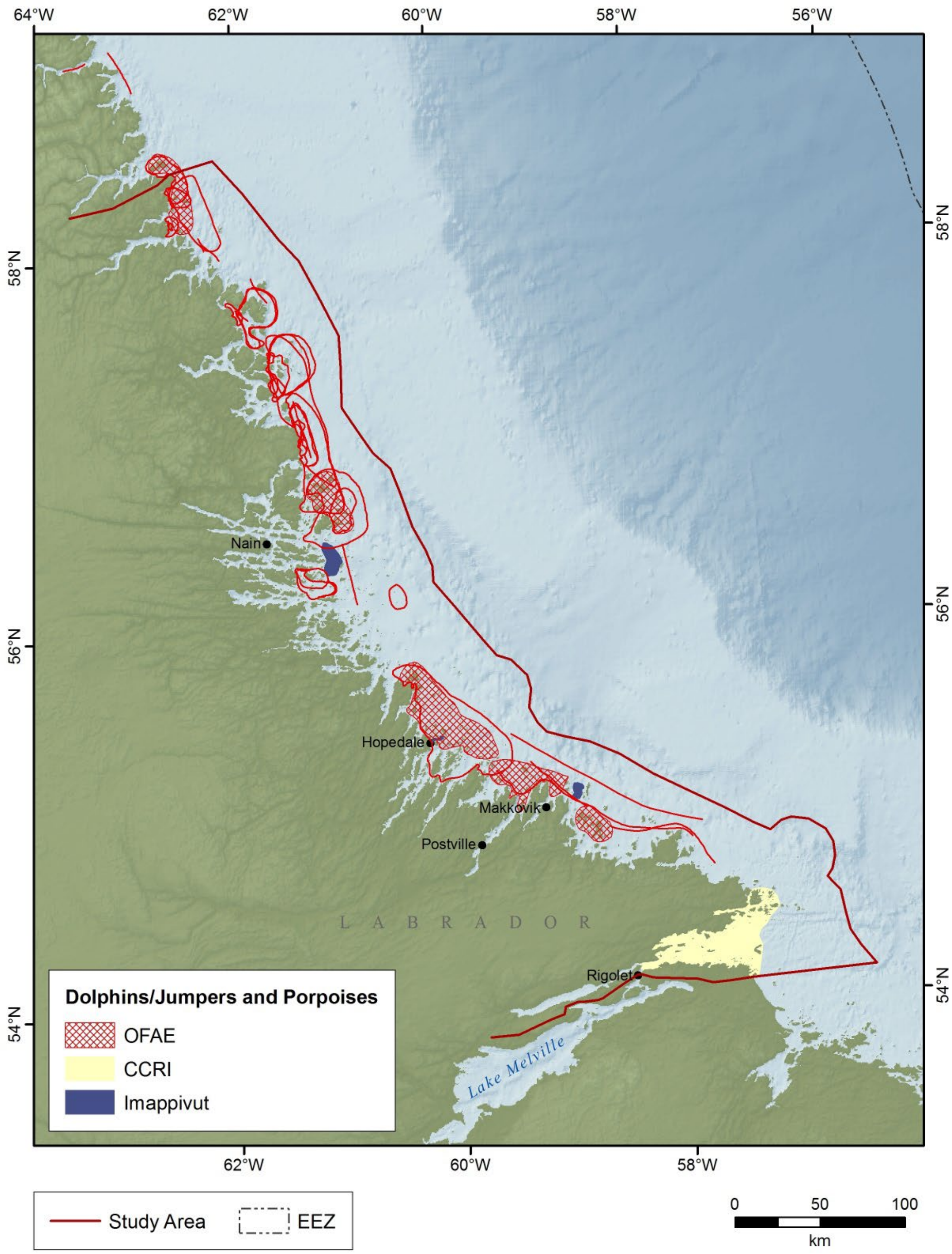


Figure 10.2: Sightings of dolphins and porpoises based on Local Knowledge recorded by Imappivut, OFAE, and CCRI.

Table 10.2 provides an overview of sightings data (including TNASS and NAISS survey data) for the study area, plus the area 20 km and 50 km outside the study area. The buffers are also visible on the maps for each species (Figure 10.3 through Figure 10.9). These buffers were added because the number of sightings within the study area is small, and the general distribution of these species reaches far beyond the study area. Several indices were calculated for buffers of 20 km and 50 km from the study area as a proxy of general distribution or importance relative to the study area. They include:

- the total number of sightings (regardless of pod size) over the entire time series (1864–2016);
- the number of years that a species was observed over the entire time series;
- the frequency of sightings (number of years observed/total number of years (total number of years that sightings were available for the study area and area 50 km outside=39);
- the total number of individuals observed over the entire time series;
- the average maximum number of individuals observed per sighting;
- the median of the maximum number of individuals observed per sighting; and
- the maximum number of individuals observed in one sighting.

While the data are collected opportunistically, the distribution of sightings records across the three sub-areas (within study area boundaries, and 20 km and 50 km buffers) illustrates habitat selection differences between species in this region. For example, the total number of sightings, frequency of sightings and total number of individuals observed of Beluga Whales and Killer Whales (Table 10.2) decreases as you move further from the coastal area. The opposite is true for Fin Whales.

The most commonly sighted species in the study area are Killer Whales (sometimes called “thrashers”), Minke Whales (referred to locally as “grumpus”) and Humpback Whales, and this is reflected in several of the indices. However, the median of the maximum number of individuals observed gives an indication of species that tend to aggregate in larger pods, such as the White-beaked Dolphin and Beluga Whale. Minke whales are most commonly seen in the Nain, Hopedale, and Rigolet areas.

Beluga Whales were observed, killed, or found dead along the coast of Labrador, mostly during spring and winter months from 1811–1928 (Brice-Bennett 1978). The majority of records were from Hebron, Okak and Hopedale, all of which occur within the study area. From the mid-1800s to the early-1900s, they were commonly seen in schools during the summer, and were noted to be found “everywhere” along the Labrador coast (Brice-Bennett 1978). However, beluga populations decreased rapidly, and by the 1920s the sight of a beluga whale south of the Torngat area was considered an unusual event (Brice-Bennett 1978). Hunters who had been active in the Okak and Hebron areas during the 1940s and 1950s described seeing large schools far into the northern bays and fjords. Belugas were usually found near the mouths of rivers where they apparently fed on char and the females bore their young before continuing on their northward migration (Brice-Bennett 1978).

Hunters interviewed for *Our Footprints are Everywhere* (Brice-Bennett 1977) described hunting for belugas along the floe edge in spring, and around seaward islands and in bays during the summer. Core beluga hunting areas were located around the seaward islands outside Hopedale, Nain and Okak and in Hebron, Saglek and Nachvak fjords. According to local informants, belugas appeared early in spring (May, June) and followed the floe edge north, travelling into bays along the coast as soon as patches of open water form in the landfast ice (Brice-Bennett 1978).

Table 10.2: Sightings information for important cetacean species in the study area. Data are from the DFO sightings database which contains records from 1864–2016, including TNASS data (2007) and NAISS data (2016). Total number of years with sightings=39. Frequency of sightings = # years with sightings for species x/total # of years in which sightings were collected (n=39).

Species	Total number of sightings			Number of years with sightings			Frequency of sightings			Total number of individuals observed			Average maximum # of individuals observed			Median of maximum # of individuals observed			Maximum # of individuals observed in one sighting		
	study area	20 km	50 km	study area	20 km	50 km	study area	20 km	50 km	study area	20 km	50 km	study area	20 km	50 km	study area	20 km	50 km	study area	20 km	50 km
Beluga Whale	9	1	0	4	1	0	0.103	0.026	0.000	34	5	0	8.5	5.0	0.0	8.5	5.0	0.0	15	5	0
Fin Whale	8	15	32	4	8	8	0.103	0.205	0.205	18	19	44	4.5	2.4	5.5	2.5	1.5	3.0	12	9	13
Harbour Porpoise	4	4	4	2	2	3	0.051	0.051	0.077	10	9	11	6.5	9.0	4.0	6.5	9.0	5.0	10	9	6
Humpback Whale	31	28	23	9	8	11	0.231	0.205	0.282	94	120	76	10.6	17.1	7.1	5.0	5.0	2.0	55	66	52
Killer Whale	29	13	6	19	7	6	0.487	0.179	0.154	219	104	19	11.5	14.9	3.2	6.0	5.0	1.5	63	81	9
Minke Whale	54	17	29	12	8	12	0.308	0.205	0.308	94	34	44	7.8	4.3	3.7	6.0	2.5	4.0	28	19	9
White-beaked Dolphin	17	14	12	6	4	6	0.154	0.103	0.154	41	27	55	10.7	9.0	10.2	8.5	12.0	8.0	23	13	20

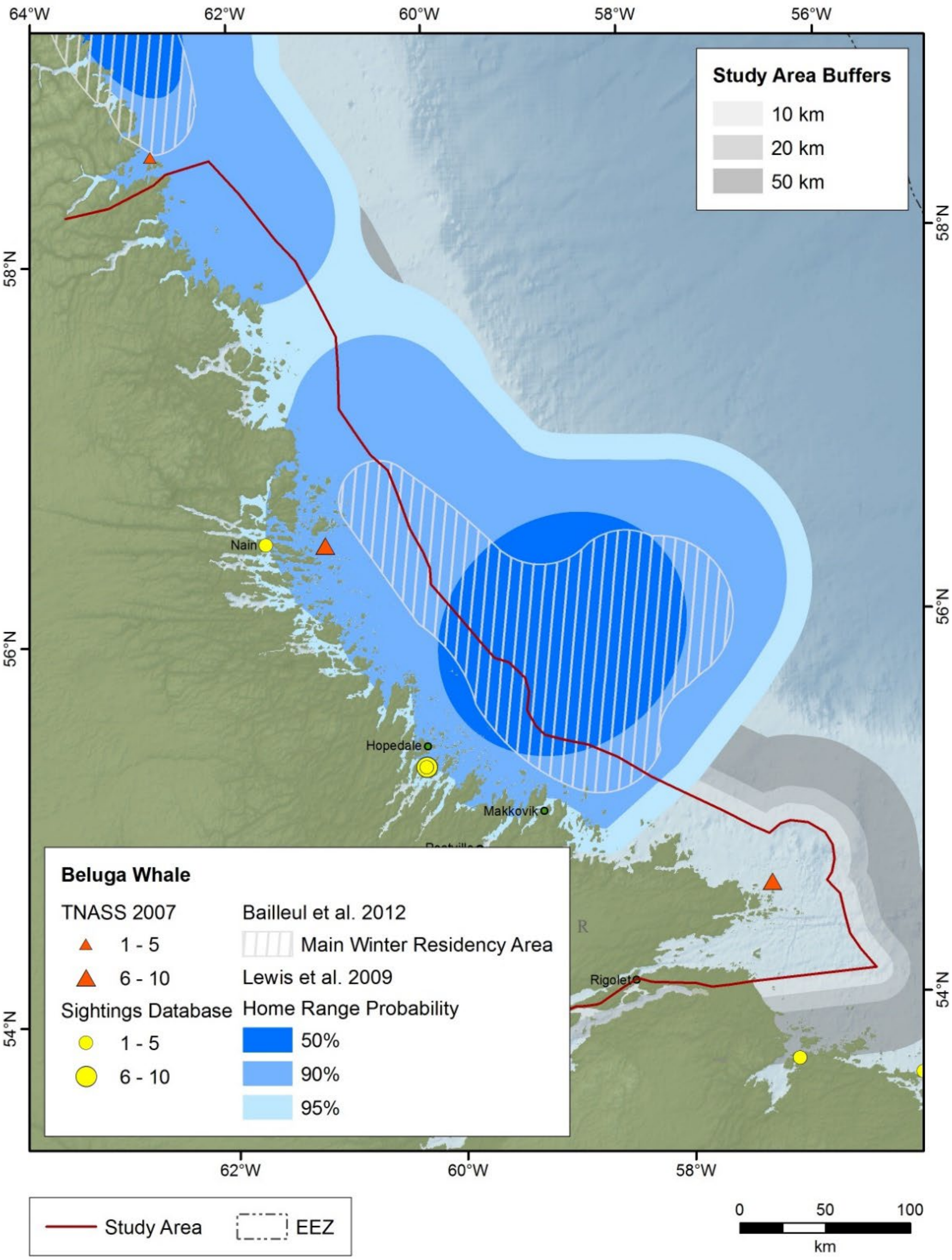


Figure 10.3: Distribution of Beluga Whale sightings and survey observations in and adjacent to the study area. Also displayed are the winter residency area (adopted from Bailleul et al. 2012) and home range probability (adopted from Lewis et al. 2009).

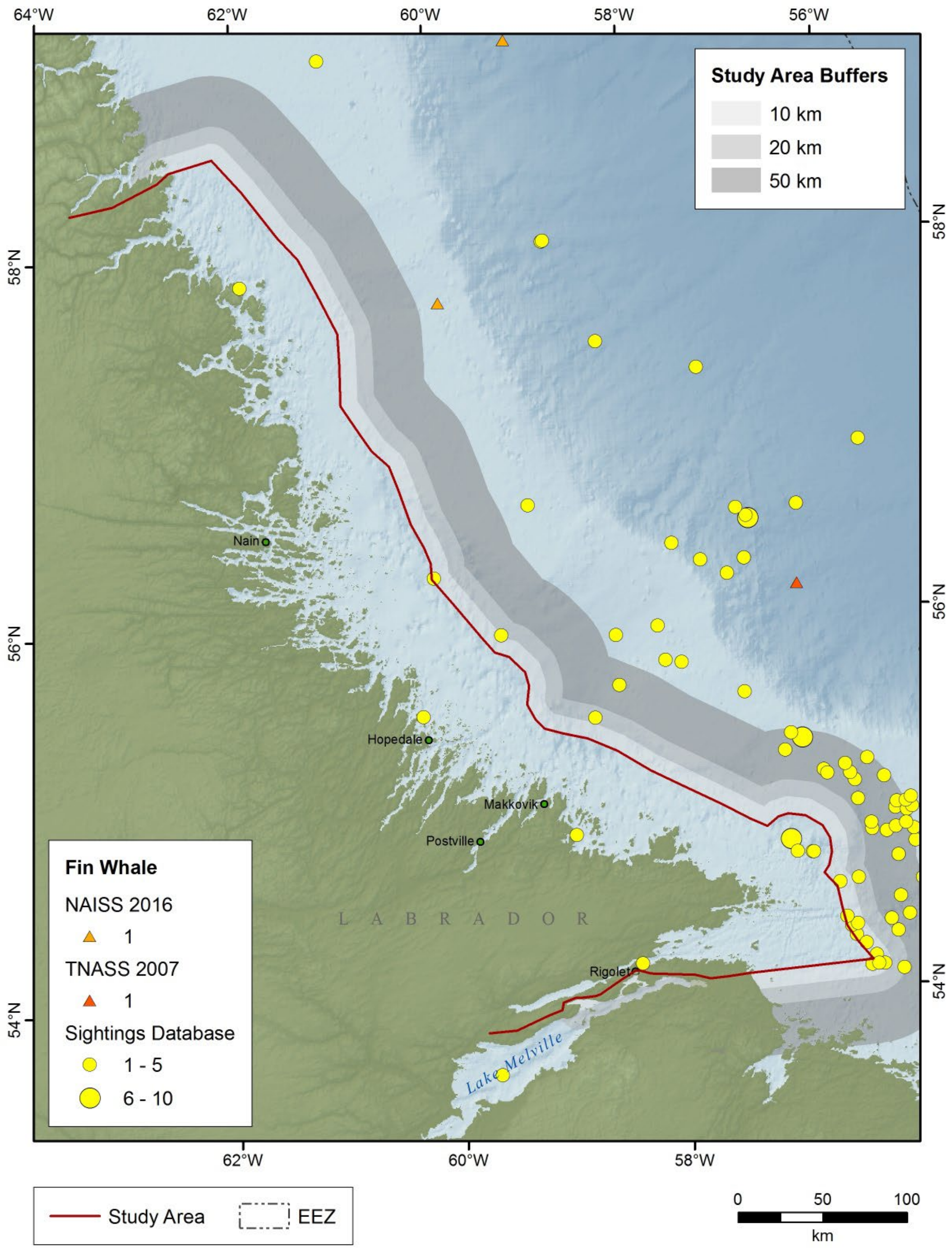


Figure 10.4: Distribution of Fin Whale sightings and survey observations in and adjacent to the study area.

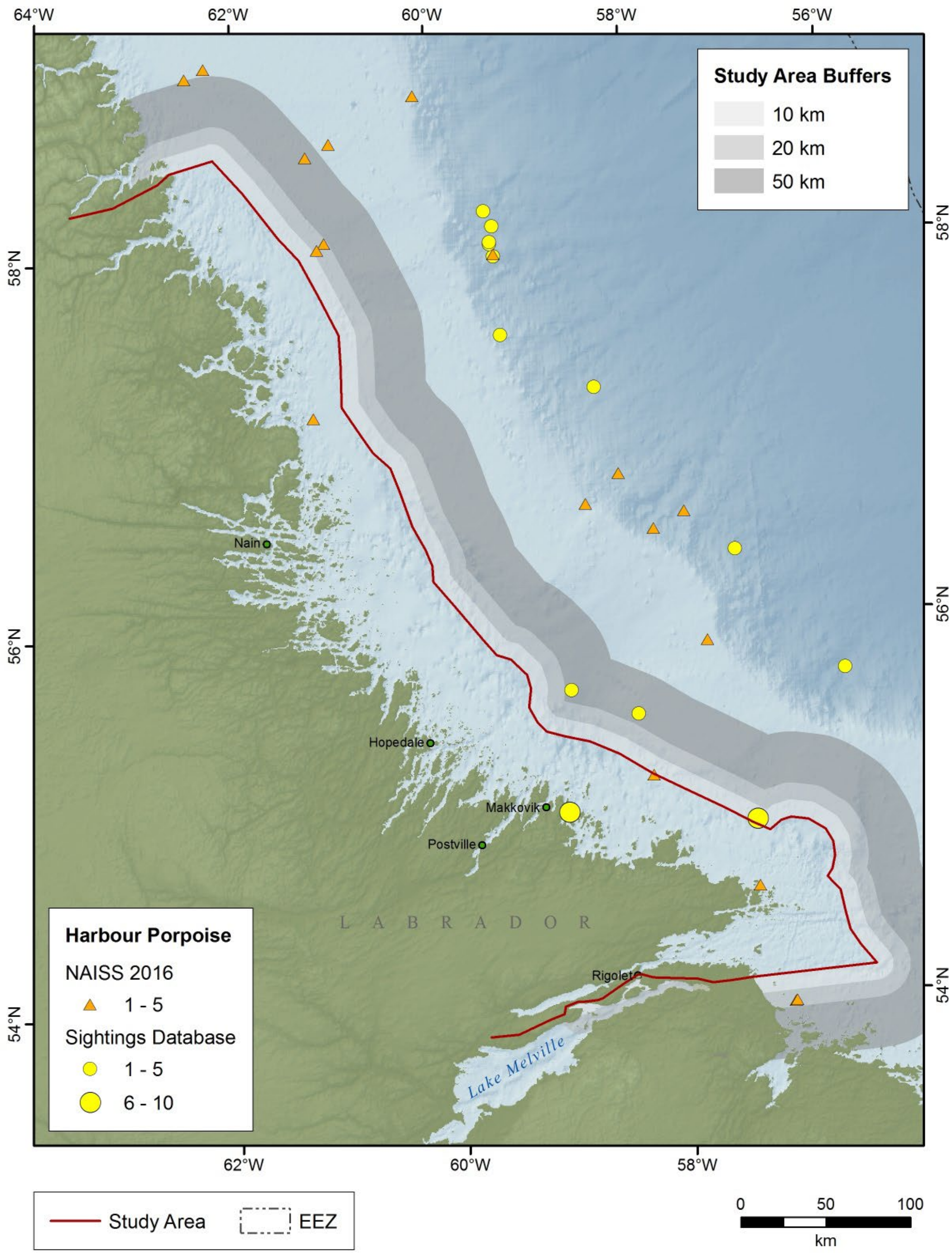


Figure 10.5: Distribution of Harbour Porpoise sightings and survey observations in and adjacent to the study area.

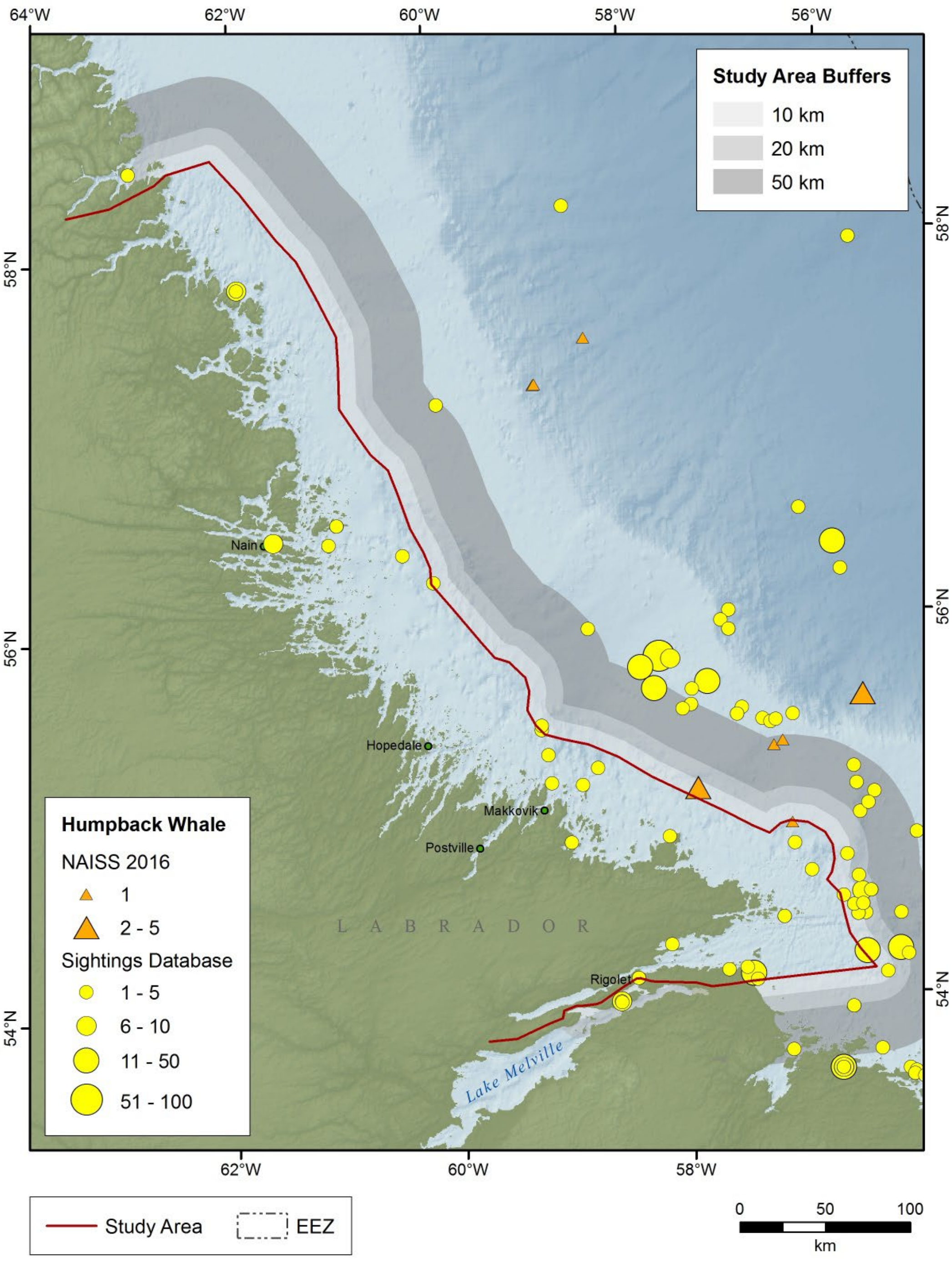


Figure 10.6: Distribution of Humpback Whale sightings and survey observations in and adjacent to the study area.

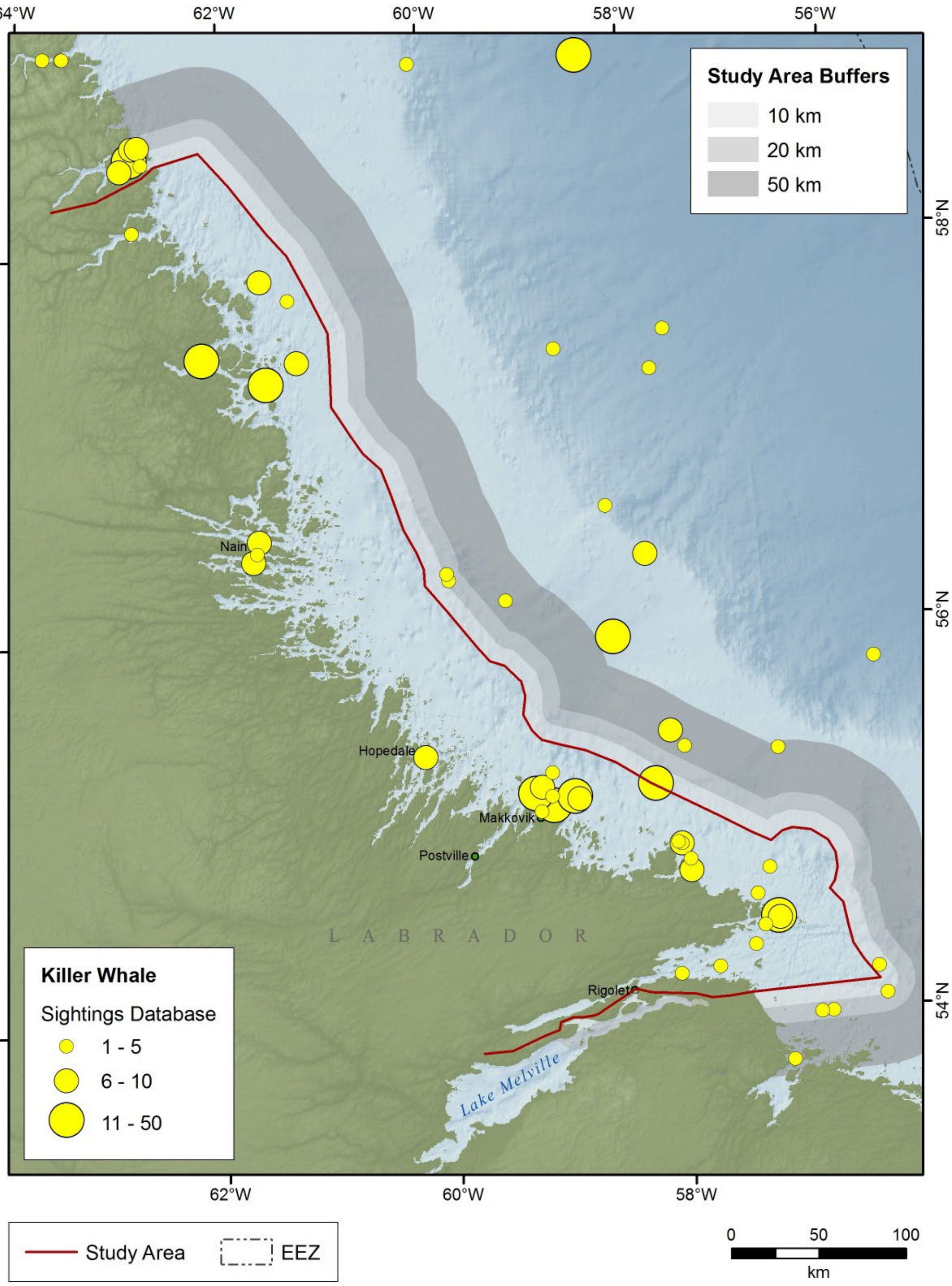


Figure 10.7: Distribution of Killer Whale sightings and survey observations in and adjacent to the study area.

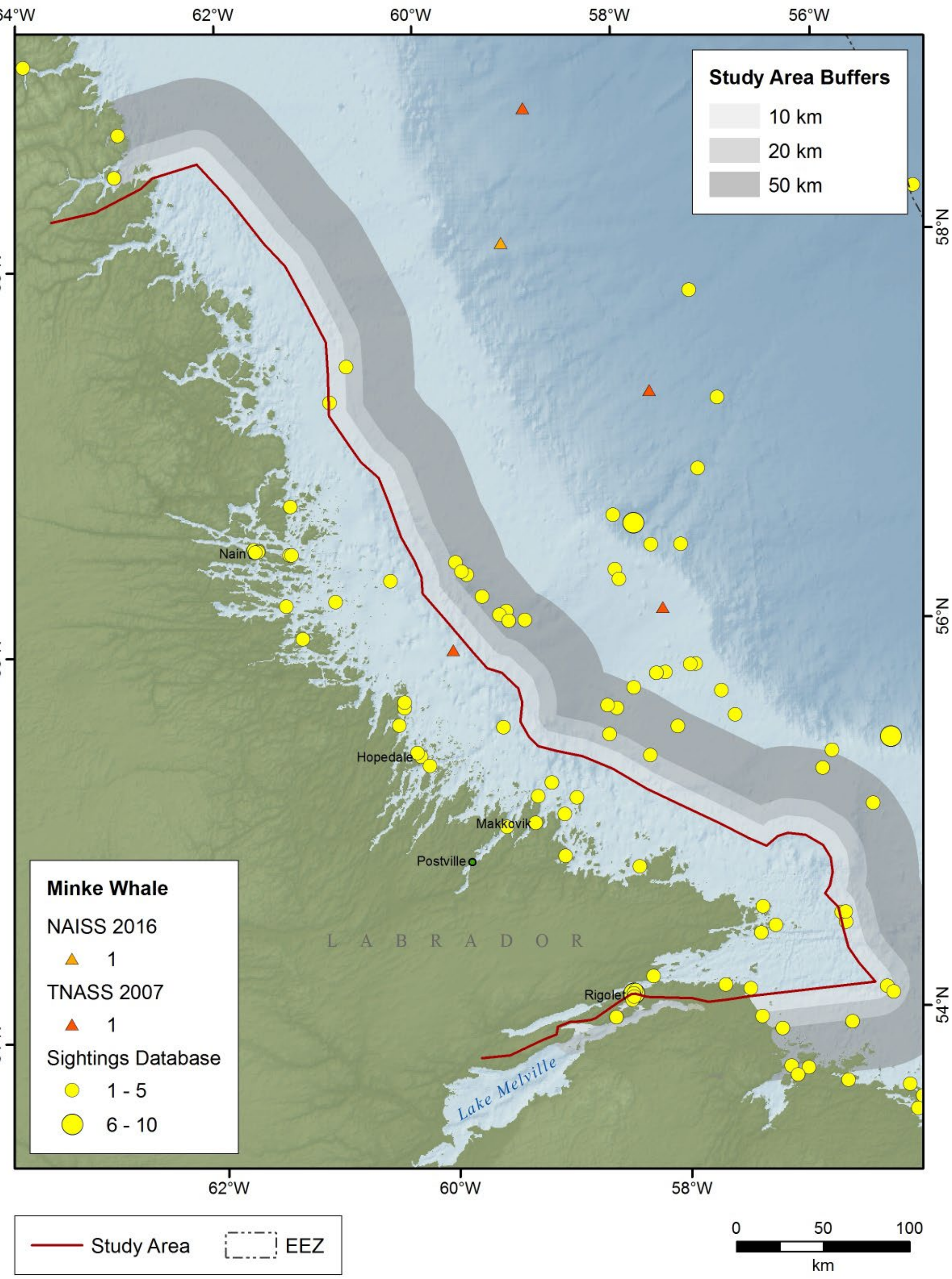


Figure 10.8: Distribution of Minke Whale sightings and survey observations in and adjacent to the study area.

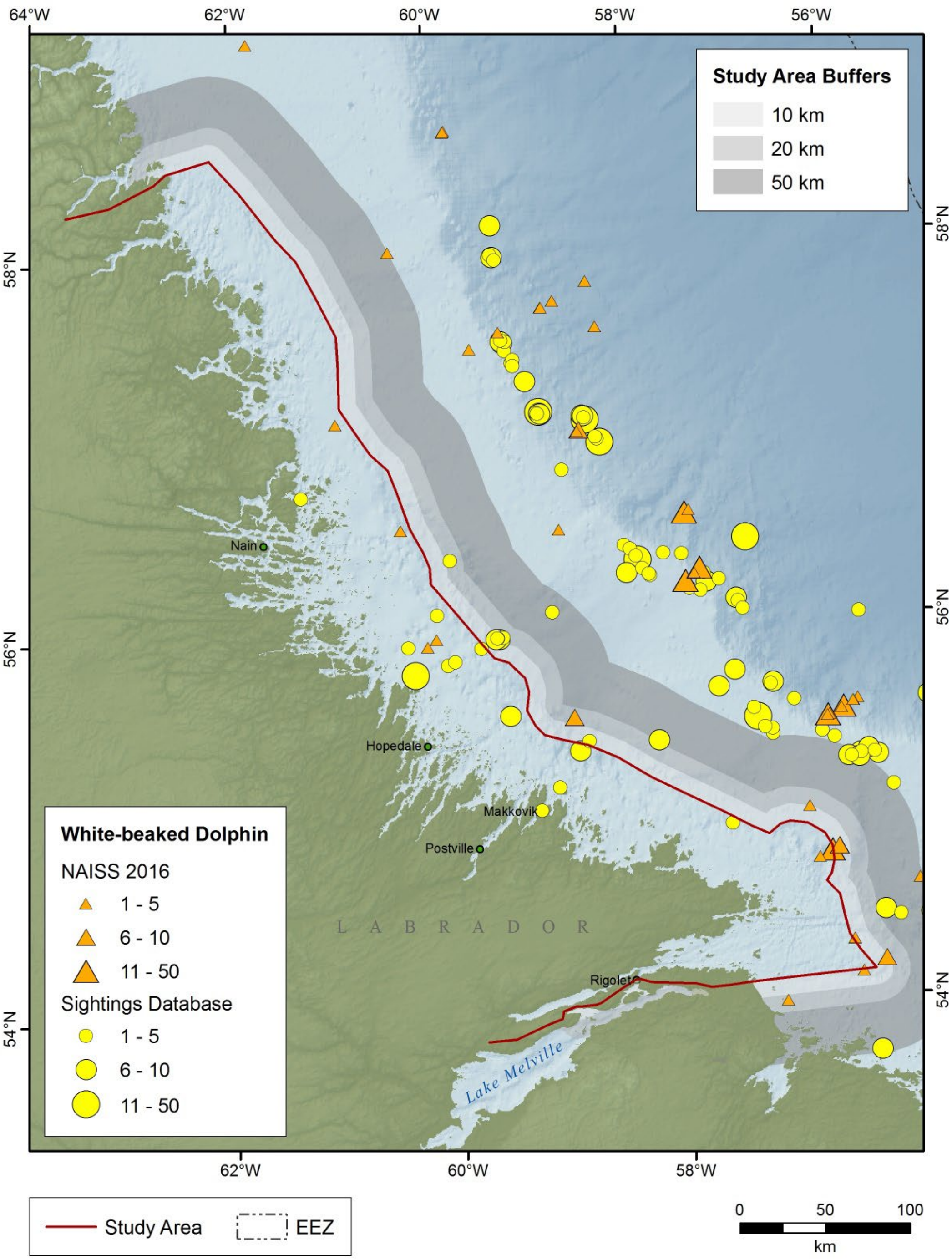


Figure 10.9: Distribution of White-beaked Dolphin sightings and survey observations in and adjacent to the study area.

10.1.2. Pinnipeds

Seal hunting has a long history in Labrador. Records of seal use have been traced back thousands of years in the archaeological record (Fitzhugh 1976) and stories of the seal hunt are part of a strong oral history (Brice-Bennet 1977). Today, seal hunting is still an essential part of life in coastal Labrador, with substantial cultural and economic benefits, as well as contributing to regional food security.

Five seal species are commonly found in the study area and are included in this document: Ringed, Harp, Bearded, Harbour, and Grey seals. Summary of the biology, ecology, and population metrics for all species is included in Appendix E, Table E-3. Hooded seals and walrus are excluded; these species are rarely recorded in coastal Labrador and are not considered residents (Boles et al. 1980). However, historical records indicate that Atlantic Walrus was sufficiently abundant throughout the Labrador coast to support a subsistence harvest in the 1700s-1800s (Fitzhugh 1977). Walrus harvest in the communities of Okak and Hebron lasted until at least the 1960s (Brice-Bennet 1977). During a 1979 OLABS aerial survey, walrus were considered rare to the area and only a single walrus was recorded (Boles et al. 1980).

Ecologically, seals are important predators in the North Atlantic. These species influence ecosystem structure and function through predation on a wide variety of taxa at most trophic levels (Bowen 1997). In turn, seals are prey for Polar Bears, Killer Whales, and Greenland Sharks (Lavigne and Kovacs 1988; Leclerc et al. 2012). In particular, Ringed Seals, Bearded Seals, and Harp Seals are primary prey for polar bears in the coastal Labrador study area (Thiemann et al. 2008). Juvenile seals are also subject to predation by foxes, gulls, and ravens (Reeves 1998).

Knowledge of pinnipeds in the study area is derived from a variety of information sources. These include:

DFO Biological Sampling Program

DFO has been working with local hunters to collect biological samples since the 1980s. This program has provided a tremendous amount of information on seal species in Newfoundland and Labrador. Biological samples, such as stomach contents, reproductive organs, and teeth, are used to assess the diet, reproductive status and trends, age and condition of seals in the region, including the study area (G. Stenson, pers. comm.).

Participatory Mapping of Local Knowledge (LK)

Local Knowledge gathered through semi-structured interviews and participatory mapping with Labrador Inuit was contributed by the Nunatsiavut Government. This includes spatial data on habitat use by Ringed, Harp, and Bearded seals.

Community-Based Coastal Resource Inventory (CCCRI)

Local knowledge of marine and coastal resources in the NL Shelves Bioregion was collected as part of a Community-Based Coastal Resource Inventory (CCRI) project, led by Oceans Division from 1996–2008. The CCRI provides qualitative presence-only data based on Traditional Ecological Knowledge (TEK) collected through interviews with individuals having direct knowledge of local areas (i.e., fishers or those with specialized local knowledge). CCRI data on seals in the coastal Labrador study area include the distribution of Ringed, Harp, Bearded, Harbour, and Grey Seals.

Our Footprints are Everywhere (OFAE)

Maps published in OFAE (Brice-Bennett 1977) were digitized, including information on core occupancy areas, movement patterns, and hunting areas for Harp, Ringed, Bearded, Harbour, and Grey Seals. Breeding areas are also included for Harbour and Ringed Seals.

Telemetry Data

Harp Seal movement patterns were derived from telemetry data (G. Stenson, pers. comm.) and filtered using the algorithm developed by Freitas et al. 2008. Kernel density surfaces were created for biologically meaningful periods throughout the year: post-molt (May to mid-June), spring migration (mid-June to July), fall migration (December), summer feeding (August-November) and winter feeding (January-March). For each of these layers, probability contours (percent volume thresholds) were calculated for 50%, 80%, 90%, and 95% volume. Polygon extraction was based on expert advice using these data.

10.1.3. Species of Interest

Ringed Seal

Ringed Seals (referred to locally as Jar Seals) are the most common resident seal along the Labrador coast and have been a long-term staple species for Labrador Inuit (Boles et al. 1980). Although Ringed Seals are not classified as a migratory species, they do move northward along the Labrador coast and into offshore areas for the summer months (Boles et al. 1980; Lowry 2016; B. Sjare, pers. comm.). All three knowledge sources indicate that Ringed Seals are concentrated in Lake Melville and on the coast near Nain and South Aulatsivik Island (Figure 10.10). Ringed Seals are also known to pup throughout the study area. Labrador Inuit hunt ringed seals throughout the year, an important cultural activity for coastal communities. For many coastal communities, Ringed Seals provide an important source of food and income from seal products like clothing.

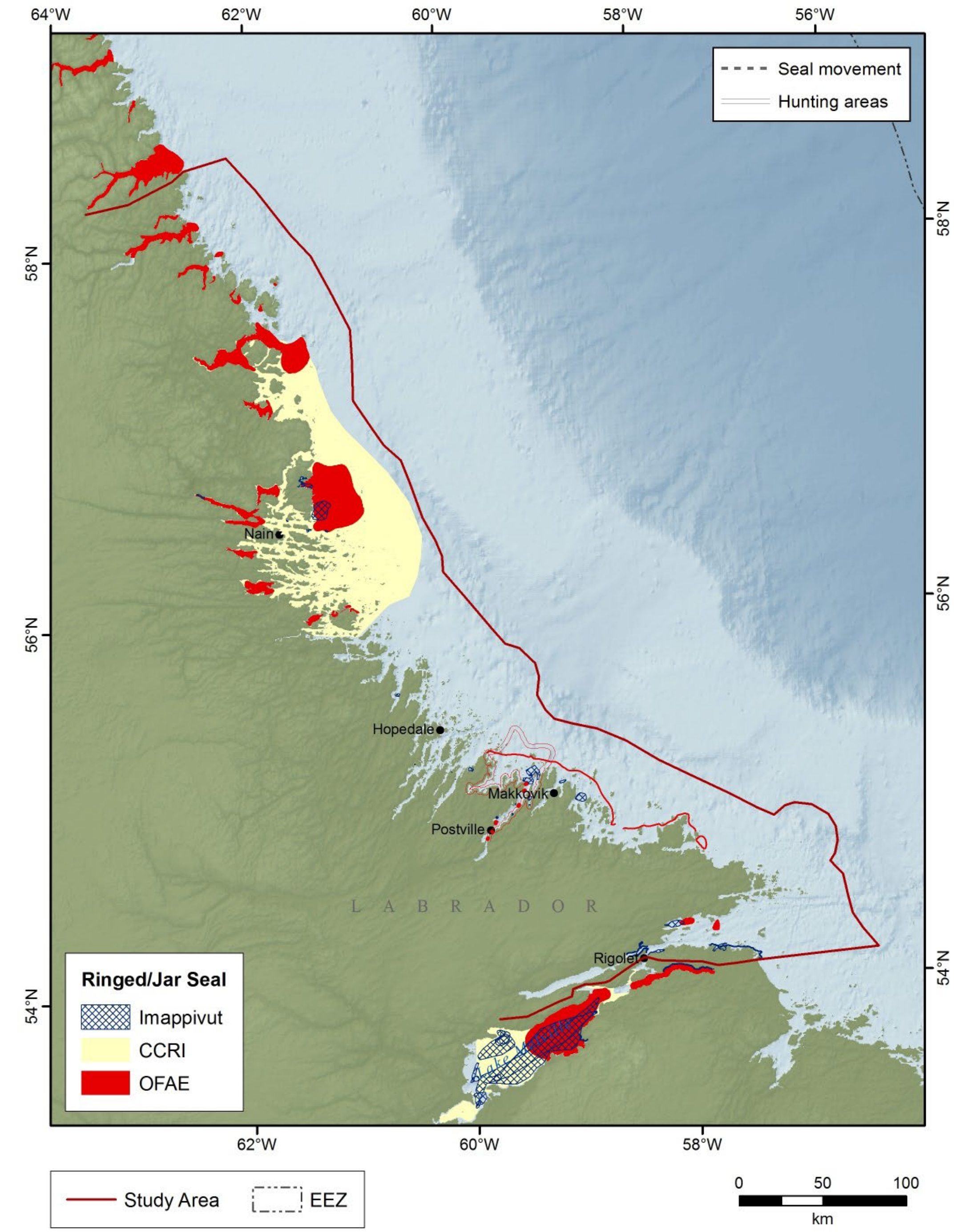


Figure 10.10: Distribution of Ringed Seal in coastal Labrador, as reported through participatory mapping of Local Knowledge, from digitized maps originally published in OFAE (Brice-Bennett 1977) and recorded by the Community-based Coastal Resource Inventory (CCRI).

Harp Seal

During the fall and spring migration, Harp Seals are the most abundant seal in Labrador waters (Boles et al. 1980). CCRI and OFAE records describe common hunting areas for Harp Seal near Nain and along the coast of Aulatsivik Island. Imappivut participatory mapping of LK indicates that Harp Seals have also been regularly hunted further south, near Rigolet, Postville, and Makkovik (Figure 10.11). Standardized observations from aircraft have indicated that harp seals are found all along the coast (G. Stenson, pers. comm.). Movement data from tagged seals shows the seasonal migration of Harp seals into, and through, the study area (Figure 10.12).

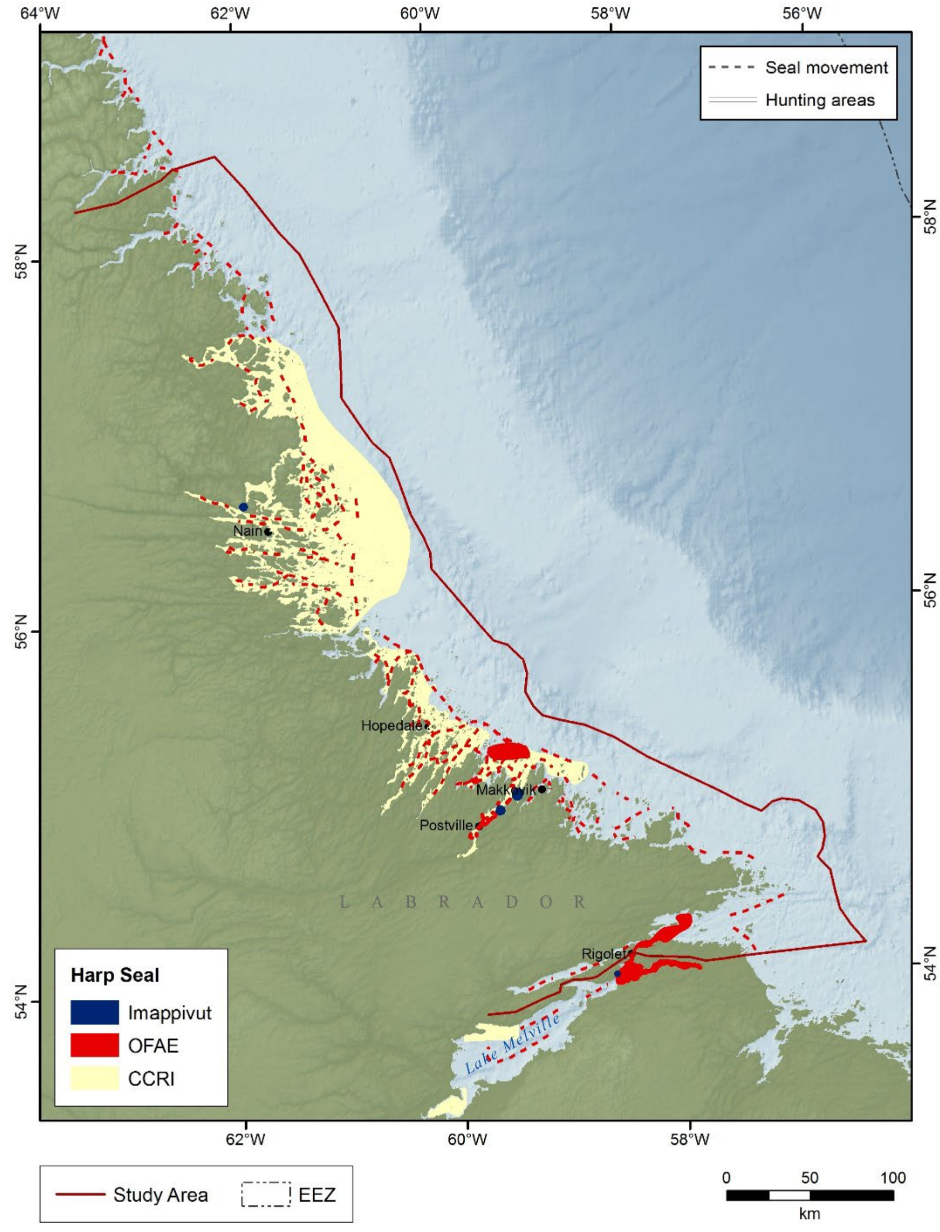


Figure 10.11. Distribution of Harp seal in coastal Labrador, as reported through participatory mapping of Local Knowledge, from digitized maps originally published in OFAE (Brice-Bennett 1977) and recorded by the Community-based Coastal Resource Inventory (CCRI).

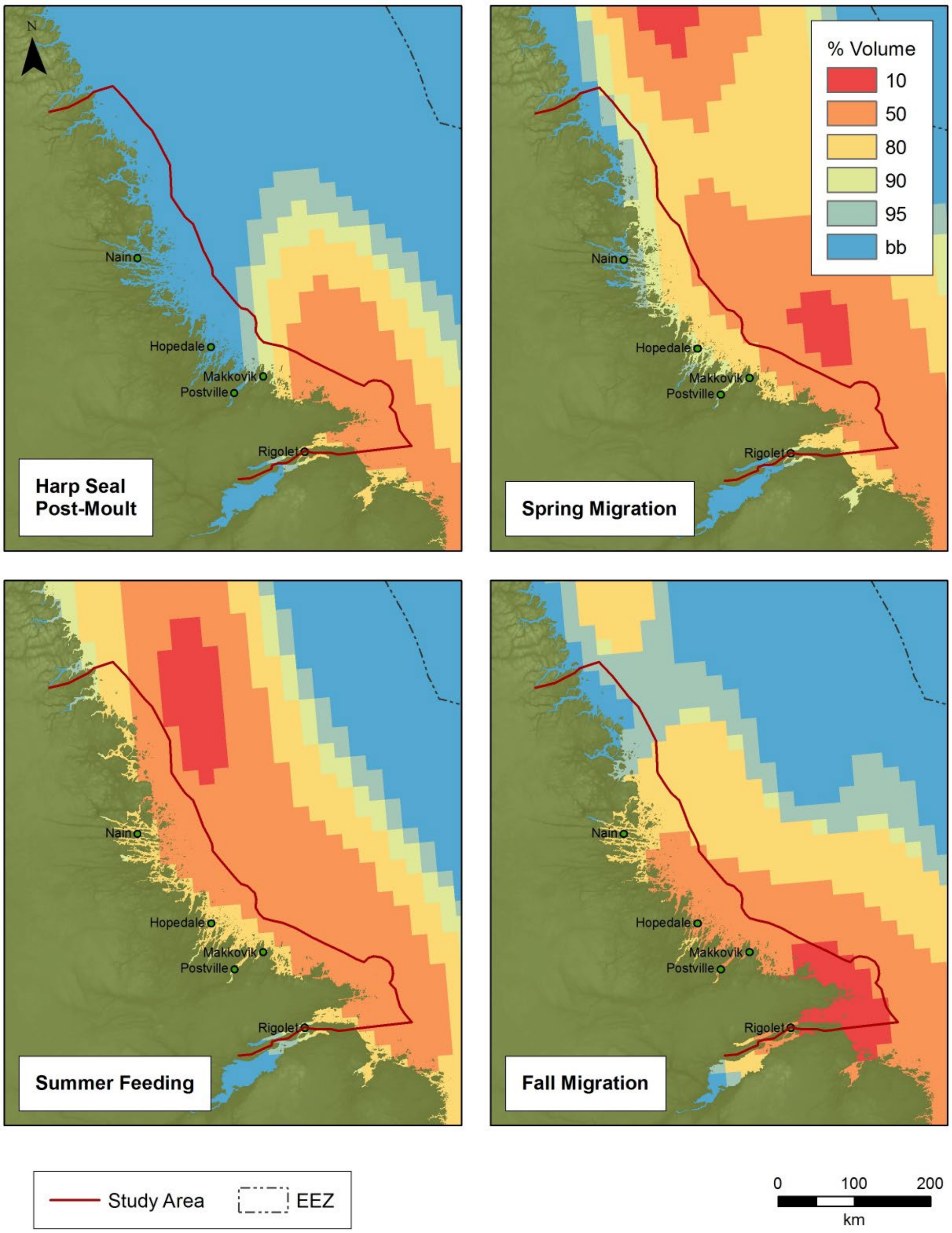


Figure 10.12. Harp seal distribution as determined by telemetry data during the post-molt period (May to mid-June), spring migration (mid-June to July), summer feeding period (August-November) and fall migration (December). The winter feeding area is not located in or adjacent to the study area and is therefore not included here.

Bearded Seal

Compared to Ringed and Harp Seals, Bearded Seals are less abundant in Labrador waters (Stenson 1994). CCRI and OFAE data show a broader distribution of Bearded seals through the study area (Figure 10.13). More recent participatory mapping of local knowledge through the Imappivut program indicates that this species is mainly hunted in Lake Melville and in a fjord near Nain.

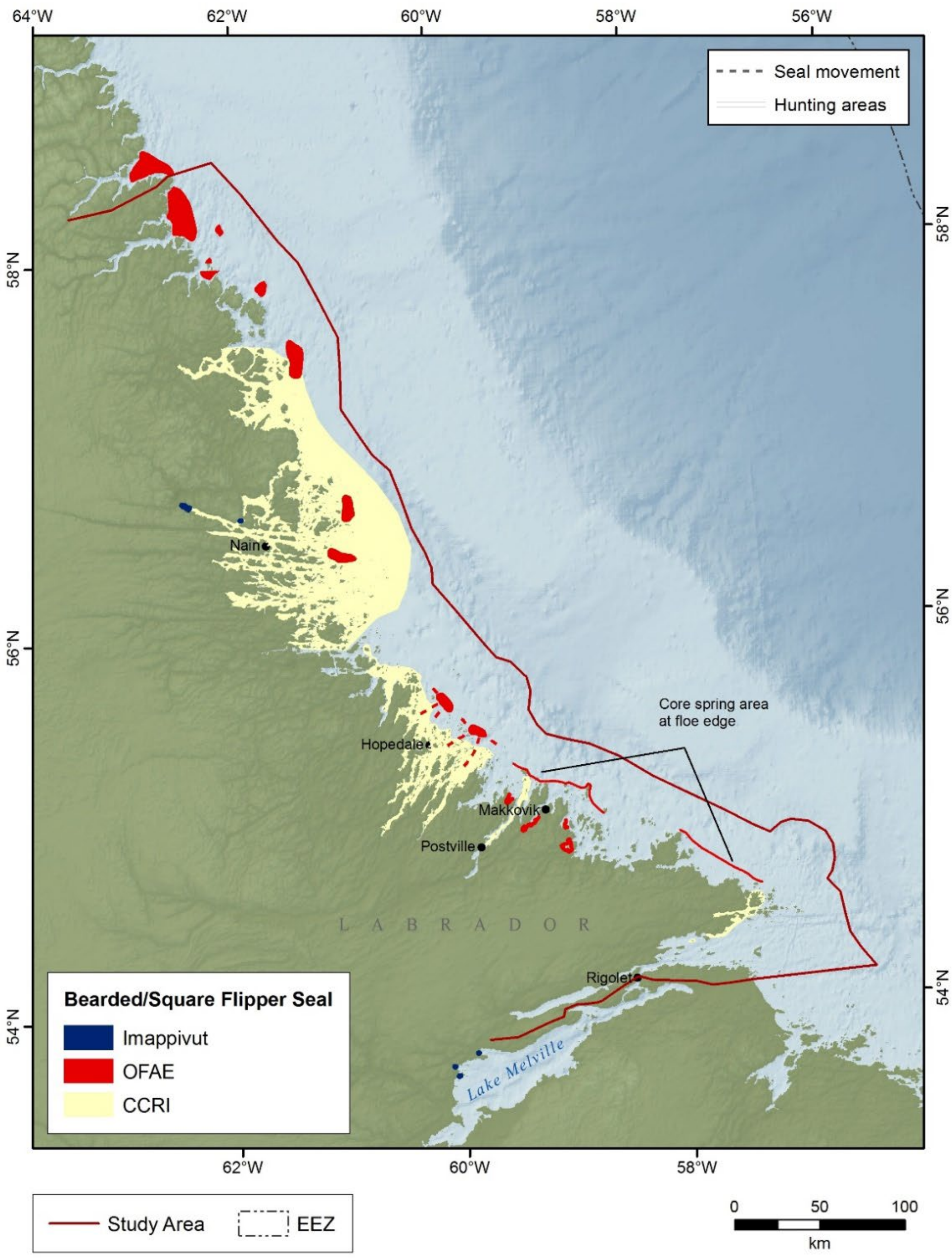


Figure 10.13. Distribution of Bearded seal in coastal Labrador, as reported through participatory mapping of Local Knowledge, from digitized maps originally published in OFAE (Brice-Bennett 1977) and recorded by the Community-based Coastal Resource Inventory (CCRI).

Harbour Seal

Harbour Seals (referred to locally as Ranger Seals) are present on all three of Canada's coasts; however, they are more abundant in the Pacific than on Atlantic shores. CCRI data indicates broad distribution of Harbour Seals in the study area, including around Nain and South Aulatsivik Island. LK and OFAE show a more restricted distribution of Harbour seals concentrated in the southern half of the study area, with most reports between Lake Melville and Tasiuyak Bay (Figure 10.14).

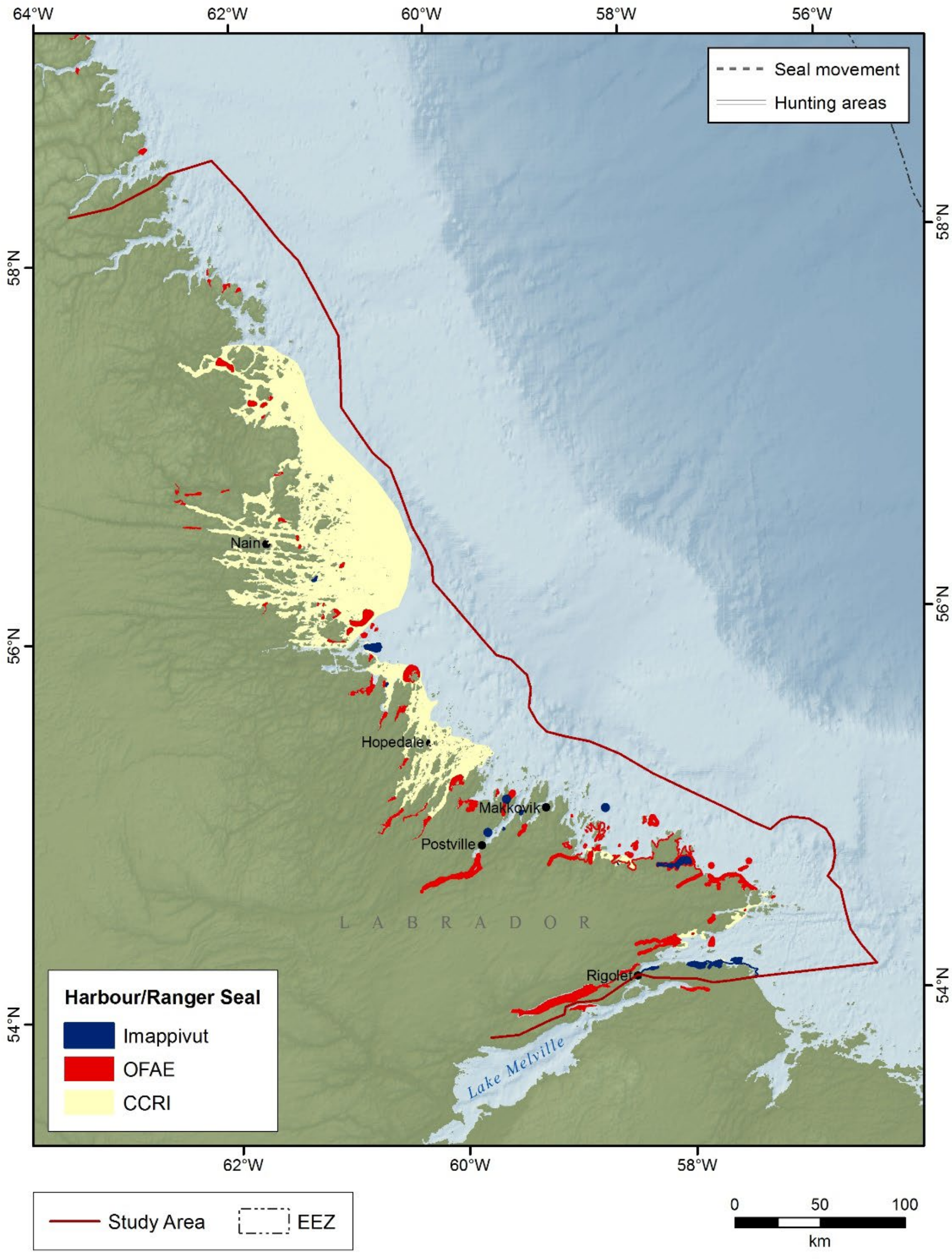


Figure 10.14. Distribution of Harbour seal in coastal Labrador, as reported through participatory mapping of Local Knowledge, from digitized maps originally published in OFAE (Brice-Bennett 1977) and recorded by the Community-based Coastal Resource Inventory (CCRI).

Grey Seals

Grey Seals from the Sable Island and Gulf herds migrate to the study area seasonally (Stenson 1994); however, information on how Grey Seals use the study area is limited. CCRI data suggest Grey seals are present throughout the centre of the study area, between Makkovik and Okak, and this species has been observed as far north as Nain (G. Stenson, pers. comm.). However, OFAE only report Grey seals in the southern end of the study area, between Groswater Bay and Ragged Island (Figure 10.15). Grey Seals were not included as a primary species of harvest interest during recent Imappivut mapping exercises, though interview participants may have knowledge on this species that can be included in future interviews and mapping efforts.

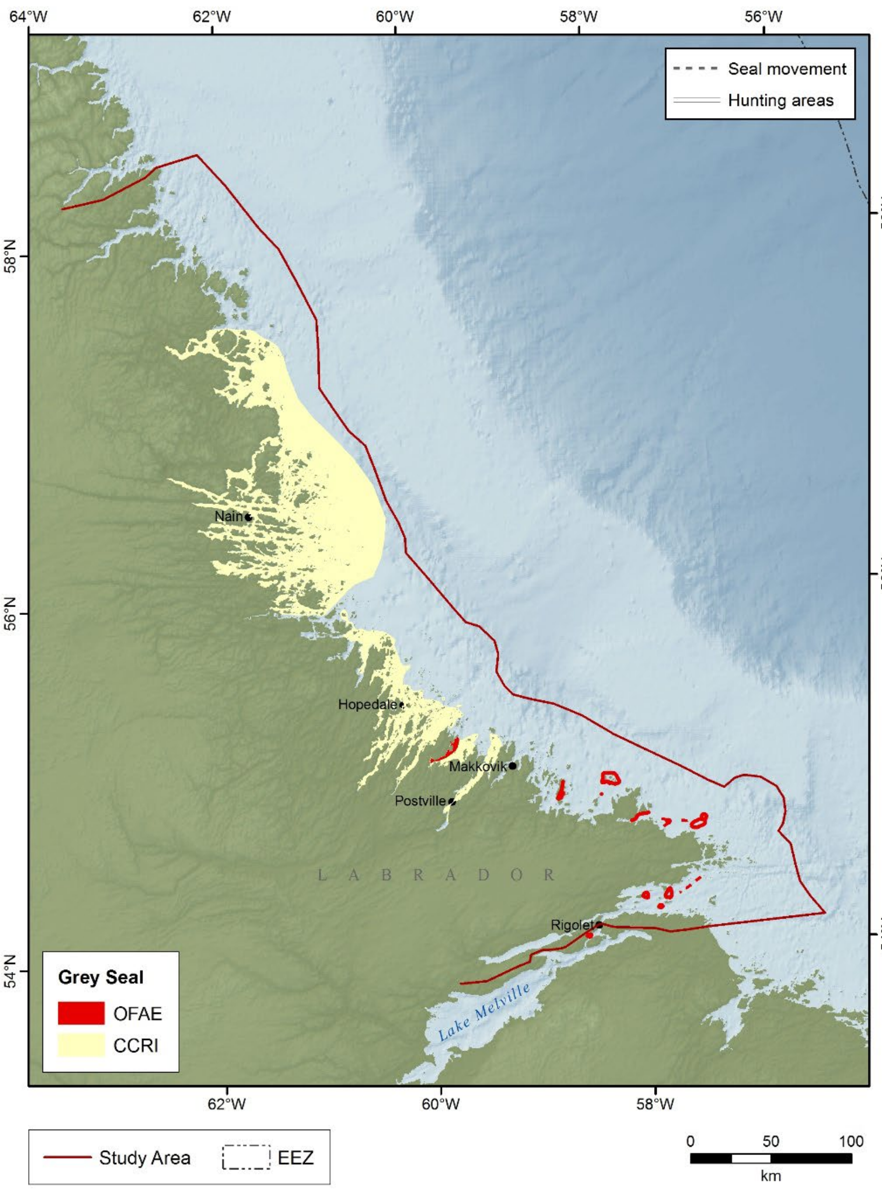


Figure 10.15. Distribution of Grey seal in coastal Labrador, based on digitized maps originally published in OFAE (Brice-Bennett 1977) and the Community-based Coastal Resource Inventory (CCRI).

10.1.4. *Sensitive Species and Habitats*

Seal populations in coastal Labrador appear to be healthy. None of these species are considered to be of conservation concern by COSEWIC, although Bearded Seals are designated as Data Deficient. However, these populations are sensitive to changes in their ecosystem, and current threats include reduced prey availability, declining sea ice, and environmental contamination.

Since 1990, there have been significant declines in important seal prey species in Newfoundland and Labrador waters, particularly capelin. Reduced prey availability is associated with recent declines in Harp Seal pregnancy rate (Stenson et al. 2016). Sea-ice conditions in the Northwest Atlantic are declining due to anthropogenic climate change. Maximum seasonal sea-ice extent in the Arctic has been at the lowest levels in the satellite record for the past two years (NSIDC 2018) and shifts are observed in the timing of seasonal melt and freeze-up (Stroeve et al. 2014). Harp Seals, Ringed Seals and Bearded Seals rely on sea ice for feeding and/or reproduction in or adjacent to the study area. Poor ice cover is associated with increased neonatal mortality, reduced pregnancy rate, and reduced food availability (Stenson and Hammill 2014; Stenson et al. 2016). For more information on sea-ice conditions refer to Section 3.

Seals are extremely vulnerable to bioaccumulation of contaminants present in their environment due to their high trophic level, low detoxification capacity, large fat reserves, and long life span. Persistent organic pollutants (POPs), including organochlorine pesticides (OCPs) and polychlorinated biphenyls (PCBs) enter the study area through long-range atmospheric transport, and from local contaminated sites. For example, PCB levels at the former military radar station in Saglek Bay, which is very near the northern edge of the study area, exceed the maximum allowable amount in the Canadian Environmental Protection Act and there is evidence that PCBs have entered the marine environment directly from that site (Brown et al. 2014). PCB contamination impairs reproduction, disrupts endocrine function, reduces immune function, and increases risk of tumor and bone lesions (Bergman and Olsson 1986; Helle et al. 1976; Nyman et al. 2003; Olsson et al. 1994; Routti et al. 2010; Routti et al. 2008). PCB contamination appears to be declining overall (Zitko et al. 1998), although dangerous concentrations have been recently recorded in Ringed seals of coastal Labrador (Brown et al. 2014). Research has also found evidence of other contaminants present in the Ringed Seals of coastal Labrador, including persistent organic pollutants (POPs), mercury (Brown et al. 2018), cadmium (Brown et al. 2016), flame retardants, and polybrominated diphenyl ethers (PBDEs) (Houde et al. 2017). However, preliminary analyses by the Canadian Food Inspection Agency have shown that harp seals do not show the same high level of contaminants as ringed seals, and the severity of these impacts are likely to be species specific (G. Stenson, pers. comm.). Earlier studies have found that relatively low concentrations of polycyclic aromatic hydrocarbons (PAH) in Harp Seals and no evidence was found of bioaccumulation with age in this species (Hellou et al. 1991).

It is likely that other seal species are similarly exposed to dangerous contaminants, and the impacts of these compounds also threaten human health in communities that rely on seal meat. For example, PCB exposure through consumption of contaminated marine diets has been linked to high cholesterol, triglycerides, and LDL based on analysis of Canada's Adult Inuit Health Survey (Singh and Chan 2018).

10.1.5. *Data Gaps and Recommendations*

For many parts of the study area, there is strong LK on the distribution of various marine mammals; however, there may be geographic bias towards more populated/more frequently used areas of the coast. This information can be supplemented by spatially explicit, systematic survey efforts.

While population trends and ecology are reasonably well understood for Harp and Grey Seals, they are poorly known for the other species. Coast-wide surveys for rings and Bearded Seals are needed to develop reliable abundance estimates. Increased tagging efforts can provide more complete information about habitat use, migration patterns and site fidelity. Greater engagement with local seal harvesters may support efforts to understand rates of neonatal abandonment and mortality in poor ice years. With the exception of Harp Seal, where body condition is well tracked, little is known about condition trends for other species of seals in the area. Data on body condition of all species of seals in the study area have been collected but are not fully analyzed. Increased monitoring of seal health would support the ability to track changes related to climate (e.g., habitat and prey) and predict future impacts.

Local communities have also expressed food safety concerns related to contaminants present in seals. Additional research to investigate potential risk of exposure to contaminants through consumption of seals could address some of these questions. Given the importance of seals more broadly for marine food webs, establishing a better understanding of contaminants in these species is an important target for social, cultural, health, and ecological research.

10.1.6. Available information

Knowledge of pinnipeds in the study area is derived from a variety of information sources. These include:

Sensitive Species and Habitats

All of the cetacean species have been assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The Eastern Hudson Bay population of beluga whale has been assessed as Endangered under COSEWIC. The Atlantic population of Fin Whales was assessed as a species of Special Concern by COSEWIC in 2005 and is currently listed on Schedule 1 as a species of Special Concern under the *SARA* (DFO 2017b). The Northwest Atlantic population of harbour porpoises has been assessed as a species of Special Concern by COSEWIC. The Northwest Atlantic/Eastern Arctic population of Killer Whales was assessed as a species of Special Concern by COSEWIC in 2008. The Atlantic population of Minke Whales and White-beaked Dolphins, as well as the Western North Atlantic population of Humpback Whales, have been assessed by COSEWIC as not at risk. Some of these species have been listed under the *Species at Risk Act* (SARA). A list of key threats for each of these species is provided in Table E-2.

There is little information on sensitive habitats for the study area with respect to cetaceans. However, it should be noted that two studies based on telemetry work (Bailleul et al. 2012; Lewis et al. 2009) have identified an area located outside of Hopedale that straddles the study area boundary as an important overwintering area for the Eastern Hudson Bay beluga (Figure 10.3).

Data Gaps and Recommendations

The majority of information available for cetaceans in this area is based on non-systematic observations, the ability to identify important or critical habitat for each species is limited. The two systematic surveys that have been completed in the last 11 years (Lawson and Gosselin 2009, 2018) reflect a broad geographic area and the resultant abundance estimates were corrected for the biases inherent in visual survey approaches using standardized methods, where possible, and species characteristics (such as surface intervals). However, with only two surveys nine years apart, population trends cannot be assessed. Regular surveys may make changes in cetacean population distribution and abundance easier to detect and quantify.

Some cetacean records (from both the DFO sightings database and from LK) do not identify observed cetaceans to species. These sightings are either identified as unknown whale or dolphin, or simply as whale or dolphin. This ambiguity reduces the ability to identify important areas or sensitive habitats within the study area at the species level, and therefore the ability to set species-specific conservation objectives at a scale finer than the study area itself. As a result of the opportunistic nature of many cetacean observations, it is difficult to identify specific habitat associations or preferences of these species.

Some recommendations to address these data gaps could include:

- regular directed and systematic surveys in Canadian waters, including coastal Labrador;
- improved public awareness and education of observers and LK holders on the identification of cetaceans to species level;
- expanded satellite tagging efforts to better understand movements, residency, and behaviour (e.g., feeding or socializing) as it relates to habitat utilization;
- deployment of acoustic recorders mounted on underwater gliders or moorings to monitor the year-round occurrence of cetaceans;
- targeted qualitative and spatial data collection of LK throughout the study area focused on cetacean observations and associated location and habitat information.

10.2. Polar Bears

10.2.1. Available Information

There are several subpopulations of Polar Bears in the Canadian Arctic and Sub-Arctic. Of these, the Davis Strait (DS) subpopulation (COSEWIC 2008b) is present in and important to the study area. Polar Bears have been listed as a species of Special Concern under the *Species at Risk Act* and are considered Vulnerable under the *Newfoundland and Labrador Endangered Species Act*. The most recent mark-recapture population survey for the Davis Strait subpopulation (2005–07) provided an estimate of 2,158 bears (Peacock et al. 2013). Additional information on Polar Bear ecology in this area is provided by a Traditional Ecological Knowledge (TEK) study conducted by the Torngat Wildlife Plants and Fisheries Secretariat (2015). Analysis of a two-year genetic mark-recapture survey (2017–18) is underway and these results will provide more detailed data about population trends and distribution of polar bears in the study area. More information on their ecology, biology, status, and trends can be found in Appendix E, Table E-4.

Sightings based on LK, *Our Footprints are Everywhere* (Brice-Bennett 1977) and CCRI data (O'Brien et al. 1998) (Figure 10.16) indicate that they are typically seen all along the coast. Most sightings are concentrated near Nain, Hopedale and Makkovik, however this due primarily to geographic bias of the observations related to concentration of hunting and travel by community members and does not directly reflect the full extent of habitat use by Polar Bears in the region.

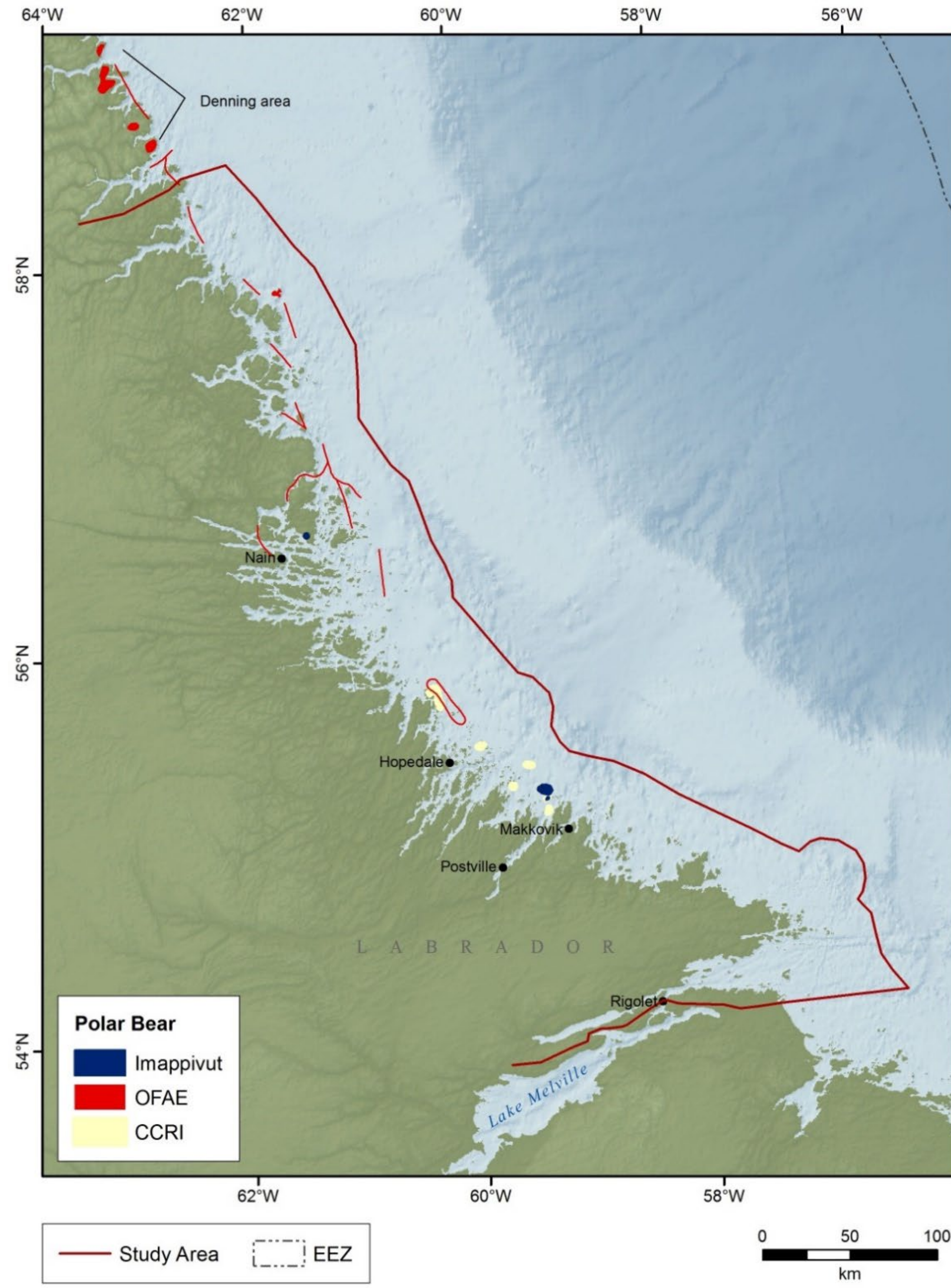


Figure 10.16: Polar bear sightings recorded by the Imappivut program, OFAE, and CCRI.

10.2.2. Sensitive Habitats

Polar Bear distribution is closely related to the movement of pack ice and the formation of land-fast ice for access to suitable food sources (COSEWIC 2008b). The status of the various Polar Bear subpopulations varies considerably due to differences in habitat and prey availability. The impacts of climate change have been observed and measured for subpopulations in other parts of the species' range, with some bears showing declining body conditions and changes in denning locations as a result of decreased sea ice (Stirling et al. 1999; Obbard and Walton 2004; Obbard et al. 2007). For instance, the Polar Bear Technical Committee (ECCC 2018) reports that the Western Hudson Bay and Southern Hudson Bay subpopulations have shown population declines over time while the Northern Beaufort Sea subpopulation has been found to be likely stable. Polar bears are reliant on seasonal sea ice for survival, making it a particularly sensitive habitat within the study area.

The Davis Strait subpopulation has been assessed as stable or potentially increasing (ECCC 2018). Scientific studies and Traditional Knowledge from Inuit hunters have provided data alternatively finding a decline in body condition and stable body condition among Davis Strait polar bears (York et al. 2015). Inuit have interacted and maintained a relationship with polar bears for generations and consider it a key part of Arctic ecosystems and culture. Harvesting Polar Bears is a culturally important activity and the species has both subsistence and economic value for Labrador Inuit who continue to hunt them for food and to sell the fur (York et al. 2015). The Davis Strait subpopulation currently has an annual harvest quota of 80 bears (York et al. 2015).

10.2.3. Data Gaps and Recommendations

Although satellite tracking studies have been conducted (Taylor et al. 2001) and LK provide valuable information on preferred habitat types for denning (York et al. 2015), knowledge gaps for Polar Bears related to the seasonal distribution and denning locations along the Newfoundland and Labrador Coast still exist. Furthermore, the population structure (sex, age) at different times of the year is not well known. Information on the number of year round residents within Newfoundland and Labrador has not been thoroughly investigated, nor has the percentage of transient individuals in the population (Brazil and Goudie 2006). Completing analysis on the 2017–18 genetic mark-recapture study could help to bridge these knowledge gaps.

Across their range, polar bears mainly hunt ringed seals, bearded seals, and harp seals (Bluhm and Gradinger 2008; York et al. 2015). Prey composition in particular subpopulations and individuals depends on the type of habitat bears use to feed, with Ringed Seals featuring more predominantly in the diets of bears using near-shore and land fast areas and Bearded; Harp Seals are consumed more by off-shore bears (Bluhm and Gradinger 2008). Polar bears from this subpopulation feed primarily on harp seals (Peacock et al. 2013). In particular, Polar Bears prey on seal pups each spring and the energy obtained during this three week period is critical for the entire year. There is uncertainty regarding the effects of climate change on the location of seal whelping patches and how more dispersed or weakened ice may impact the bear's ability to feed on the whelping patch (G. Stenson, pers. comm.).

11. Marine Birds

The study area incorporates several areas (or portions thereof) that are recognized as important marine ecosystems, and specifically important to marine birds. For example, Ecologically and Biologically Significant Areas (EBSAs) have been identified in the Nain Area, Hopedale Saddle, Hamilton Inlet (see Section 12). It should be noted that EBSA identification in coastal Labrador was largely based on best available broad scale survey data (e.g., bioregional) and established criteria, and as in other EBSA processes, emphasize areas evidenced as especially significant when compared to the surrounding marine bioregional landscape (DFO 2013). Important Bird Areas (IBA Canada 2018) have also been identified within and adjacent to the study area, including Nain Coastline, Offshore Islands Southeast of Nain, Goose Brook, Quaker Hat Island, Northeast Groswater Bay, South Groswater Bay Coastline, Tumbledown Dick Island and Stag Islands. Like EBSAs, IBAs are identified based on criteria that emphasize significance based on geographical context (e.g., Global, Regional, and Sub-regional), and emphasize threatened bird species, range-restricted species, biome-restricted species, and congregations (IBA Canada 2018). Marine birds and IBAs in Labrador have been the focus of previous comprehensive compilation of related data and information, including much of what is presented in this chapter and more (Lock et al. 1994, Russell and Fifield 2001a, b, c). Given these available materials, emphasis of this chapter is placed on key information sources, new information, new analyses, and previously unavailable information.

Birds in the study area can become concentrated, especially during breeding when movement is constrained by demands related to pair maintenance, incubation, chick provisioning and defense. Birds otherwise can form concentrations when roosting, during pre-migratory staging, migratory staging, moulting, and wintering (e.g., in ice-free areas). Even species that do not breed in the study area can become concentrated in this region during their annual cycle, especially when and where resources are predictably abundant and available.

As per processes above, assessment of the study area began with review of ECCC Canadian Wildlife Service (CWS) datasets with large spatial coverage (Allard et al. 2014). Additionally, recently compiled LK (below) was also examined to inform assessment of the study area as it relates to marine birds. In recognition of known spatiotemporal gaps in survey coverage, other complementary and confirmatory information sources, approaches, and updates, also were considered in this assessment. The potential additional contribution of yet unexamined existing information held by others, including local sources, academic sources, and individuals also is acknowledged. Though warranted, a fully comprehensive review of all available information was not possible due to time constraints, barriers to availability, and ongoing challenges associated with merging disparate data, based on different metrics, derived from different methodologies.

Where possible, this process emphasizes species-specific information, derived from published reports and primary literature. Most, but not all, of the information sources presented here continue to be updated and enhanced. Important novel approaches, information and data are mentioned and presented, specifically if expected to offer confirmatory and complementary evidence related to important sites for marine birds and more broadly to marine ecosystems. Those marine bird species not known to occur within the study area with regularity are excluded.

11.1. Available Information

Six principal data sources were used to inform our understanding of the distribution and abundance of marine birds within the study area: Local Knowledge, shorebird surveys, waterfowl surveys, colonial waterbird surveys, tracking studies, and at-sea marine bird surveys. Information in this chapter is presented primarily according to these knowledge sources. Where appropriate, complementary survey approaches are treated together, to benefit from multiple perspectives on specific species, species groups, and areas of importance. Recognizing relevance of the study area to local communities and human well-being, relevant information is presented starting from the coastline, and then extending seaward. Where appropriate, specific marine bird species and/or species groupings are given additional attention (e.g., culturally significant and/or at-risk species). Summary information on all marine bird data sources is presented in Table 11.1. It should be noted that many of the datasets explored here contain varying quantities of incidental records of non-target species, many of which were not treated here.

Local Knowledge available and presented in this chapter was compiled by the Imappivut marine planning initiative. The Nunatsiavut Government gathered data on marine birds through semi-structured interviews (n=45) (Bryman and Teevan 2005; Creswell and Poth 2018) and Direct to Digital participatory mapping methodologies (Olson et al. 2016) with Labrador Inuit (Nunatsiavut

Government, 2018). Interview participants discussed a wide variety of aspects related to marine birds in the study area, including hunting and egg collecting locations and conservation concerns. Local Knowledge of marine birds collected by the CCRI project (O'Brien et al. 1998) and *Our Footprints Are Everywhere* (Brice-Bennett 1977) are also included.

Systematically collected species-specific counts over broad scales (e.g., from formal aerial or land-based surveys during migration) are unavailable for shorebirds like sandpipers, plovers, and waders along large portions of the Labrador coastline. Local Knowledge contributes to addressing this gap and will help identify opportunities for additional effort along the Labrador coastline. The Atlantic Canada Shorebird Survey offers potential for individuals to gather information systematically. Repeated within-season surveys follow a defined protocol and typically occur during spring, summer and fall periods at established locations (Gjerdrum et al. 2012). Efforts to enhance opportunities for active engagement in such volunteer-based citizen-science monitoring in Labrador are ongoing.

Table 11.1: Monitoring datasets available to assess distribution and relative abundance of marine birds within the Study area.

Data Focus / *Name*	Source	Description	Temporal Coverage Assessed	Spatial Coverage	Data Type
Colony Level					
Local Knowledge	Nunatsiavut Government P. McCarney	Local Knowledge; colony locations	Imappivut 2017–18; CCRI 1998, OFAE 1980	Study area	Point, polygon
Atlantic Waterbird Colony Database (ARWCD)	CWS Atlantic; S. Wilhelm	Colony locations and counts; focus colonial marine birds	<1960–2017; spring, summer	Atlantic Canada; complete for study area	Point
Coastal					
Local Knowledge	Nunatsiavut Government P. McCarney	Local Knowledge; important waterfowl areas, feeding and nesting locations	(CCRI, Imappivut, OFAE)	Study area	Point, polygon
Atlantic Canada Shorebird Survey (ACSS)	CWS Atlantic; J. Paquet	Ground surveys, incidental observations; all shorebirds	2014; summer	Atlantic Canada; incomplete for study area	Point
Eider Winter Exploratory Survey	CWS Atlantic; S. Gilliland, C. Lepage, with NG and partners	Aerial surveys; Common Eider	2010; winter	Complete for Study area	Point
Labrador Fall Staging Survey	CWS Atlantic; W. Lidster, C. Baldwin	Aerial surveys; waterfowl	1992; fall; waterfowl	Black Tickle to Saglek	Point
Labrador Fall Staging Survey	CWS/OLABS; Atlantic; T. Lock	Aerial surveys; waterfowl	1980; fall; waterfowl	Black Tickle to Saglek	Point

Data Focus / *Name*	Source	Description	Temporal Coverage Assessed	Spatial Coverage	Data Type
Scoter Exploratory Moulting Area Surveys	CWS Atlantic; S. Gilliland, USFWS	Aerial surveys; moulting scoters	1998	Most of study area	Polygon
Coastal Waterfowl Survey	CWS Atlantic; T. Lock	Aerial surveys; all waterfowl, by coastal 'block'	1978; gulls, guillemots	Atlantic Canada; complete for study area	Polygon
Barrow's Goldeneye Records	CWS Atlantic	Incidental observations; Barrow's Goldeneye	1885–2016; year-round	Atlantic Canada; incomplete for study area	Point
Labrador Eider Breeding Season Survey	CWS Atlantic; S. Gilliland	Aerial surveys; Waterfowl and gulls (including Harlequin Duck, Barrow's Goldeneye)	1994; June; within Coastal Waterfowl Survey	Complete for study area	Polygon; points for Harlequin Duck
Labrador Eider Breeding Season Survey	CWS Atlantic; A. Lock	Aerial surveys; Common Eider	1980; June; within Coastal Waterfowl Survey	Complete for study area	Polygon; points on maps
Labrador Eider Colony Survey	Nunatsiavut Government/CWS; K. Chaulk	Aerial surveys; Common Eider	2006; June; Points	Complete for study area	Point
Offshore					
Imappivut Marine Planning Initiative	Nunatsiavut Government P. McCarney	Local Knowledge; important waterfowl areas, feeding and nesting locations	(CCRI, Imappivut, OFAE)	Study area	Point, polygon
Eastern Canada Seabirds at Sea (ECSAS)	CWS Atlantic; C. Gjerdrum	Ship-of-opportunity surveys; focus seabirds	2006–18; year-round	Atlantic Canada; incomplete for study area	Polygon; 300 m width, one side; summarized by point; presence absence

Data Focus / *Name*	Source	Description	Temporal Coverage Assessed	Spatial Coverage	Data Type
Programme intégré des recherches sur les oiseaux pélagiques (PIROP)	CWS Atlantic; C. Gjerdrum	Ship-of-opportunity surveys; focus seabirds	1966–92; year-round	Atlantic Canada; incomplete for study area	Line; unlimited width, one side; summarized by point; presence absence
Tracking data					
Seabirds; see Table 11.3	Multiple sources	Multiple technologies	2008–17	Atlantic Canada; incomplete for study area	Point, polygon
Harlequin Duck tracking	Robert et al. 2008	Satellite telemetry	2001	NW Atlantic	Point
Harlequin Duck tracking	Chubbs et al. 2008	Satellite telemetry	2001–02	NW Atlantic	Point
Harlequin Duck tracking	Brodeur et al. 2002	Satellite telemetry	1996–97	NW Atlantic	Point
Scoter tracking	O'Connor 2008	Satellite telemetry	2006; moulting	Labrador	Point
Scoter tracking	SDJV; Atlantic and Great Lakes Sea Duck Migration Study 2015	Telemetry	2001–18	Continental	Point
Scoter tracking	Lamb et al. 2020	Telemetry	2001–18	Continental	Point
Habitat					
Shoreline Classification and Pre-Spill database	ECCC EPOD; Sergy 2008	Air photo/video derived shoreline characteristics, foreshore and backshore; focus environmental emergencies	2008	Atlantic Canada; incomplete for study area	Line

Note: Data are of occurrences unless specified as presence-absence (including inferred).
ECCC (Environment and Climate Change Canada)
CWS (Environment Climate Change Canada-Canadian Wildlife Service)
Spring (Sp): March, April, May
Summer (S): June, July, August
Fall (F): September, October, November
Winter (W): December, January, February

Knowledge relating to waterfowl spanning the study area is presented here in multiple complementary forms. This includes LK as well as information derived from systematic waterfowl breeding and non-breeding season surveys, as well as incidental records from published sources. The bulk of available information originates from CWS aerial surveys, but also includes other formal and informal boat and land-based observations by other agencies, researchers, and individuals. The Atlantic Coastal Waterfowl Survey dataset mostly contains data derived from aerial surveys of waterfowl (e.g., ducks and geese) occurring within coastal and inshore waters. The common sampling unit for the dataset is the coastal (and inshore) waterfowl 'block' (Figure 11.1; Lock et al. 1996). 'Blocks' were initially designed to reflect prominent coastline features that separate coastal segments, inshore bays and estuaries, and thus aimed to delineate functionally distinct waterfowl habitat units (Lock et al. 1996). Records include counts of birds of each species observed within each polygon during each survey visit. Although observers aim to identify individuals or flocks of birds to species, this is not always possible. In these instances, individuals are assigned to genus, or to subfamily (i.e., Merginae [sea ducks], Anatinae [dabbling ducks], Aythyinae [bay ducks], Anserinae [geese]), etc. Some incidental records (i.e., not gathered consistently) of other bird species, mostly marine, are included. Of note, records can include coastal and inshore zone species not well captured through other surveys (e.g., loons, grebes, gulls, shorebirds, and cormorants). Although the Atlantic Coastal Waterfowl Survey database is still being used by EC-CWS Atlantic Region, data have not been added in several years.

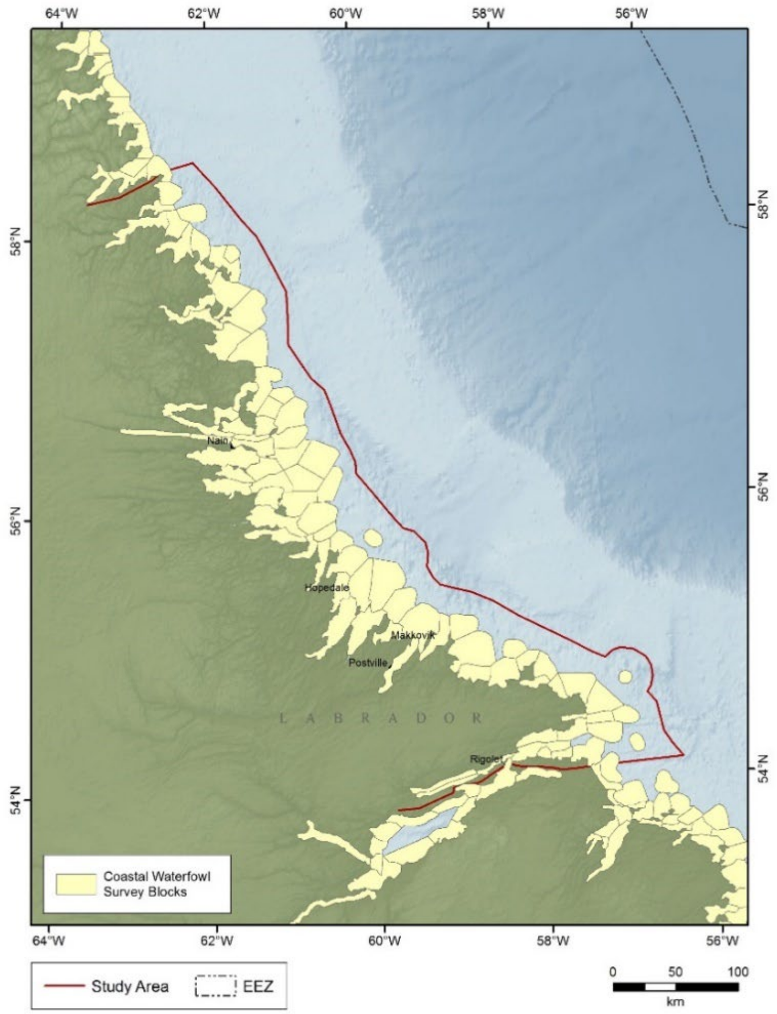


Figure 11.1: Coastal Waterfowl Survey Blocks

Additional surveys directed at waterfowl are being undertaken within the study area, typically generating point data. These, if desired, easily can be summarized by 'block' or otherwise. Relatively recent examples include surveys of scoters and eiders. The Eider Exploratory Winter Survey focuses on distribution and abundance of eiders and other target species within Labrador coastal and inshore waters. Spatial coordinates of individual birds and/or flocks are recorded. Increasingly, surveys record distance information and flight tracks so that true densities and zero values can be derived.

Marine bird colony information includes colonial seabirds and colonial waterfowl. CWS undertakes periodic aerial surveys of coastlines spanning the study area to update information within the Atlantic Colonial Waterbirds Database. This database contains records of individual colony counts, by species, for known colonies located in Atlantic Canada. Although some colonies are censused annually, most are visited much less frequently. Methods used to derive colony population estimates vary markedly among colonies and among species. For example, census methods devised for burrow-nesting alcids typically rely on ground survey techniques. As such, they tend to be restricted to relatively few colonies. In contrast, censuses of large gull or tern colonies, which are geographically widespread, rely on a combination of broad scale aerial surveys, and ground surveys at a subset of these colonies. Land-based counts are undertaken to correct aerial counts, differentiate species that are indistinguishable from the air, and to survey cryptic species (e.g., burrow-nesting species). Records are not limited to formal CWS survey data, and include records derived from written descriptions of incidental observations by individuals. Surveys of eider colonies present specific challenges and thus historically have not been captured well within the colony database. As a result, dedicated aerial surveys prior to, or early in, the breeding season have been directed at determining counts of eiders associated with individual nesting islands in Atlantic Canada. In Atlantic Canada, information from these dedicated surveys were summarized by coastal 'block' and captured within the Atlantic Coastal Waterfowl Survey dataset (see above). More recently, dedicated surveys are conducted using georeferenced flock information (points). This approach was used to produce maps of eider pre/early breeding season distribution along the Labrador coast and are captured in the colony database.

Information on marine bird colony seaward extensions (i.e., area used for foraging during the breeding season) is generated through combination of published estimates of mean-maximum foraging range derived, where possible, from locally-available data including GPS (Global Positioning System) and GLS (Global Location Sensor) tracking data. In the absence of sufficient local tracking data (i.e., obtained from representative samples over long time periods), general estimates of foraging range (mean and mean maximum) are used to delineate species-specific marine buffers within which foraging activities undertaken by all breeding adults at a site can confidently be assumed to take place. Further refinements of these potentially large areas, available for the study area, can be achieved through information on colony size (i.e., number of individuals), and knowledge of foraging behaviour as it relates to prey distributions and habitat associations (Ronconi et al. 2022).

At-sea marine bird survey data summaries generated for the study area but derived through broader regional efforts, are presented in this chapter. Data from at-sea surveys are available dating back to the 1960s, as part of PIROP (Programme Intégré de Recherches sur les Oiseaux Marins). This program was renewed in 2006 as the ECSAS (Eastern Canada Seabirds at Sea) program, which incorporated updates with modern protocols that allow for distance sampling and true density estimation. Due to its remoteness, the Labrador Sea has not received the same sampling as other eastern Canadian regions; this gap was identified in the context of offshore oil and gas interests in the Labrador Sea. In 2013, the ESRF (Environmental Studies Research Fund) funded at three year study to augment data collection of pelagic seabirds in the Labrador Sea, which filled a number of gaps (Fifield et al. 2016; Figure 11.2). Efforts to use predictive species distribution modeling are underway, and seasonal distributions and abundances of seabirds have been estimated outside of surveyed regions, including throughout the current study area (Fifield et al. 2017). Examples are presented as contributions to this chapter.

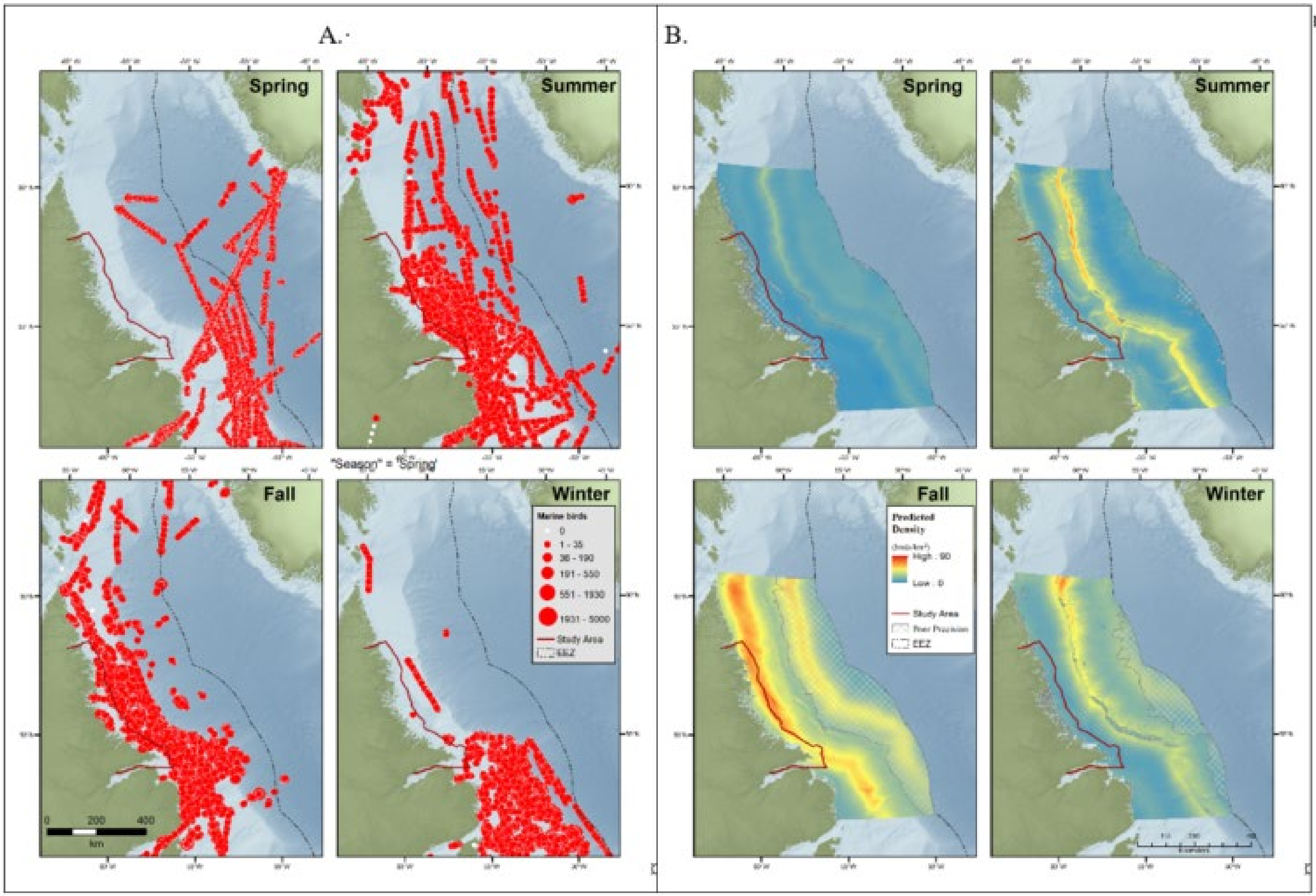


Figure 11.2: Seasonal locations of observations and relative abundances (A: 2006–17) and predicted densities (B: 2006–14) of seabirds in the study area and surrounding waters. Note the cross-hatched areas of poor prediction precision in B.

These boat-based observations provide a basis for analyses of year-round spatiotemporal distributions of marine birds and can be complementary to tracking data and confirmatory when used with information on colony seaward extensions.

With the advent of miniaturized telemetry and data-archiving devices suitable for marine birds, a wealth of annual tracking has emerged on many species, some of which have been shown to use the study area. Although the study area was known to host birds throughout the year, it was not previously known that the Labrador Sea, and Davis Strait to the north, host globally significant concentrations of non-breeding birds from both the Northeast and Northwest Atlantic, including from colonies as far away as Norway. Even Atlantic Puffins from the UK are making excursions into the study area and adjacent waters in late summer (Jessop et al. 2013). Taken together it is becoming clear that the study area, and adjacent deep waters to the north, south and east are internationally important wintering grounds for a range of Arctic breeding marine birds (Table 11.2 and Table 11.3). To illustrate, pelagic waters of the southern Labrador Sea, adjacent to Canada's EEZ, have been designated as an EBSA by the CBD as a result of the intersection of core foraging and wintering areas for three seabird species originating from 20 breeding colonies in the Northeast and Northwest Atlantic (CBD 2014).

Table 11.2: Status of sensitive bird species known to occur within the study area.

Common Name (Inuktitut / English)	***Latin Name* / Population**	**COSEWIC**	**Sch. 1**	**SARA**	**Newfoundland and Labrador**
Katjituk / Barrow's Goldeneye	*Bucephala islandica* Eastern population	SC	Yes	SC	Vulnerable
Eskimo Curlew	*Numenius borealis*	EN	Yes	EN	Endangered
Kutsiutik / Harlequin Duck	*Histrionicus histrionicus* Eastern Population	SC	Yes	SC	Vulnerable
Naujarluk / Ivory Gull	*Pagophila eburnea*	EN	Yes	EN	Endangered
Red Knot *rufa* ssp.	*Calidris canutus rufa*	EN	Yes	EN	Endangered
Red-necked Phalarope	*Phalaropus lobatus*	SC	No	No Status	No Status

EN=Endangered
TH=Threatened (none in study area)
SC=Special Concern

Table 11.3: Tracking and telemetry studies of seabird species using the study area.

Species (Inuktitut / English)	Latin Name	Source colonies	Extent of use of study area	Timing	Source
Akpak / Thick-billed Murre	*Uria lomvia*	Eastern Canadian Arctic	Extensive	Mid-winter	McFarlane Tranquilla et al. 2013
		Greenland	Extensive	Fall through spring	Frederiksen et al. 2016
		Eastern Canada (Gannet Islands, Labrador)	South edge	Summer (breeding)	Pratte et al. 2017
Akpak / Common Murre	*Uria aalge*	Eastern Canada (Gannet Islands, Labrador)	South edge	Summer (breeding)	Pratte et al. 2017
Saviatsojak / Razorbill	*Alca torda*	Eastern Canada (Gannet Islands, Labrador)	South edge	Summer (breeding)	Pratte et al. 2017
Kingutuk / Atlantic Puffin	*Fratercula arctica*	Ireland	Mostly south portion	August/ September	Jessop et al. 2013
		Mainly Iceland	Mostly southeast portion	Winter	Fayet et al. 2017
		Eastern Canada (Gannet Islands, Labrador)	South edge	Summer (breeding)	Pratte et al. 2017
Anugisiutik / Northern Fulmar	*Fulmarus glacialis*	Canadian High Arctic	Throughout	Fall and winter	Mallory et al. 2008
Nautsak / Black-legged Kittiwake	*Rissa tridactyla*	Canadian High Arctic, Greenland, Arctic Norway, Faroe Islands	Extensive, esp. east portion	Fall through spring	Frederiksen et al. 2012
Naujarluk / Ivory Gull	*Pagophila eburnea*	Canada, Greenland and Norway (Svalbard)	Extensive, esp. north portion	Winter	Gilg et al. 2010 Spencer et al. 2016

Marine birds have recognized inherent biodiversity value, they contribute significantly to human well-being, and constitute valuable ecological indicators for ecosystem planning and effectiveness monitoring to inform adaptive management. Here, other than at-risk species, emphasis is placed on species of local significance, species that are unique to the study area, and species recorded during surveys in numbers reaching top 10% values (i.e., top decile) for Eastern Canada (Scotian Shelf, Gulf of St. Lawrence, and NL Shelves marine bioregions), specifically for waterfowl counts, colony sizes and at-sea data. Intent is to highlight those species for which the study area is of highest relative importance, when assessed at a large spatial scale, while providing context through presentation of essentially continuous data.

11.2. Local Knowledge

During Imappivut interviews, participants identified the important food value of marine birds during both spring and fall hunts. In the fall, participants discussed hunting Canada Goose (*Branta canaden*sis) and various species of ducks, including Common Eider (*Somateria mollissima*), American Black Ducks (*Anas rubripes*), teals (*Anas discors* and *Anas crecca*), and Red-breasted Merganser (referred to locally as shell birds) (*Mergus serrator*). Thirty interview participants discussed hunting ducks or geese and identified key hunting locations for these species. Interview participants also described hunting lesser Canada Goose (*B. c. parvipes*), and some commented that they have seen an increase in this subspecies in recent years. Canada Goose is the primary focus of the spring hunt for marine birds among Labrador Inuit. During the spring season, Labrador Inuit gather various species of eggs, including ducks, Black Guillemot (referred to locally as pigeons) (*Cepphus grille*), gulls (*Larus* spp.), and terns (*Sterna* spp.). Interview participants also discussed occasionally hunting murres (also called turrs) (*Uria* spp.) and various shorebird species, including primarily sandpipers which are referred to locally as beachy birds or nan saries (Family: *Scolopacidae*).

Imappivut interview participants documented both inland (ponds and wetlands) and coastal (island ponds and shorelines) hunting locations that are particularly important and productive for geese and ducks. Participants specifically identified groups of islands that geese and ducks frequently use for nesting and staging during migrations throughout the entire study area, with particularly important groups of islands identified around Rigolet and outside of Kaipokok Bay near Makkovik (Figure 11.5, Figure 11.6).

11.3. Shorebirds

Local knowledge sources identified widespread distribution of shorebirds throughout the study area, particularly noting observations of sandpipers and Greater Yellowlegs (*Tringa melanoleuca*) in the Rigolet region (Figure 11.3).

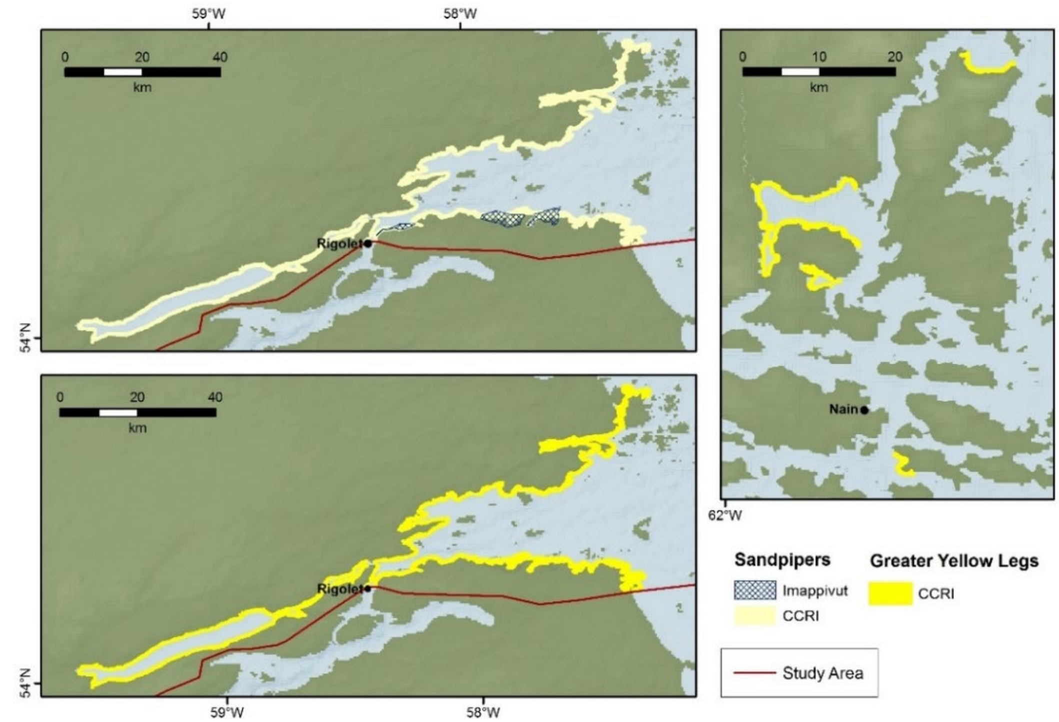


Figure 11.3: Local Knowledge of the distribution of Sandpipers (Sitjagiak) and Greater Yellow Legs (Kanaiqik) within the study area.

Despite limited availability of systematic shorebird surveys (Figure 11.4), those available and work by Todd (1963), Godfrey (1986), Harrington (1994), and Veitch (1993, unpublished field journal records) indicate regular occurrence by a broad diversity of species within the study area. Some, including Semipalmated Sandpiper (*Calidris pusilla*), Least Sandpiper (*Calidris minutilla*), Wilson's Snipe (*Gallinago delicata*), Spotted Sandpiper (*Actitis macularia*), Solitary Sandpiper (*Tringa solitaria*), Greater Yellowlegs and Short-billed Dowitcher (*Limnodromus griseus*) are documented breeders in appropriate habitat in adjacent terrestrial areas on the Labrador Peninsula. White-rumped Sandpiper (*Calidris fuscicollis*), Spotted Sandpiper, Least Sandpiper, Semipalmated Sandpiper and Red-necked Phalarope (*Phalaropus lobatus*) have been observed during migration at Atlantic Canada Shorebird Survey sites at Nain and Hebron, though all could be expected at that time in intertidal flat and beach habitats along the study area coastline (Todd 1963). Other species expected during migration in appropriate habitats within the study area include Semipalmated Plover (*Charadrius semipalmatus*), American Golden-Plover (*Pluvialis dominica*), Black-bellied Plover (*Pluvialis squatarola*), Purple Sandpiper (*Calidris maritima*), Pectoral Sandpiper (*Calidris melanotos*), Sanderling (*Calidris alba*), Ruddy Turnstone (*Arenaria interpres*) and Dunlin (*Calidris alpina*). The Endangered Red Knot (*Calidris canutus rufa*) is known to occur in Labrador, though records from within the study area are sparse. The Endangered Eskimo Curlew (*Numenius borealis*) also is known to occur within the study area but confirmed records have not been obtained in decades.

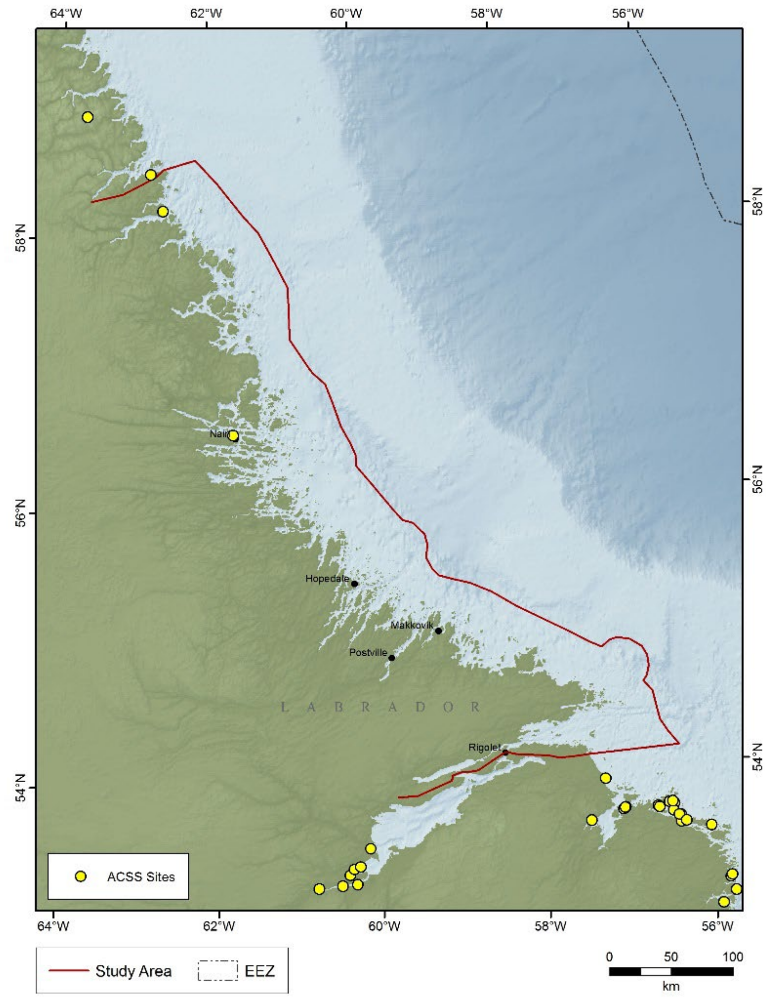


Figure 11.4: Atlantic Canada Shorebird Survey sites.

Of the two species of phalarope known to occur regularly within the study area, only one, the Red-necked Phalarope is considered as a common breeder in appropriate terrestrial habitat on the Northern Peninsula (Godfrey 1986). Though recorded coastally, both phalarope species are encountered regularly at-sea during migration and are thus treated with other species occurring offshore.

11.3.1. Waterfowl

CWS Coastal Waterfowl Survey ‘block’ maps present maximum counts by species (or groups, where individuals were not identified to species), across all survey ‘block’ polygons. Different waterfowl subfamilies are known to rely on different food resources, found at different places and depths and on different substrates. For example, outside the breeding season, geese and dabbling ducks typically forage in intertidal and shallower inshore areas; bay ducks forage in more protected coastal and inshore waters <7 m in depth; while sea ducks typically find their prey within more exposed coastal and inshore waters <30 m in depth. Surveys were focused on one or more species (e.g., breeding eiders or moulting scoters), and coverage of a block typically is incomplete across habitat types. For example, surveys focusing on Common Eider (*Somateria mollissima*) cover deeper waters and offshore islands but have poor coverage of inshore shallow water areas that are used by dabbling ducks and geese. As such, an unknown number of individuals can be missed on any given survey visit due to survey timing, light conditions, weather conditions, omissions in survey coverage, etc. Maxima were used to best reflect the potential for a survey polygon to host waterfowl. Note that variation in size among 'blocks' can constitute a source of bias in comparisons. Given limited survey effort, polygons with low maximum values should not be interpreted as having low ecological value, even for the species mapped. Though Coastal Waterfowl Survey frequency in Labrador is low relative to other parts of Eastern Canada, many surveys are geographically comprehensive, and in some instances can provide evidence of persistence in use. Where available, other datasets are presented according to their data type (e.g., points versus polygons).

Geese

Canada Goose (*Branta canadensis*) is the dominant goose species in the study area. Geese that use the study area include the North Atlantic Population Canada Goose that breeds in interior Newfoundland, Labrador, and parts of Quebec, as well as the Temperate Canada Goose that breeds in southern Canada and the USA and migrates north to moult. Greater Snow Goose (*Chen caerulescens*) has been detected during surveys, but no records of significance are associated with this portion of the Labrador coastline. Congregations of geese occur at migratory staging areas, mostly from Nain and south, including a top decile maximum count of 6,250 individuals recorded in the Catos Island 'block' located within the Goose Brook IBA (Figure 11.5, left panel). This number represents roughly 5% of the North Atlantic population. Ten other Coastal Waterfowl Survey blocks in the study area have hosted numbers from 300 to 600 individuals. Labrador Inuit hunt geese in both spring and fall, though most hunting occurs during the fall migration. Imappivut interviews identified certain geese nesting areas (Figure 11.5, right panel) but interviews did not specifically focus on identifying this feature. Typically, participants highlighted feeding and staging areas as they are used more prominently for hunting locations. Imappivut interview participants also discussed observations of changes in geese, identifying an observed shift to higher numbers of physically smaller geese, raising questions about potential presence of, or changes in, composition of geese subspecies throughout the region (e.g., *Branta hutchinsii*). Ongoing research and monitoring conducted in partnership between the Canadian Wildlife Service and the Nunatsiavut Government is currently attempting to estimate geese species composition and abundance in the study area. As of spring 2019, sampling efforts are currently concentrated in Nain, Hopedale, and Makkovik, with plans to expand to Postville and Rigolet in coming years.

Dabbling Ducks

Though the American Black Duck (*Anas rubripes*) is the dominant species within this group (Figure 11.6), a number of dabbling duck species are known to breed in appropriate terrestrial habitats adjacent to the study area. These include uncommon breeders such as the Northern Pintail (*Anas acuta*) and others encountered with increasing frequency such as Green-winged Teal (*Anas carolinensis*) (Figure 11.7). The American Black Duck, breeding predominantly from Saglek south, is encountered along coastlines during the summer moulting period in coastal areas in flocks 50–100 or more individuals, with block counts reaching nearly 1,000 individuals at a few locations.

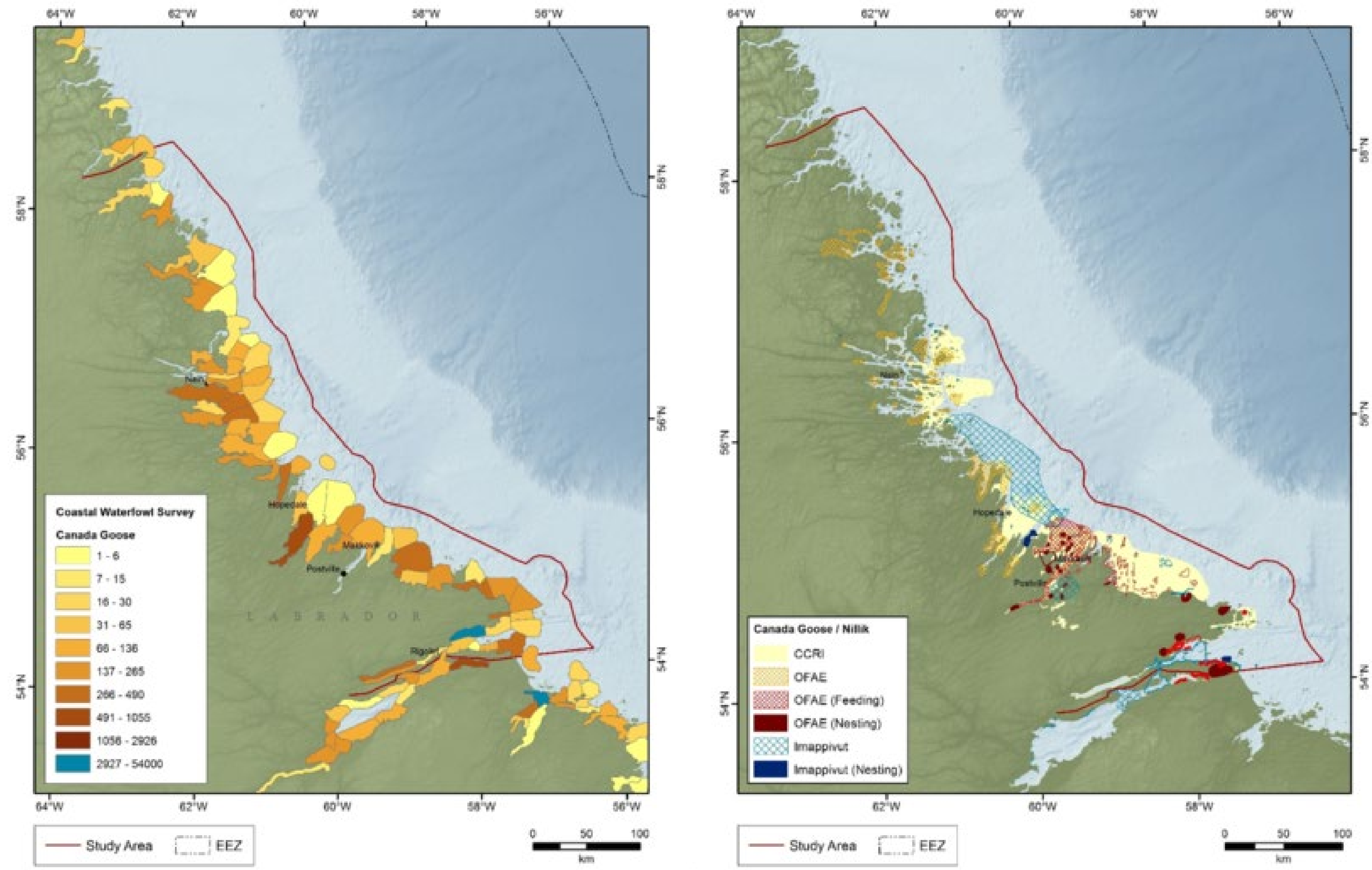


Figure 11.5: Distribution of Canada Goose based on survey maxima (left) and Local Knowledge (right).

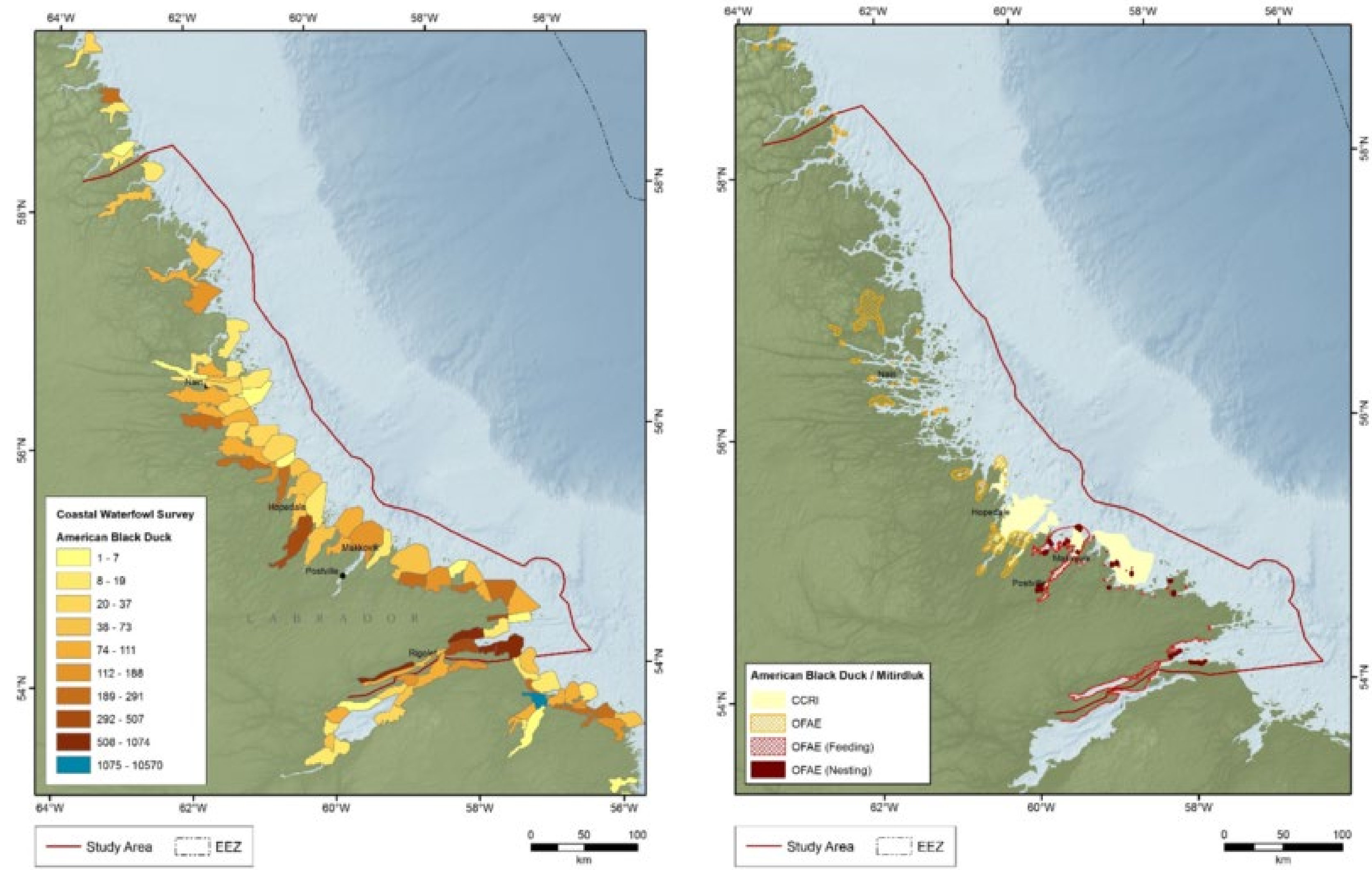


Figure 11.6: Distribution of American Black Duck based on survey maxima (left) and Local Knowledge (right).

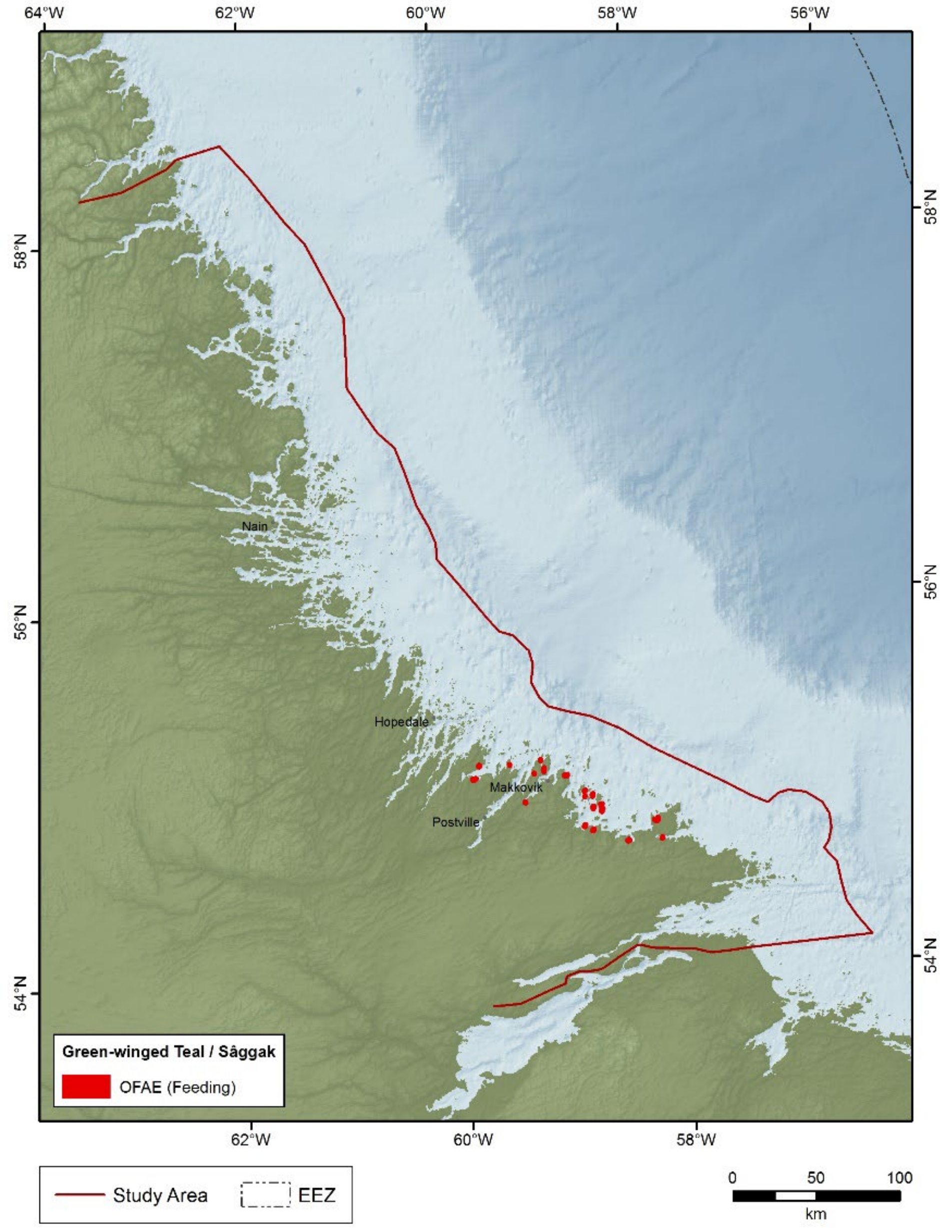


Figure 11.7: Local Knowledge reports of Green-winged Teal.

Bay Ducks

The Greater Scaup (*Aythya marila*) is the dominant species within this group. No Coastal Waterfowl Survey blocks within the study area are known to host important numbers of scaup, or other bay duck species (Figure 11.8). Deep Inlet is known to have hosted over 300 individuals, but it remains the only block in the study area where any counts obtained have surpassed 10 individuals. However, large pre-moulting aggregations of 1,500 to 3,000 individuals were observed in the Backway, just outside the study area (S.G. Gilliland, pers. comm.).

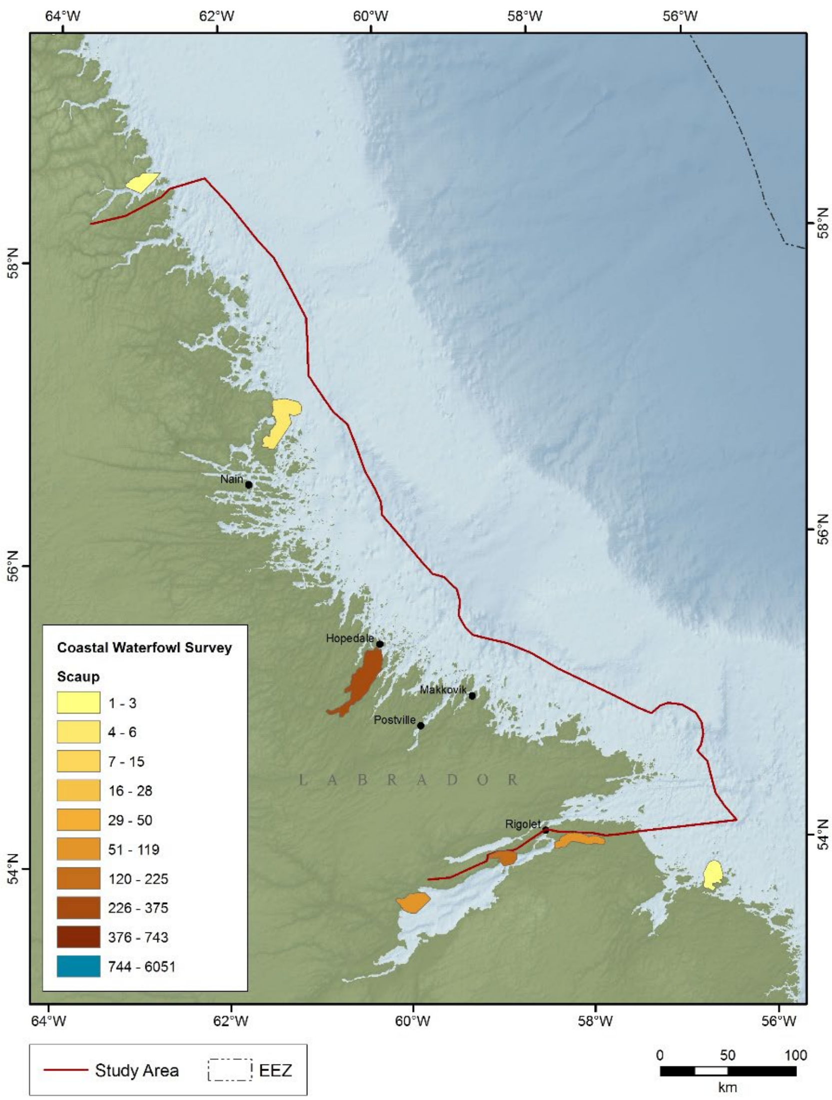


Figure 11.8: Scaup survey maxima.

Sea Ducks - Eiders

The Common Eider is the dominant marine bird within the study area (Figure 11.9 and Figure 11.10) and is a commonly hunted species by Labrador Inuit. Here, its population is made up of individuals from two subspecies. The more northern *borealis* subspecies is a common and widespread breeder on coastal islands throughout the study area, predominantly from Saglek south. Important nesting areas include sites within the Nain Coast IBA and in areas off Hopedale and Makkovik (Figure 11.10; Chaulk et al. 2005). Direct tracking of these northern subspecies breeding eiders has not yet been conducted but based on the subspecific composition of eiders hunted in eastern Canada and the northeast US, it is expected that most of this population winters mainly along the coasts of northern Newfoundland and the northern Gulf of St. Lawrence (Reed and Erskine 1986, Gilliland et al. 2009). The more southerly subspecies *dresseri* also nests on coastal islands within the study area, predominantly in its southern portion. Breeding overlap and intergrades are prevalent between the two subspecies within the study area (Mendall 1980). Important *dresseri* nesting areas include sites within the

Table Bay IBA and South Groswater Bay IBA. Breeding female common eiders have been banded in both of these IBAs and those data shows that they winter throughout Newfoundland, the northern Gulf of St. Lawrence, but range as far south as coastal Nova Scotia and Maine (Gilliland and Robertson 2009). Key moulting sites within the study area include Tumbledown Dick and Stag Islands IBA. Small wintering flocks occur within the study area, but numbers are much lower in comparison to other areas (i.e., hundreds, not thousands; see Figure 11.10). Of note, about 45,000 eiders were detected wintering north of the study area at Button Island, evenly split between Common Eider and King Eider (*Somateria spectabilis*). Though several Coastal Waterfowl Survey blocks within the study area have hosted 1,000 individuals or more (either June or September), numbers do not reach top decile values (Figure 11.9); however this result reflects more the extensive distribution of eiders across eastern Canada and that eiders breeding in Labrador are more broadly distributed (Chaulk et al. 2006, unpublished survey) and not concentrated into a few large colonies (and coastal blocks) as seen in other parts of Atlantic Canada.

Sea Ducks - Mergansers

Red-breasted Merganser (*Mergus serrator*) is the dominant species in this group, breeding in appropriate terrestrial habitats adjacent to the entire study area (Figure 11.11, left panel). Numbers driven by this species reach top decile values (475+) at Catos Island and Okak Bay blocks. Several other locations in the study area have hosted 200 or more individuals. Common Merganser (*Mergus merganser*) also occurs but in lower numbers, breeding only in areas adjacent the southern limit of the study area.

Sea Ducks - Goldeneyes

Common Goldeneye (*Bucephala clagula*) is the dominant of the two goldeneye species. Though neither species is known to breed in vicinity of study area coastline, numbers during migration and moult reach top decile values (450+) at several locations, including Okak Harbour, Kiglapait, Webb Bay, Nain Bay, Voisey Bay, Deep Inlet and Dog Islands survey blocks (Figure 11.11, right panel). Barrow's Goldeneye (*Bucephala islandica*) is treated separately as a species-at-risk, below.

Sea Ducks - Scoters

Scoters breed throughout southern and western Labrador, possibly breeding in appropriate terrestrial habitats adjacent to the study area. Largest flocks in the study area are detected in June and in August (Figure 11.12). Scoters during the summer moulting period may be particularly vulnerable to disturbance (O'Connor 2008). It is possible to extract surveys targeting moulting scoters from the Coastal Waterfowl Survey database. Surf Scoter (*Melanitta perspicillata*; occurring during non-breeding and summer moulting) is considered the dominant scoter species in Labrador (Figure 11.12). It is the most widely distributed and occurs at the highest densities (Gilliland and McAloney 2009, S. Gilliland, pers. comm., Gilliland and Savard 2021). White-winged Scoter (*Melanitta deglandi*) and Black Scoter (*Melanitta americana*) breed in low densities in appropriate adjacent terrestrial habitats and are encountered mostly during the summer moulting period. Top decile counts (2,400+) within the study area have been recorded in survey blocks including: Tasiyuyak Bay (White-winged Scoter; June), Misfit Island: 2,956 (scoters; August), Voisey Bay: 4,359 (scoters; June), Nukasusatok: 4,670 (scoters; August), Ford: 10,175 (scoters; August), Waggon Island: 2,665 (scoters; June), Ticoralak Bight: 3,094 (Surf Scoter; June) and Double Mer North: 2,895 (scoters; August). Tracking information for scoters is available that could shed light on important staging areas (S.G. Gilliland, pers. comm.).

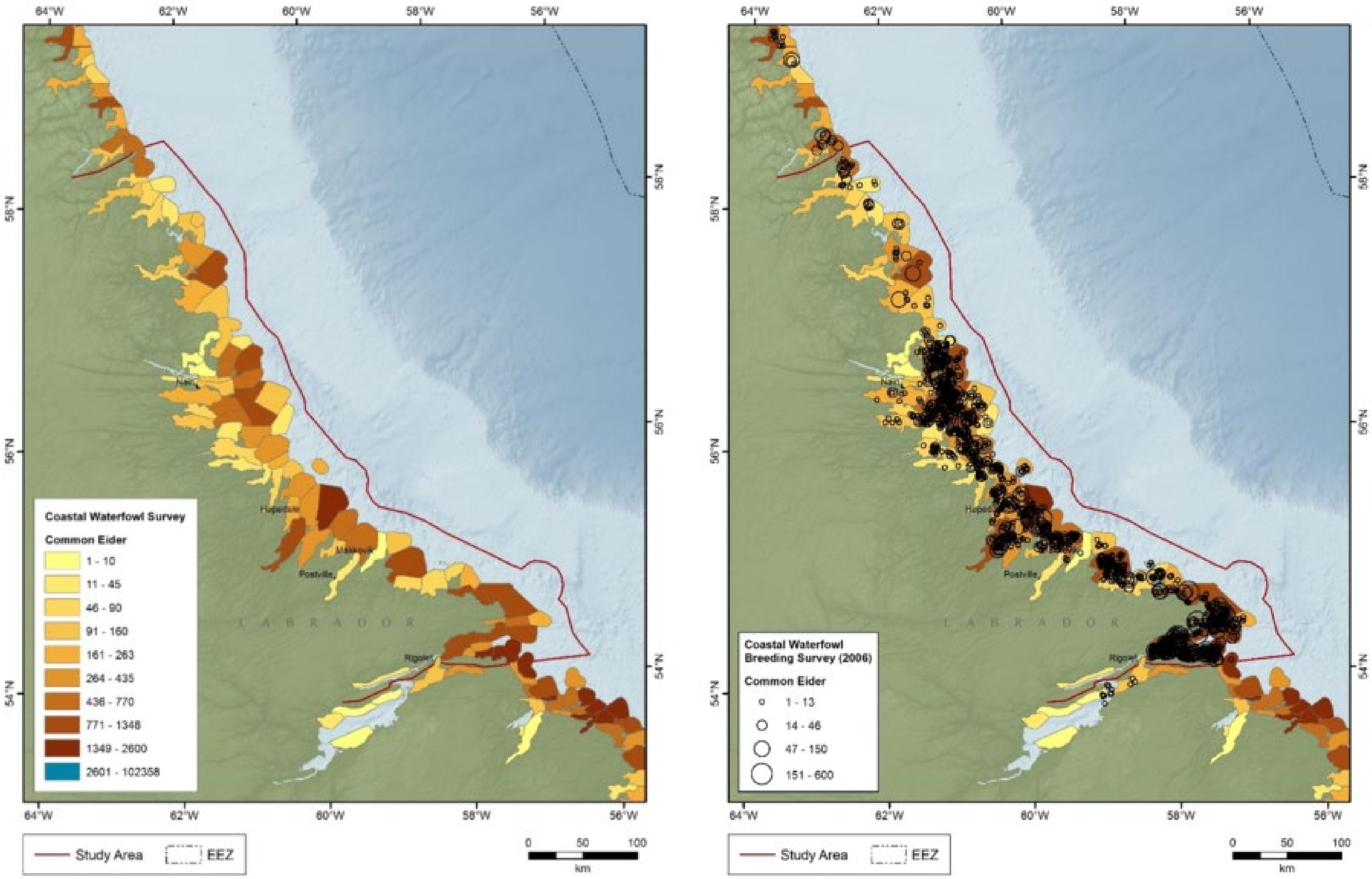


Figure 11.9: Eider survey maxima (left) and Eider survey maxima showing incorporation of 2006 breeding survey data (right).

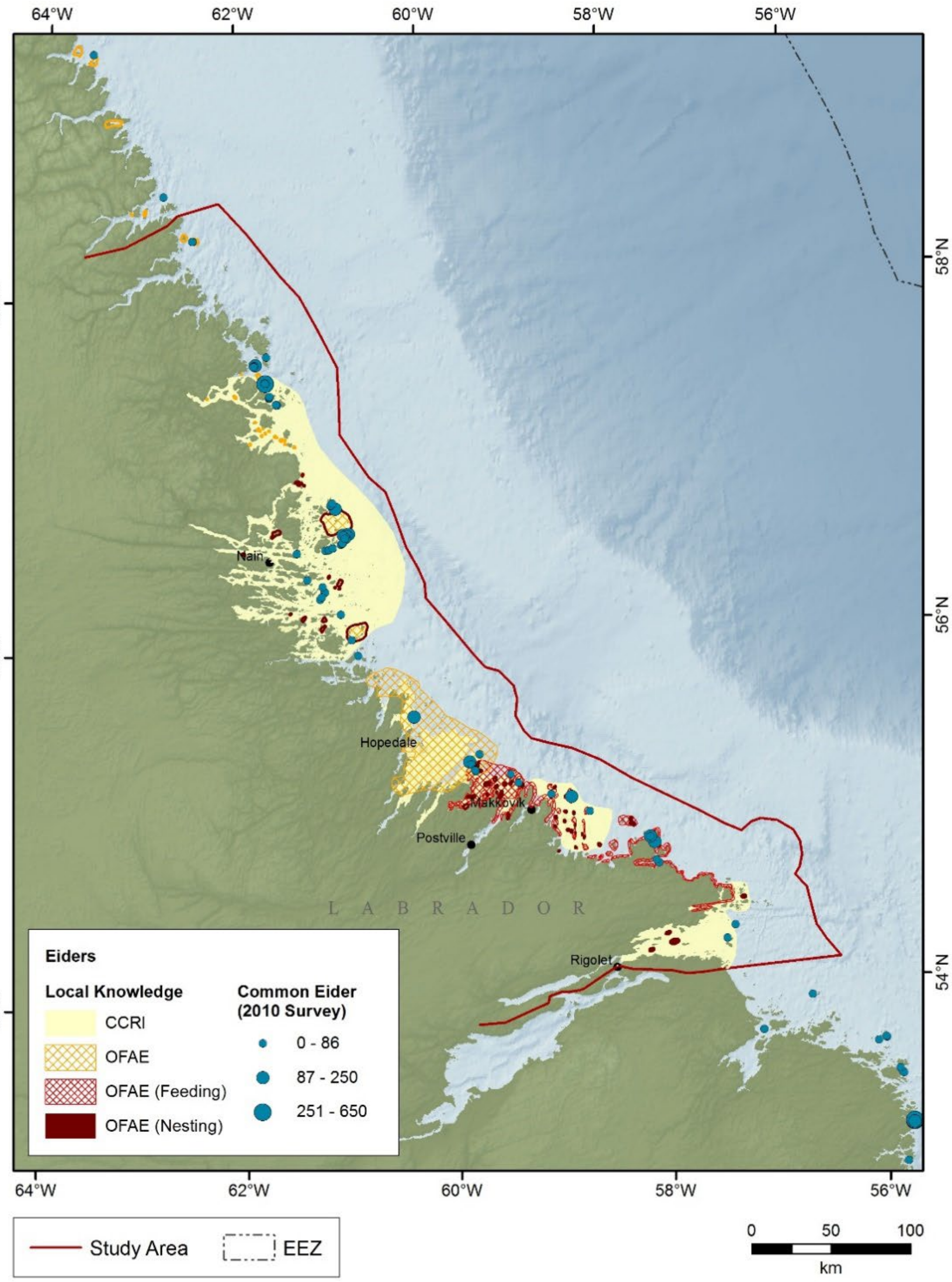


Figure 11.10: Eider exploratory winter survey data from 2010 (left) and Local Knowledge of Eiders (right).

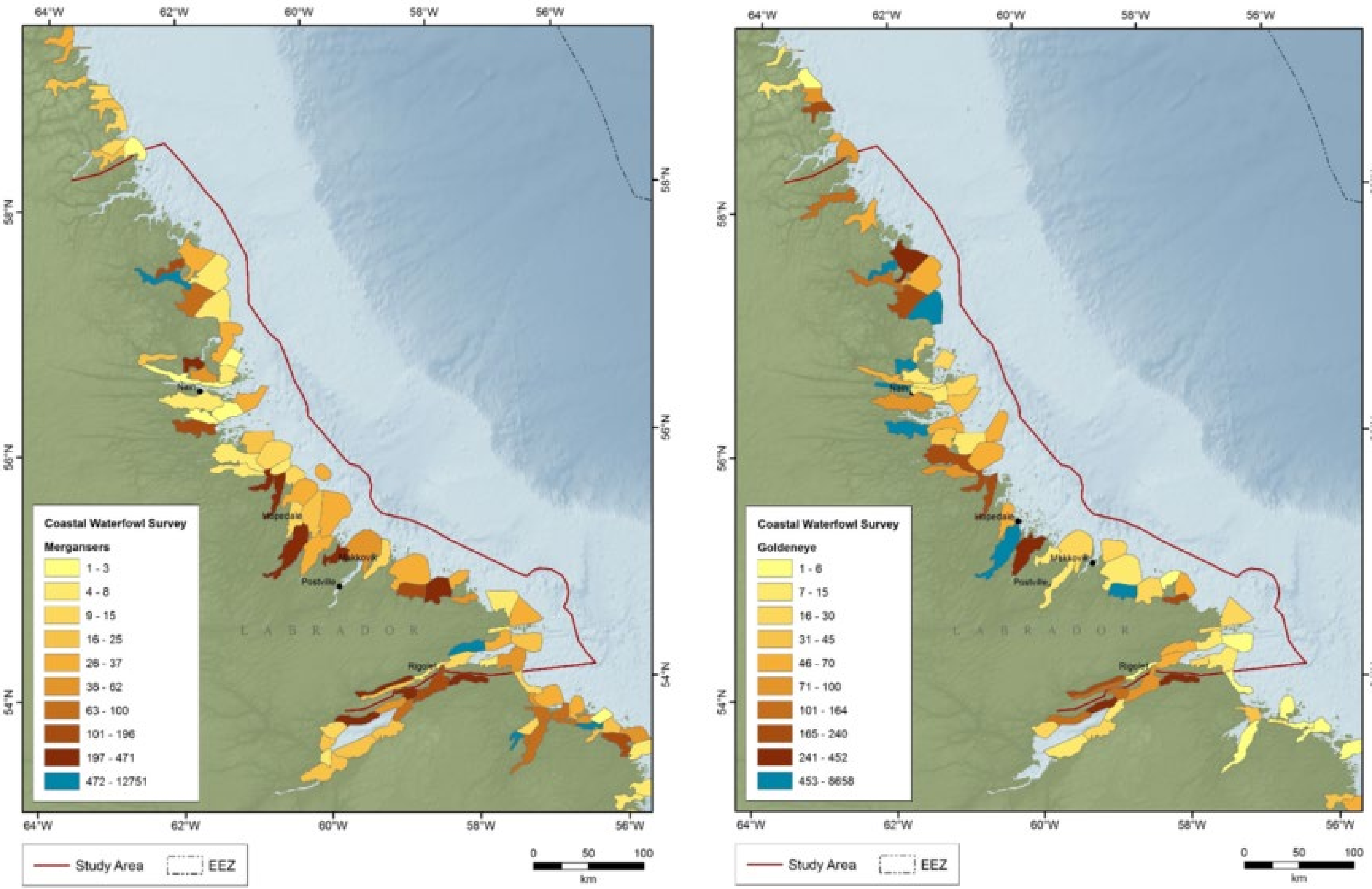


Figure 11.11: Merganser survey maxima (left) and Goldeneye survey maxima (right).

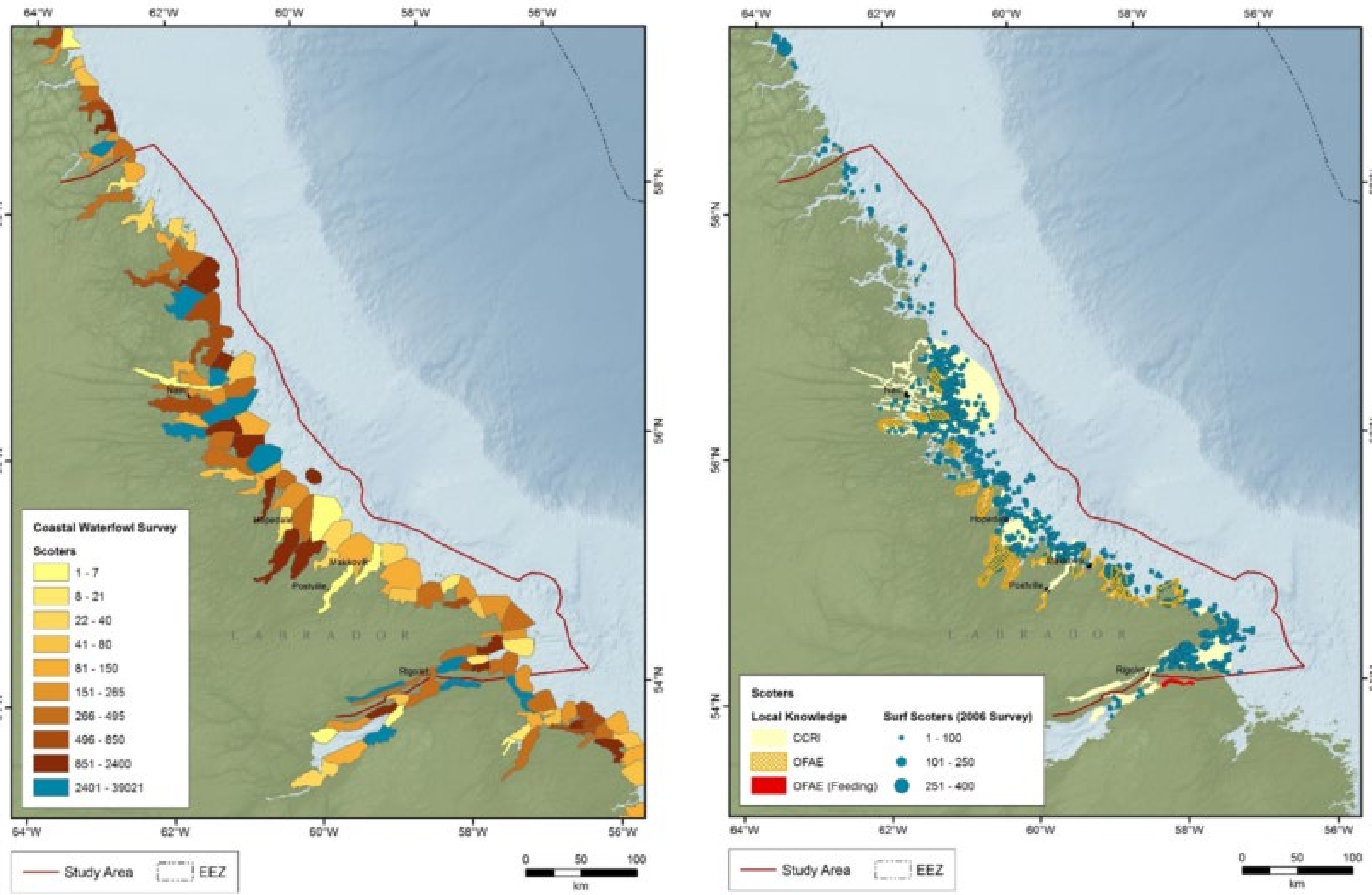


Figure 11.12. Local Knowledge and survey information on the distribution and density of Scoters in Northern Labrador.

Sea Ducks - Other

Long-Tailed Duck (*Clangula hyemalis*) is an easily-identified but difficult to survey species as it can be found in deeper water habitats not used by other species. As such, it is often inadequately represented in other multispecies surveys (see Figure 11.13) and has not yet been the focus of a targeted survey. Such efforts are underway elsewhere in Eastern Canada that could inform survey planning within the study area.

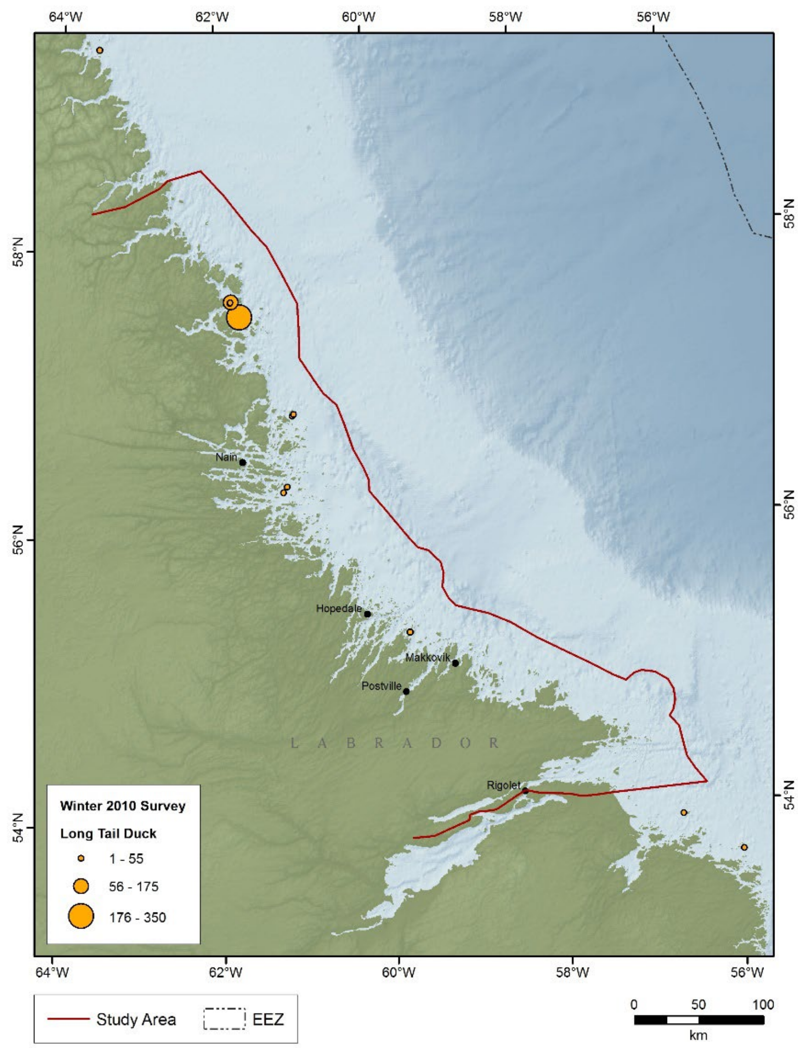


Figure 11.13: Long-tailed Duck counts collected during the 2010 winter survey.

Waterfowl Species at Risk

The Eastern population of Harlequin Duck (*Histrionicus histrionicusis*) is listed under SARA as Special Concern. This small population contrasts with the larger western Pacific population. Labrador hosts a large portion of the eastern population and areas within the study area are important moulting and staging areas (Trimper et al. 2008). Imappivut interview participants recorded Harlequin Duck observations throughout the study area and in at least one case commented on increased observations in recent years. Within the study area, numbers recorded during Coastal Waterfowl Surveys reach top decile counts (50+) only within the Tumbledown Dick and Stag Islands IBA (only Tumbledown Dick Island is within study area bounds; Figure 11.14). It should be noted that the adjacent Gannet Islands IBA is known to constitute an important moulting site (Gilliland et al. 2002), while top decile count pre-moulting flocks have been recorded at sites in adjacent Torngat National Park. Extensive tracking information exists for this species that highlights a number of important staging areas in the study area, specifically Okak Bay (and areas north of the study area), areas around Nain, and Groswater Bay (Figure 11.15). Birds staging on the Labrador coast originate from breeding areas throughout its eastern Canadian breeding range, and many, especially from the northern areas, migrate to Greenland for the winter (Brodeur et al. 2002, Chubbs et al. 2008, Robert et al. 2008).

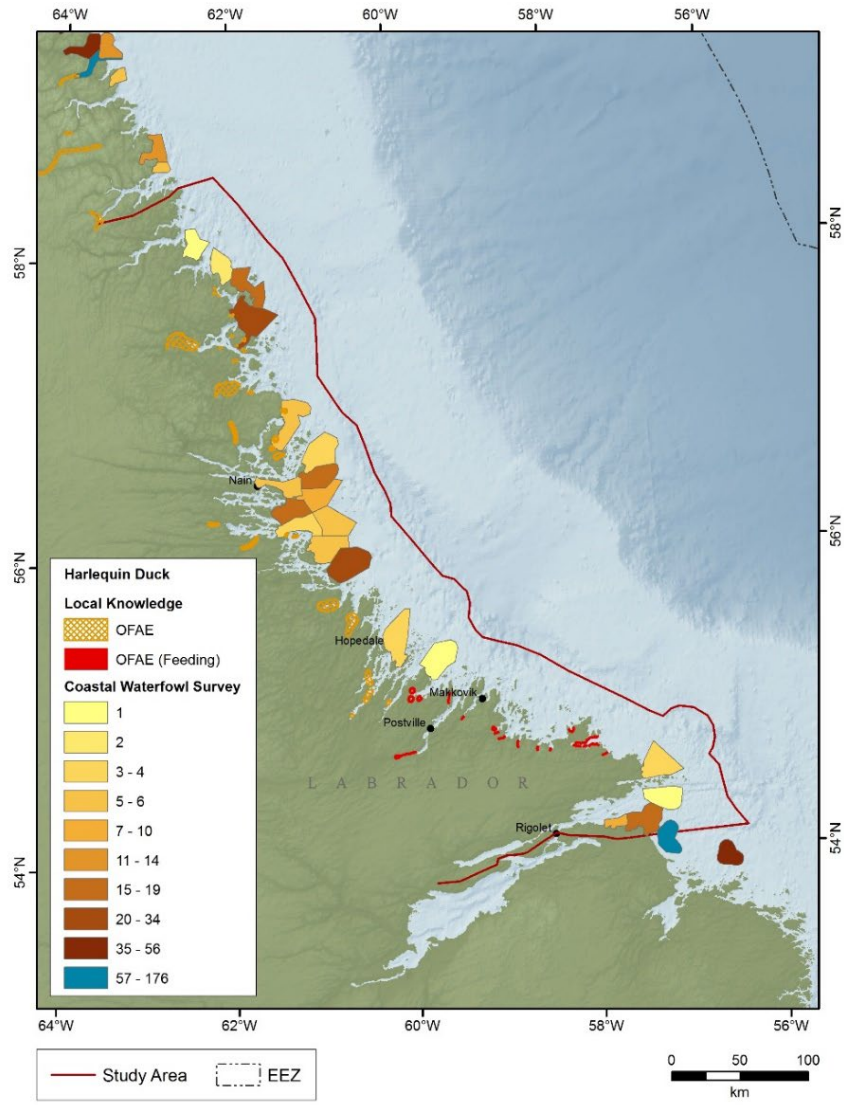


Figure 11.14: Harlequin Duck survey maxima.

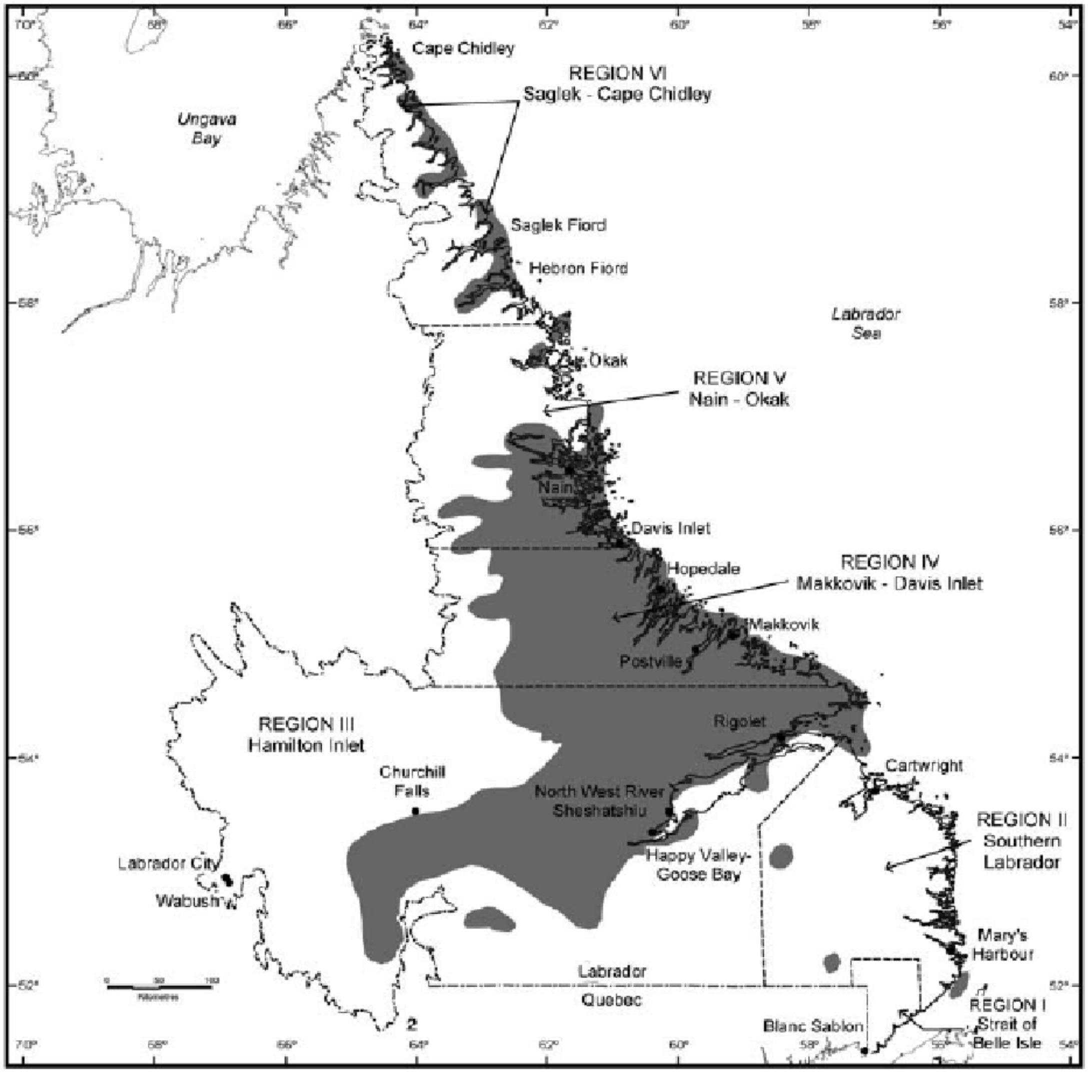


Figure 11.15: Harlequin Duck staging, breeding, and molting areas in Labrador (Trimper et al. 2008).

The Eastern population of Barrow's Goldeneye is listed under SARA as Special Concern. Its small Eastern population also contrasts with a larger Western population. During Coastal Waterfowl Surveys, only blocks within Torngat National Park were found to host this species. However, a recent compilation of incidental records undertaken by CWS has revealed a number of occurrences within the study area, including one incidental sighting near Nain, within the Strathcona Run 'block', reaching the top decile for survey values (Figure 11.16). The relative significance of these sites for the Eastern Population is otherwise unknown.

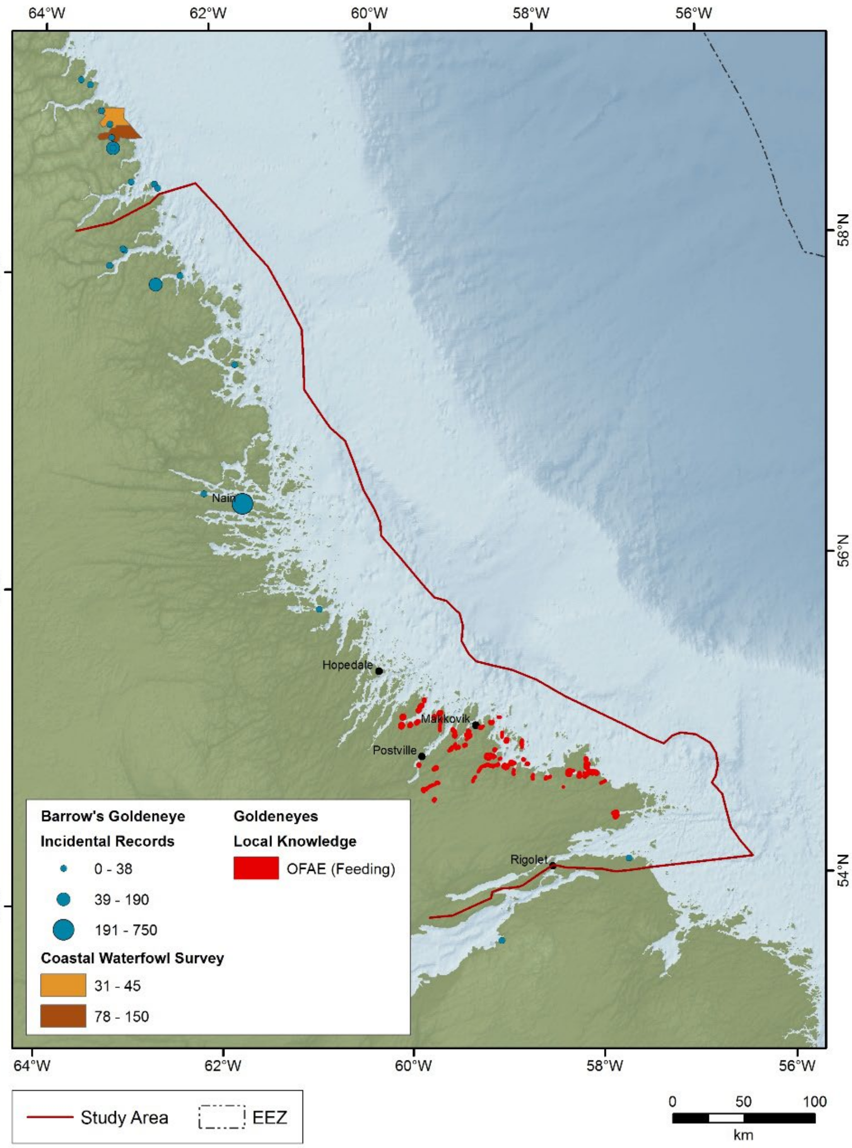


Figure 11.16: Barrow's Goldeneye survey maxima, incidental records, and Local Knowledge of Goldeneyes distribution.

11.3.2. Marine Bird Colonies

For some species, notably large gulls, maxima reached in the 70s or 80s may have benefitted from important anthropogenic sources of food, leading to numbers that may not be seen again (Cotter et al. 2012). Certain sites, historically known to host colonies, may no longer be suitable due to natural and/or human causes. Though persistently used locations may be the focus of long-term habitat conservation planning, alternative potential nesting sites, used or not, may offer opportunities for nesting in the future, leading to enhancement of resilience. Unlike other parts of Atlantic Canada, some colonial nesting species, notably eiders and large gulls, are widely dispersed across the many islands available on the Labrador coast, and frequently switch nesting islands from year to year (Chaulk et al. 2006, unpublished survey, Robertson and Chaulk 2016). This dynamic selection of nesting islands is due to the vagaries of local sea ice melt in the spring (Chaulk et al. 2007), and the presence of potential avian prey (Robertson and

Chaulk 2017). Although not assessed directly in Labrador, terns likely also exhibit this dynamic selection of nesting islands. Auk colonies, on the other hand, are generally stable and persist from year to year.

Surveys of Common Eider nesting on colonies present specific challenges as females are difficult to detect from the air. As a result, dedicated aerial surveys of males prior to or early in the breeding season are used to estimate numbers of females assumed to be associated with individual nesting islands. Some of these dedicated survey data are available as points (see Common Eider breeding June 2006 breeding season survey), and as polygons summarized within coastal ‘blocks’ (e.g., Common Eider survey ‘block’ maxima).

Gull and Tern Colonies

Gulls are broadly distributed throughout the study area (Figure 11.17). The Herring Gull (*Larus argentatus*) is a common colonial breeding species within the study area, predominantly south of Nain. Though no single colony presents top decile counts (~900+), it is noted here as adjacent colonies collectively may form important aggregations (Figure 11.18), and as noted above this species is widely distributed and does not form large colonies in Labrador. Surveys undertaken from 2012–14 suggest that the range of this species is increasing northward.

The Great Black-backed Gull (*Larus marinus*) also is a common colonial species within the study area. Though no single colony presents top decile counts (~250+) adjacent colonies collectively may form important aggregations (Figure 11.19), and similar to Herring Gull this species is widely distributed and does not form large colonies in Labrador.

The Glaucous Gull (*Larus hyperboreus*) is an especially significant colonial species within Labrador and within the study area, as it nests nowhere else in Eastern Canada. All colonies of this species in Eastern Canada are located north of Makkovik (Figure 11.20, extending beyond the study area boundary to the northern tip of Labrador (and further into other Arctic regions). Counts reach the top decile (~150+) at several locations, further emphasizing the importance of the study area for this species. Of note, Ukallik Island, within the Nain Coastline IBA, supports 1% of the continental breeding population of the species, as does an unnamed island South of White Bear Island and Cod Island North of Clarke Inlet. Though the study area incorporates the majority of Glaucous Gull colonies within Eastern Canada, with maxima at several colonies in the top decile, surveys undertaken from 2012–14 suggest important declines (60%), consistent with declines seen in other jurisdictions across the Arctic (Petersen et al. 2015).

Terns, including Arctic Tern (*Sterna paradisaea*) and Common Tern (*Sterna hirundo*) are common colonial breeding species within the study area, especially prevalent within its southern extent (Figure 11.21). These two species are very similar in appearance and are difficult to differentiate from the air (i.e., during aerial surveys). As such, totals derived from surveys include individuals of both species and assessment against relative abundance thresholds is not possible. Regardless, several colonies exceed 250 individuals, and a few are adjacent, forming larger aggregations. These can be considered important, in relation to size and distribution of other tern colonies in Eastern Canada.

Other colonial species in this group include the Ring-billed Gull (*Larus delawarensis*), known to occur at a few colony locations within the study area, but not in important numbers (Figure 11.22). It is more common and abundant within the Lake Melville system. The Black-legged Kittiwake (*Rissa tridactyla*), a small gull, is known to breed within the study area (Quaker Hat Island), but in relatively small numbers (Figure 11.22)

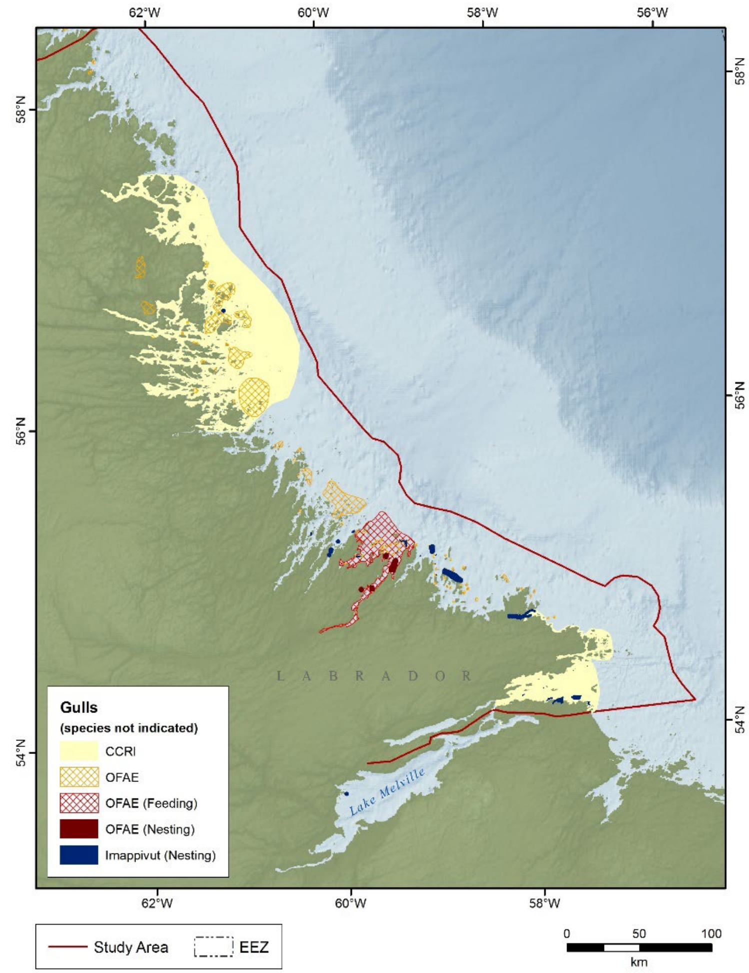


Figure 11.17: Local Knowledge records of gull distribution (species not indicated).

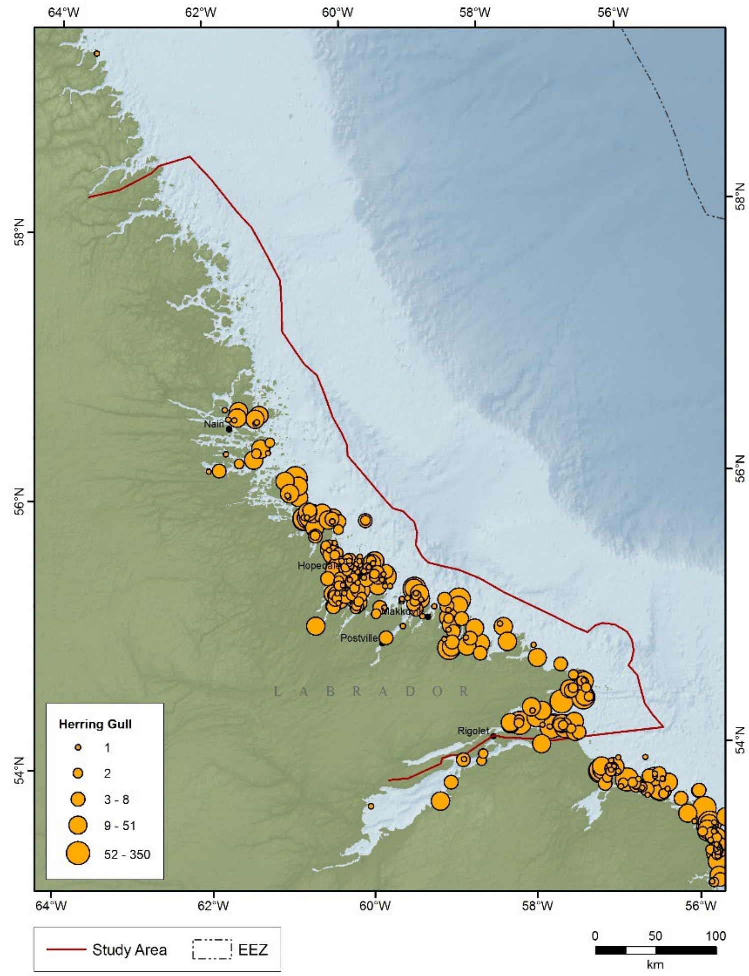


Figure 11.18: Herring Gull colony maxima.

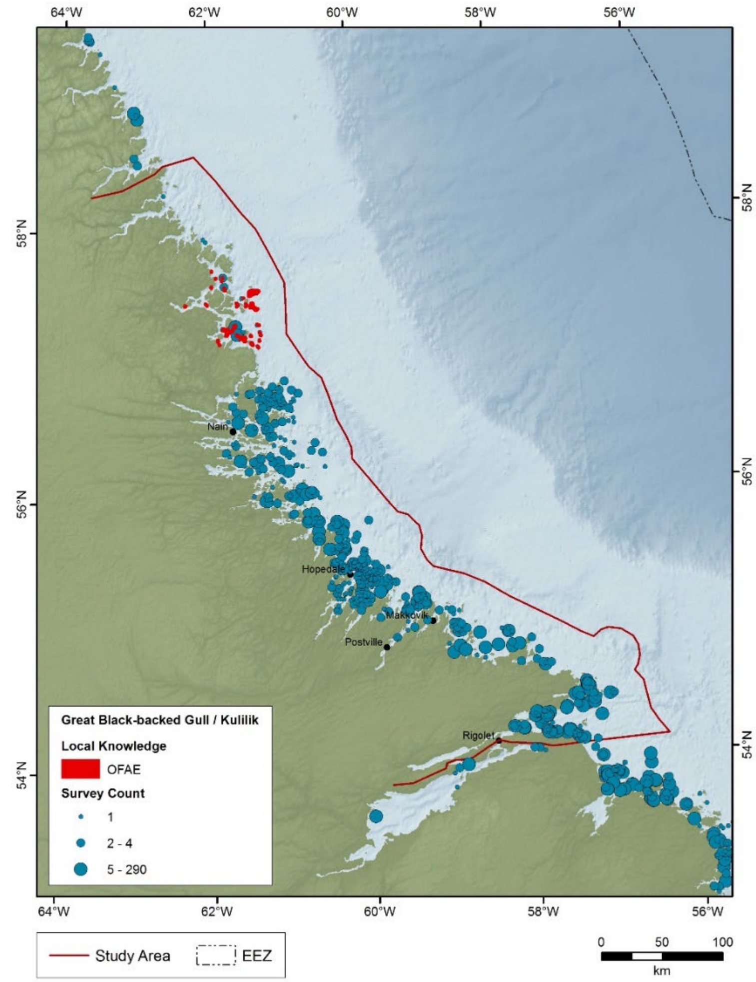


Figure 11.19: Survey counts and Local Knowledge of Great Black-backed Gull distribution.

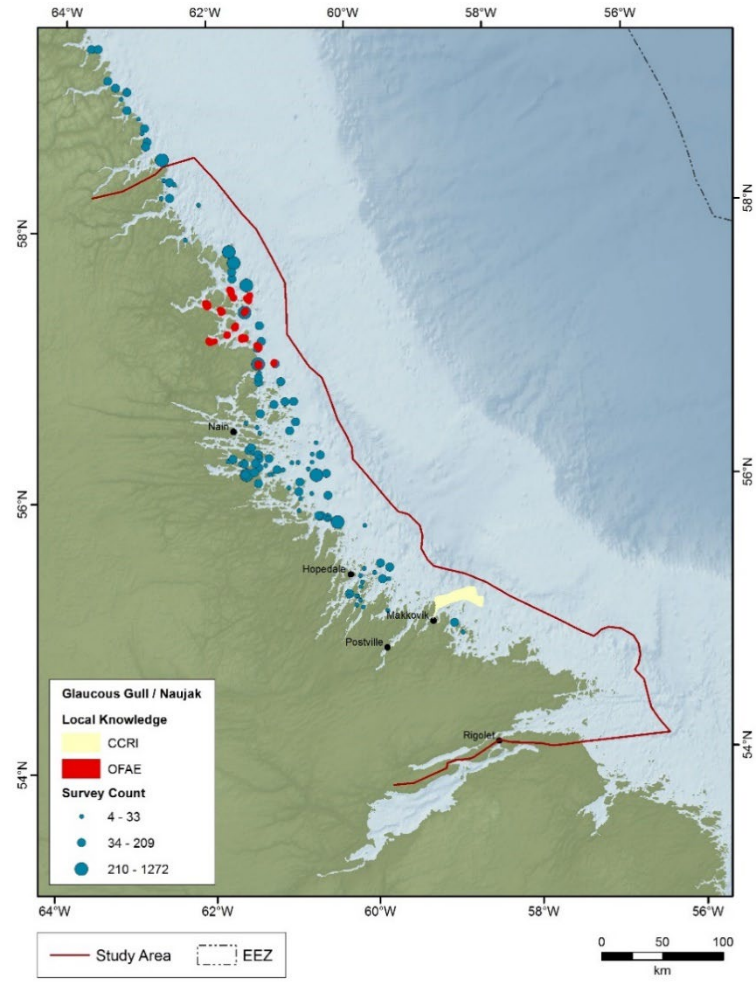


Figure 11.20: Survey counts and Local Knowledge of Glaucous Gull.

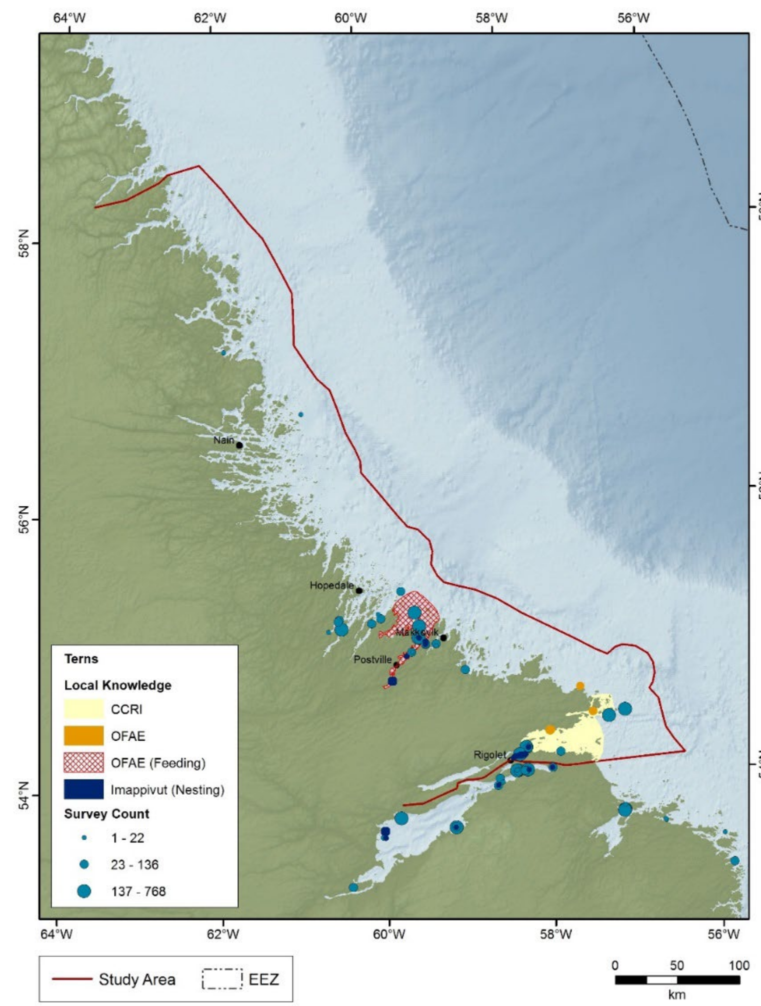


Figure 11.21: Survey counts and Local Knowledge of Tern distribution.

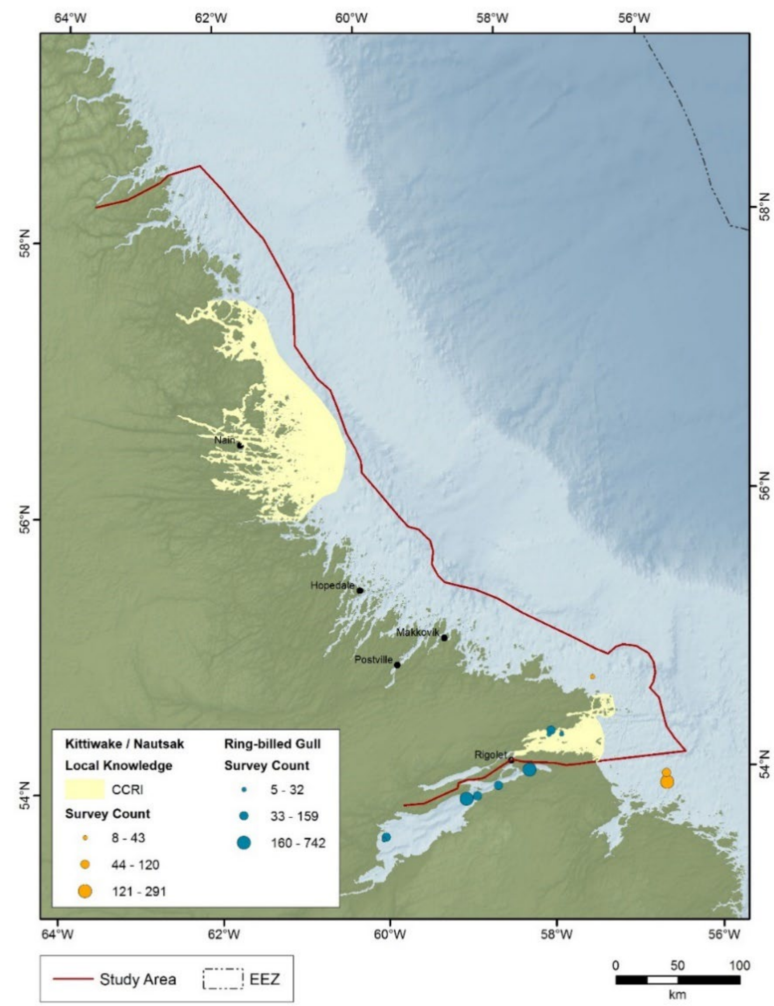


Figure 11.22: Survey counts and Local Knowledge of Black-legged Kittiwake and Ring-billed Gull distribution.

Other Colonial Species

The Northern Fulmar (*Fulmarus glacialis)* has not yet been confirmed as breeding in the study area, but two pairs were seen in suitable breeding habitat on the Herring Islands, and small numbers do nest at the nearby Gannet Islands. Two double-crested Cormorant (*Phalacrocorax auritus*) colonies with hundreds of individuals present were reported in Hamilton Inlet in 2001–03 (Chaulk et al. 2004), representing a northern range expansion for the species.

Marine Bird Colony Seaward Extensions

During the breeding season, the spatial distribution of breeding adults is constrained by the requirements of reproduction (site and mate guarding, incubation, chick rearing, etc.) and colonial marine bird species become highly concentrated at colony locations. Such sites tend to be persistent/enduring and are generally well-known, especially in the case of larger congregations and alcids. Individuals from these colonies use adjacent and nearby marine areas for foraging, bathing, preening, roosting, and social interaction, and often are referred to as colony 'seaward extensions'. To best represent habitat use by species associated with a given colony, extending beyond the terrestrial breeding site, a set area around the colony can be defined according to foraging range (Thaxter et al. 2012). Foraging ranges have been shown to vary among individuals and among colonies. They have also been shown to vary within the breeding season, and across years (Bogdanova et al. 2014). Nonetheless, foraging ranges, specifically mean and mean maximum foraging range, have been found to be useful in helping define the general geographic extent of potentially important habitat surrounding colonies (Mallory and Fontaine 2004; Thaxter et al. 2012, Soanes et al. 2016). Such buffers are expected to encompass areas where marine birds are most likely to occur (Thaxter et al. 2012), though the actual area used can be much smaller. Tracking data are increasingly helping improve foraging range and area use calculations for multiple species, at increasing numbers of locations and across years. Buffers also can be assessed with consideration of species' individual sensitivities to disturbance. Knowledge of colony seaward extensions can contribute to planning, with consequent management of disturbance and potentially harmful activities (e.g., fishing, tourism, development) in the vicinity of bird colonies. By combining breeding season tracking data (see below) and seabird colony data, it is possible to enhance colony buffers through creation of predictive distribution models as a function of foraging ranges (distance from colonies), foraging habits (foraging strategies), and habitat features (distance from shorelines). This approach makes it possible to more accurately map the spatial "footprint" of breeding seabirds among multiple colonies along extended sections of coast (Ronconi et al. 2022).

Rather than present maps of species-specific colony seaward extensions, available published estimates are presented in Table 11.4.

Table 11.4: Published information on general foraging ranges of species breeding colonially within the study area. Distances are reported in kilometres.

Common Name (Inuktitut / English)	Mean Max. (sd)	Mean (sd)	Source	Geographic Range of Studies
Imekutailik / Arctic Tern	20	<10	BNA: Hatch, 2002	North America: not reported
	12.24	11.75	BirdLife International	Mostly Europe
	24.2 (6.3)	7.1 ± 2.2	Thaxter et al. 2012	Mostly Europe
	10.3 (5.8)	-	Rock et al. 2007	Country Island, NS
Kingutuk / Atlantic Puffin	-	-	BNA: Lowther et al. 2002	North America: n/a
	62.2	30.35	BirdLife International	Mostly Europe
	105.4 (46.0)	4	Thaxter et al. 2012	Mostly Europe
	32.2 (3.7)	-	Pratte et al. 2017	Gannet Islands, NL
Pitsiulâk / Black Guillemot	4	<0.7	BNA: Butler and Buckley 2002	North America; Arctic Canada
	12	4.96	BirdLife International	Mostly Europe
	-	15	Mallory and Fontaine 2004	Arctic Canada
Akpak / Common Murre	120	-	BNA: Ainley et al. 2002	North America; Witless Bay, NL
	60.61	24.49	BirdLife International	Mostly Europe
	84.2 (50.1)	37.8 (32.3)	Thaxter et al. 2012	Mostly Europe
	38.3 (21.5)	-	Pratte et al. 2017	Gannet Islands, NL
Common Tern	20	-	BNA: Nisbet et al. 2017a	North America; New England
	33.81	8.67	BirdLife International	Mostly Europe

Common Name (Inuktitut / English)	Mean Max. (sd)	Mean (sd)	Source	Geographic Range of Studies
	15.2 (11.2)	4.5 ± 3.2	Thaxter et al. 2012	Mostly Europe
	12.6 (6.8)	9.3 ± 1.3	Rock et al. 2007	Country Island, NS
Naujak / Glaucous Gull	<60	-	BNA: Weiser and Gilchrist 2012	North America; Alaska
Kulilik / Great Black-backed Gull	-	-	BNA: Good 1998	North America: n/a
Herring Gull	32 (95%)	8 (median)	BNA: Nisbet et al. 2017b	North America; New England
	46	21	Thaxter et al. 2012	Mostly Europe
Saviatsojak / Razorbill	-	-	BNA: Lavers et al. 2009	North America; n/a
	31	10,27	BirdLife International	Mostly Europe, Gulf of Maine
	48.5 (35.0)	23.7 (7.5)	Thaxter et al. 2012	Mostly Europe
	41.3 (21.1)	-	Pratte et al. 2017	Gannet Islands, NL
Thick-billed Murre	170 (max.)	-	BNA: Gaston and Hipfner 2000	North America; Arctic Canada
	-	30	Mallory and Fontaine 2004	Arctic Canada
	41.2 (17.3)	-	Pratte et al. 2017	North America
Naujalukak / Ring-billed Gull	-	10.8	BNA: Pollet et al. 2012	North America; mostly ground feeding

11.3.3. At-Sea Surveys

Ecologically, the study area presents evidence of important concentrations of several marine bird functional groupings occurring within various portions of the annual cycle. These include: planktivores (Dovekie), surface-seizing plank-piscivores (phalaropes, storm-petrels), shallow diving pursuit generalists (shearwaters), surface shallow diving piscivores (gulls, terns), pursuit diving piscivores (alcids). Patterns associated with important concentrations of these functional groupings indicates a diverse and productive prey base reflective of enabling physical and biological conditions.

Data are collected by expert observers hosted aboard ships-of-opportunity travelling over large geographic areas. PIROP (1965–92) and ECSAS (2006-present). Some host vessels target priority areas (e.g., DFO Atlantic Zonal Monitoring Program lines, RV survey program, Sustainability Surveys for Fisheries), while others may be specifically tasked to support offshore oil and gas operations, and simply addressing knowledge gaps (e.g., dedicated coral and sponge surveys). These data provide critical information for environmental assessments related to offshore development, emergency response related to oil spills, risk assessments, marine protected area planning, marine spatial planning, and other marine management and conservation initiatives. Data are collected year-round and provide the only geographically comprehensive information on bird densities at sea within the NL Shelves marine bioregion, most notably in deeper water areas generally accessible to large vessels.

Following a standardized protocol (Gjerdrum et al. 2012), a survey consists of a series of 5 minute observation periods (10 minute observation periods were used prior to November 2007) while the ship is steaming, dedicated to detecting birds. As many consecutive observation periods are conducted as possible, regardless if birds are present or not (i.e., presence and absence are recorded). At the beginning of each observation period the ship's position, time of day, ship speed and direction, and a number of environmental variables (i.e., visibility, sea state, swell height, wind speed and direction) are recorded. Surveys are conducted while looking forward from the ship's bridge (travelling 4–19 knots), scanning at a 90˚ angle from either the port or starboard side, limiting observations to a transect band 300 m wide from the beam of the ship (for PIROP, transect width is unlimited). The transect is continuously surveyed to count and identify birds present in air or on water. Binoculars are used to confirm species identification when necessary, and other details, such as age, moult, and behaviour. All birds observed on the sea surface are continuously recorded throughout the observation period. A count of all flying birds passing through the transect would be a measure of bird flux and would overestimate bird density (Tasker et al. 1984). Therefore, flying birds are recorded using instantaneous counts at regular intervals throughout each survey (Tasker et al. 1984). The perpendicular distance between the observer and bird(s) sighted is also recorded.

For the purpose of this treatment of at-sea data, an "important area" is defined where measures of species' linear densities derived from at-sea surveys fall within the top decile class of counts (top 10%), as calculated for all of Eastern Canada (within Canada's Exclusive Economic Zone). We used Kernel Density Estimation using a 10 km search radius, with 1 km cell resolution to highlight clusters of high counts, excluding values of "0". Associated maps present decile classes (each class by definition containing an equal number of 1 km^2 cells for the bioregion). The top decile class is highlighted in bright green.

The maps provided were derived from a compilation of both PIROP (1965–92) and ECSAS (2006–ongoing) data completed in 2012, allowing for assessment at the scale of Eastern Canada. Though a small number of additional surveys have been undertaken within the study area, these are not expected to dramatically influence patterns. However, we have summarized data from both periods, including updates of ECSAS to 2018, in order to enable comparisons, primarily to explore persistence in patterns between these two large datasets. Results of these comparisons were not available at the time of preparation of the draft of this chapter.

Thick-billed Murre (breeding and non-breeding) occurs in top decile concentrations within study area (Figure 11.23). Patterns are most evident in areas adjacent to Nain, but also appear off Hopedale and at the northern limit of the study area. Given survey gaps, and top decile concentrations extending beyond study area out to shelf edge (1,000 m bath line), patterns are suggestive of extensive use of the study area and adjacent shelf by this species.

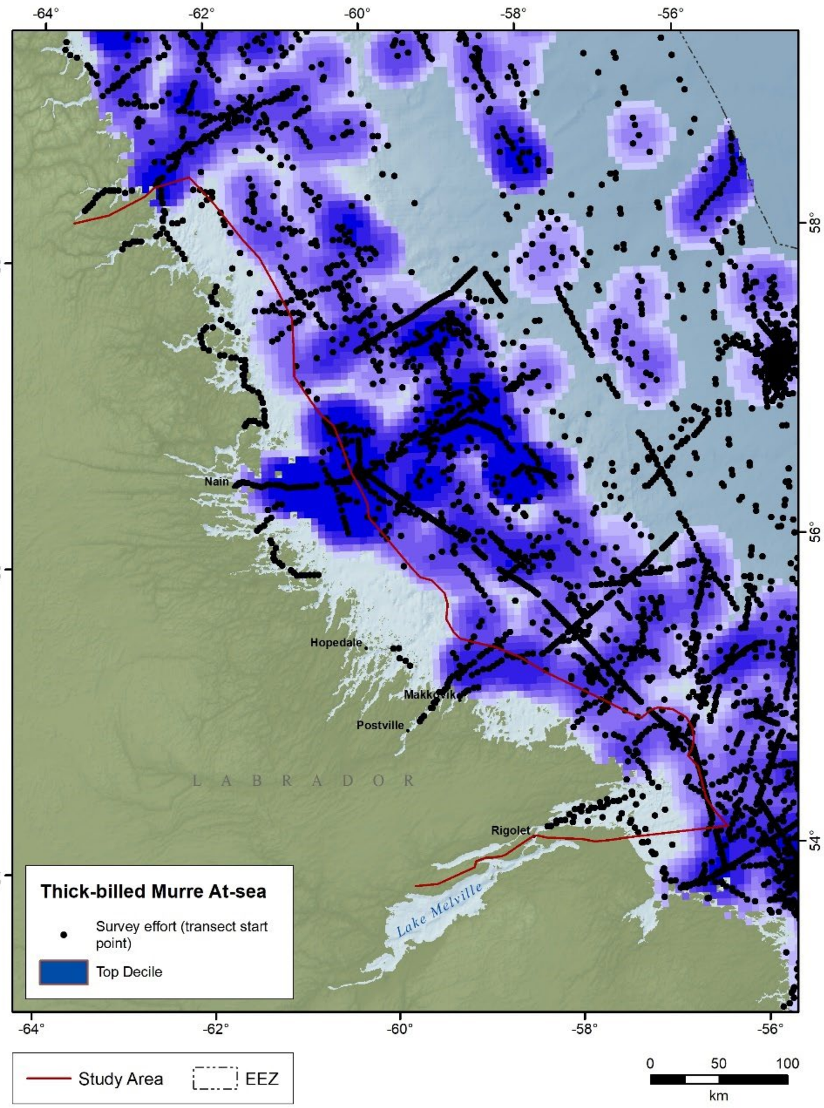


Figure 11.23: Estimated distribution and density of Thick-billed Murre at-sea.

Common murre (breeding and non-breeding) also occurs within the study area, but relative densities do not reach the top decile (Figure 11.24). Such concentrations are evident in areas immediately adjacent to the south, near the Gannet Islands.

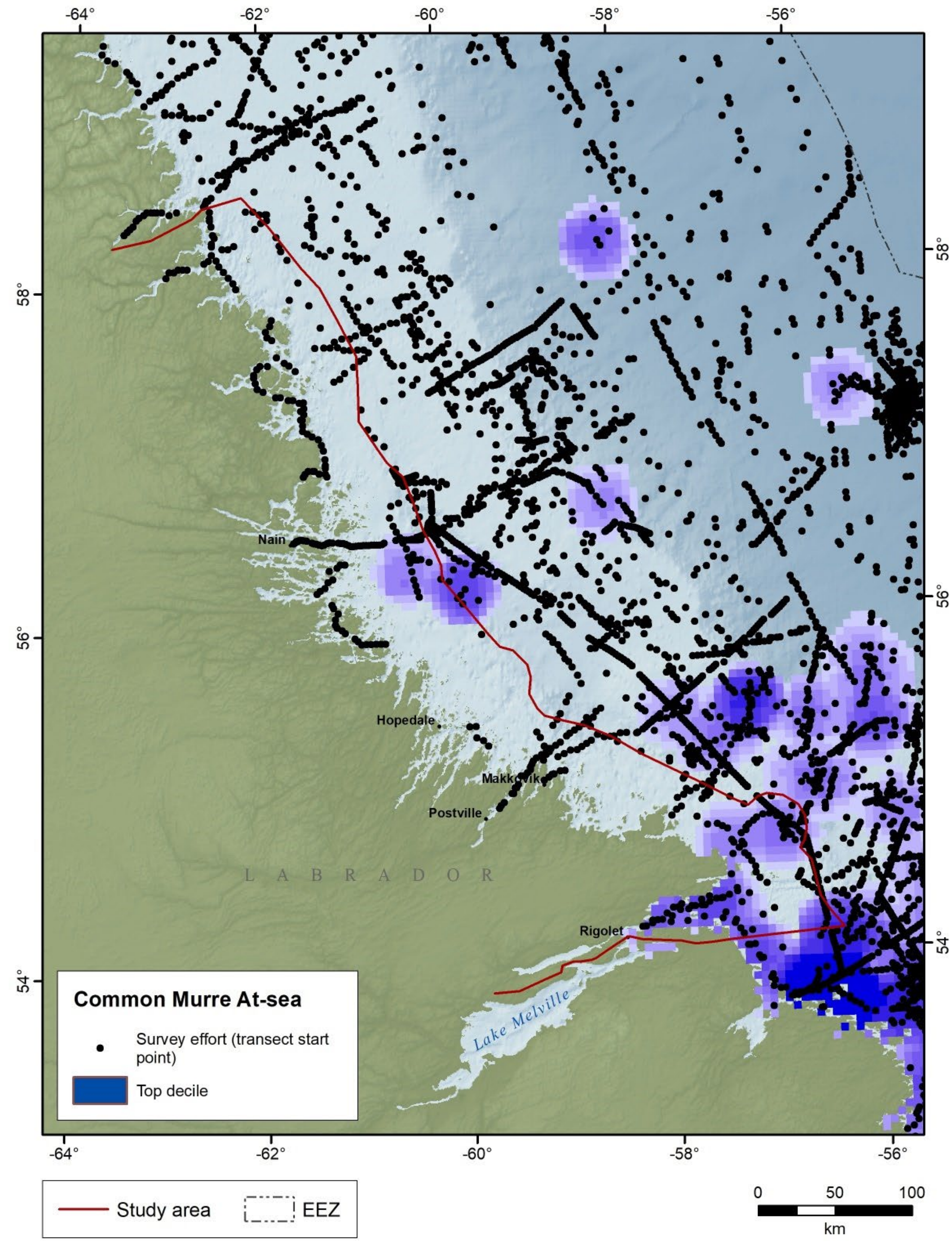


Figure 11.24: Estimated distribution and density of Common Murre at-sea.

Atlantic Puffin (breeding and non-breeding) occurs in top decile concentrations within the study area (Figure 11.25). Highest relative densities are evident throughout Groswater Bay and areas adjacent to the north and south, also including patterns extending to the Gannet Islands. Top decile values are also reached in areas seaward from Natuashish.

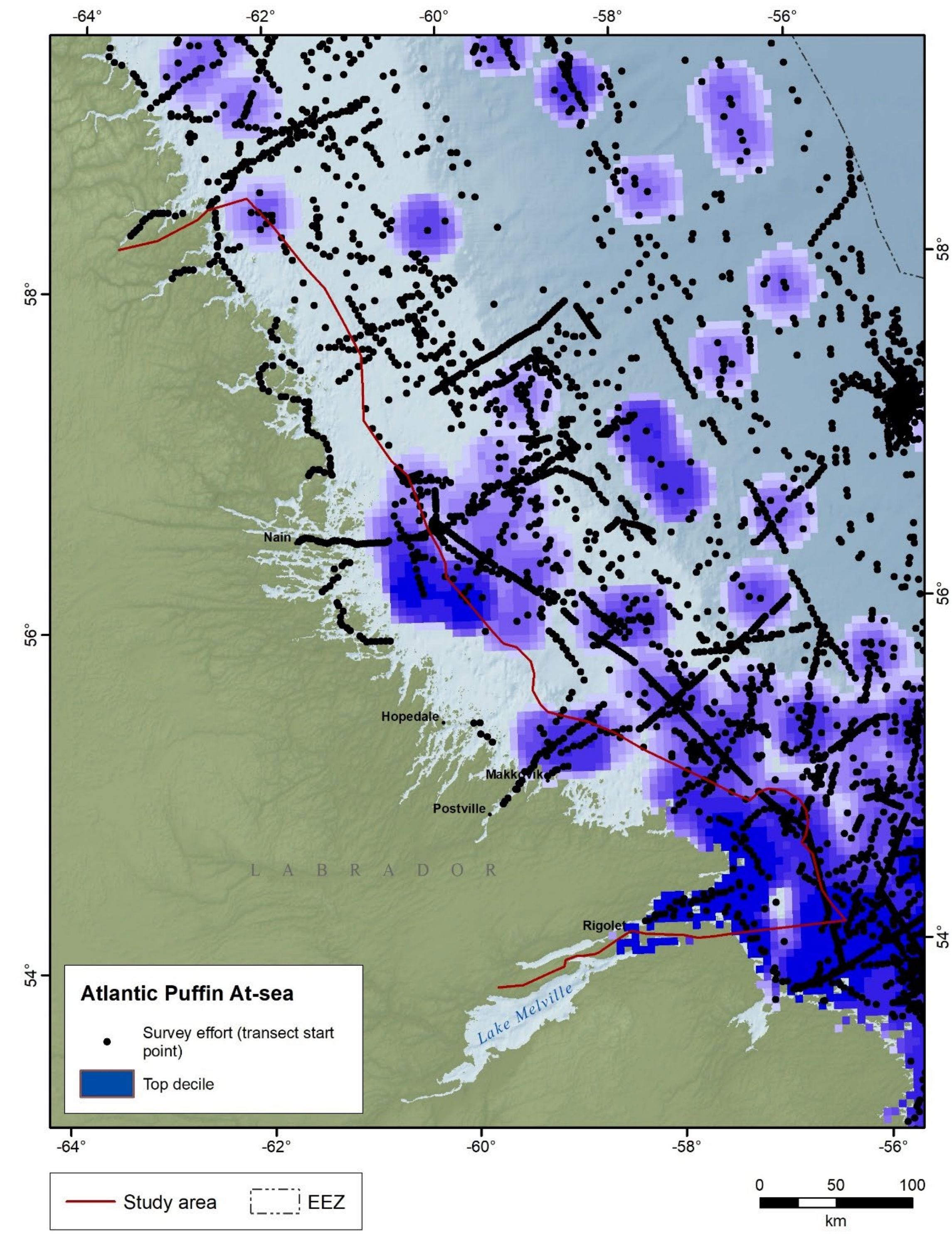


Figure 11.25: Estimated distribution and density of Atlantic Puffin at-sea.

Razorbill (breeding and non-breeding) occurs in top decile concentrations within the study area, most notably in northern Groswater bay and areas immediately north (Figure 11.26).

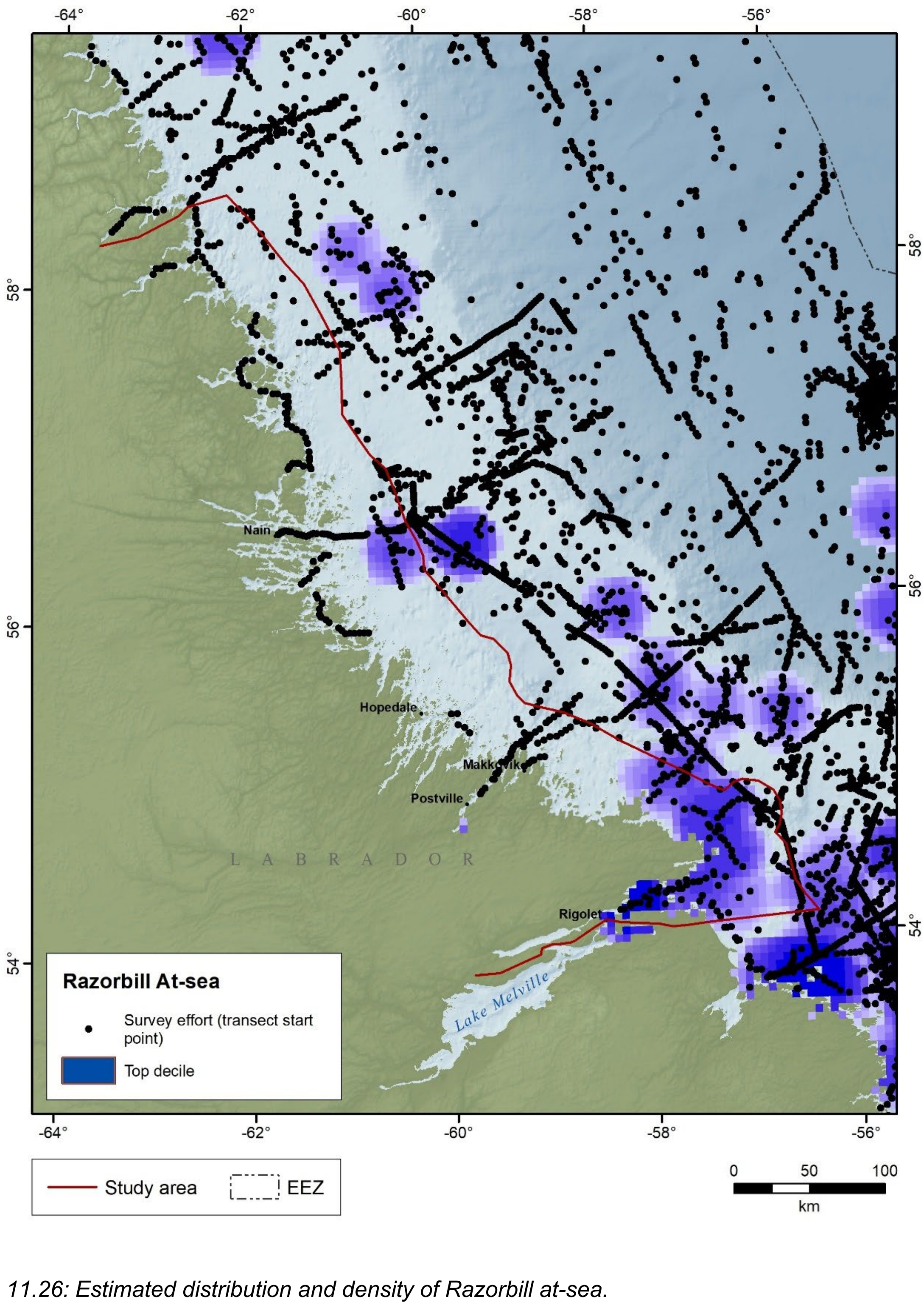


Figure 11.26: Estimated distribution and density of Razorbill at-sea.

Large alcids, as a group, occur in important concentrations within the study area (Figure 11.27). Available evidence is associated with area offshore from Nain, northern Groswater Bay, and an area extending north from the Gannet Islands.

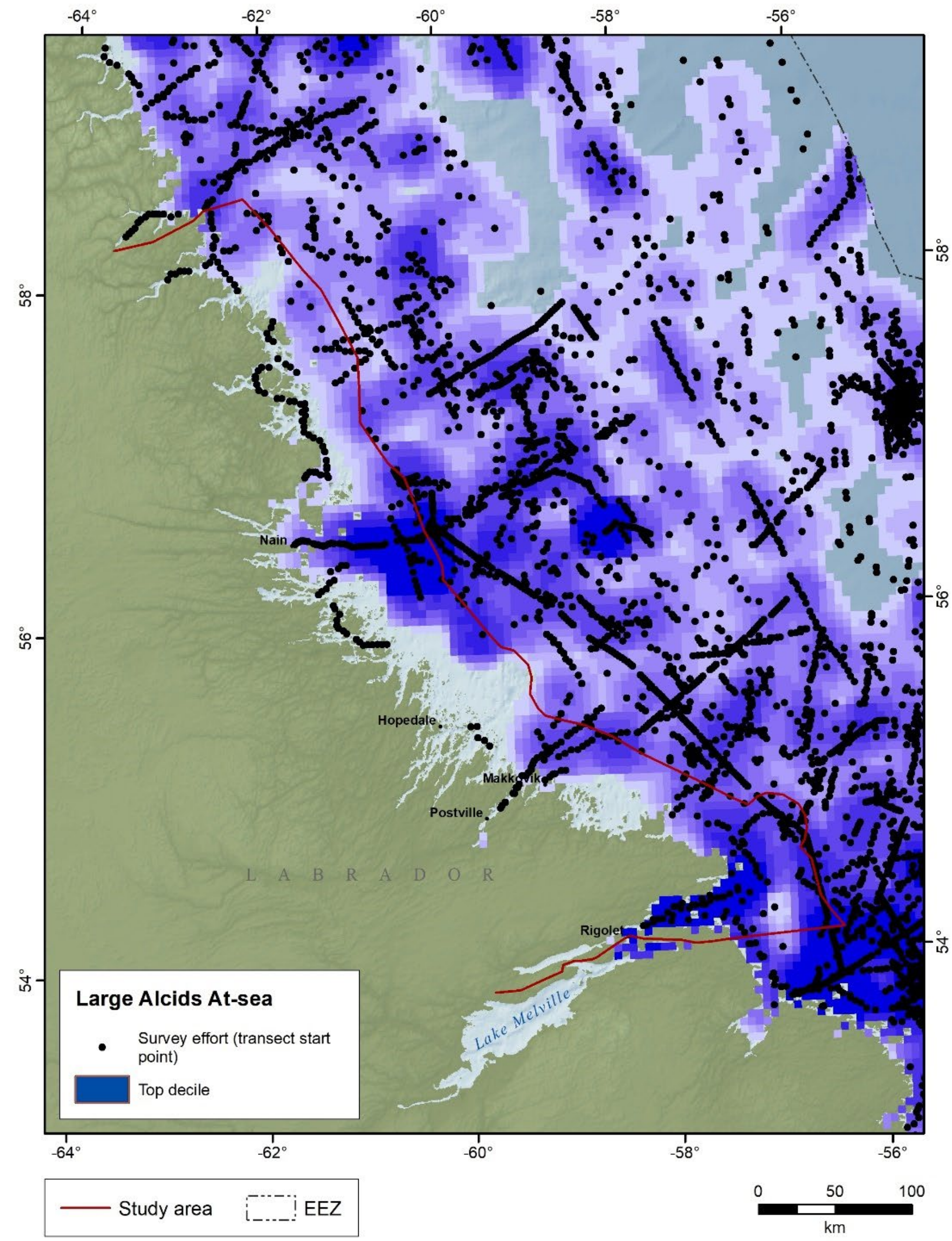


Figure 11.27: Estimated distribution and density of Large alcids (murres, puffins, and Razorbills combined) at-sea.

Black Guillemot (breeding and non-breeding) occurs within the study area, but perhaps due to its association with inshore coastal areas, beyond the normal reach of most at-sea surveys, records are sparse within the at-sea survey databases. This species is better represented within multi-species breeding season aerial surveys.

Dovekie (non-breeding) occurs in top decile concentrations within the study area, with patterns being most evident in areas offshore of Nain (Figure 11.28). Top decile patterns also are evident out to the shelf break (1,000 m bath line) and are suggestive of extensive use of the study area and adjacent shelf by this species.

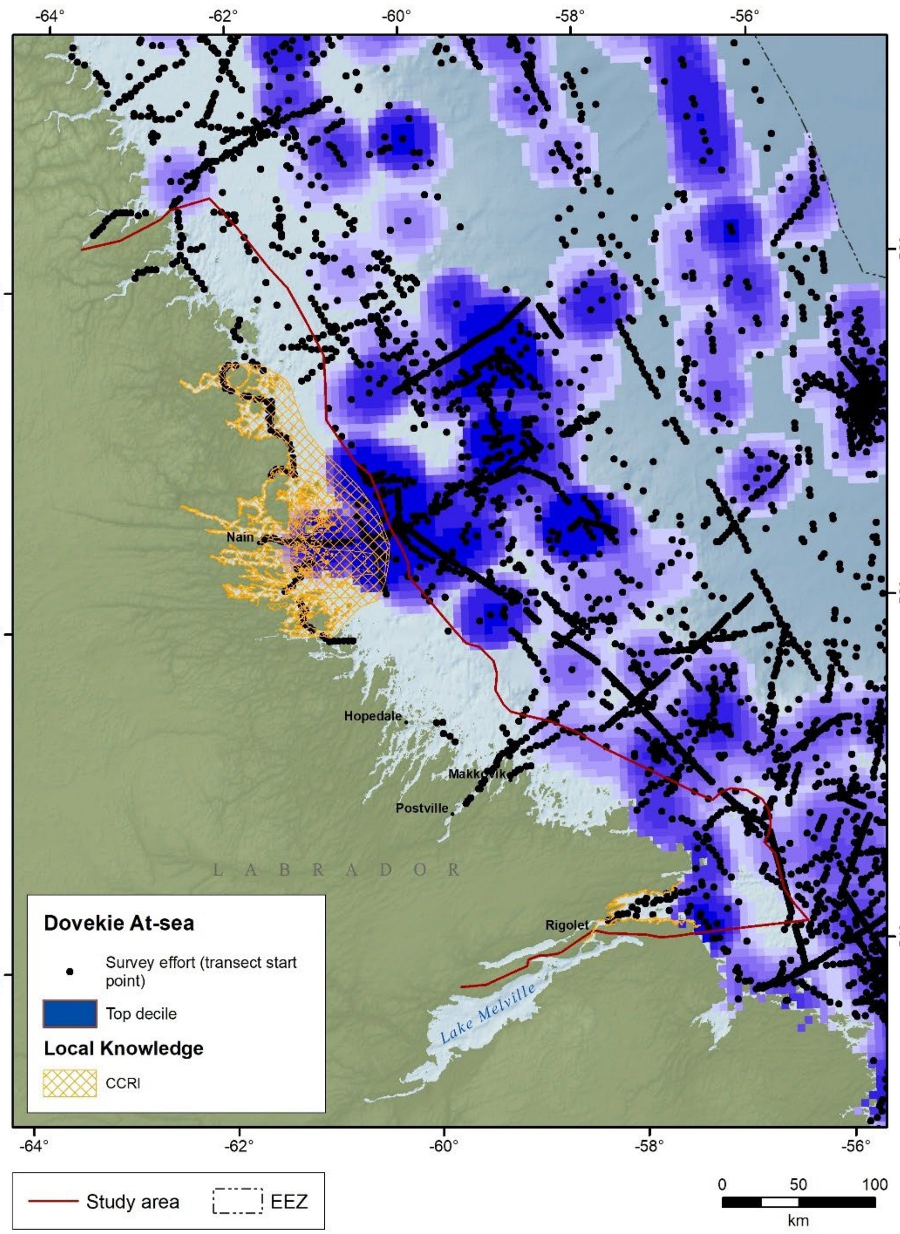


Figure 11.28: Estimated distribution and density of Dovekie at-sea and Local Knowledge of Dovekie distribution.

Terns (breeding and non-breeding) as a group occur in top decile concentrations within the study area, with patterns most evident in its southern half (Figure 11.29). Patterns associated with colonies at Hopedale and Groswater Bay, but extend to areas further offshore, beyond foraging range of nesting birds. Evidence of important concentrations also detected along portions of outer shelf, and beyond. Due to difficulty of identification of individuals to species during the course of at-sea as well as aerial surveys of colonies, species resolution is generally unavailable within the study area.

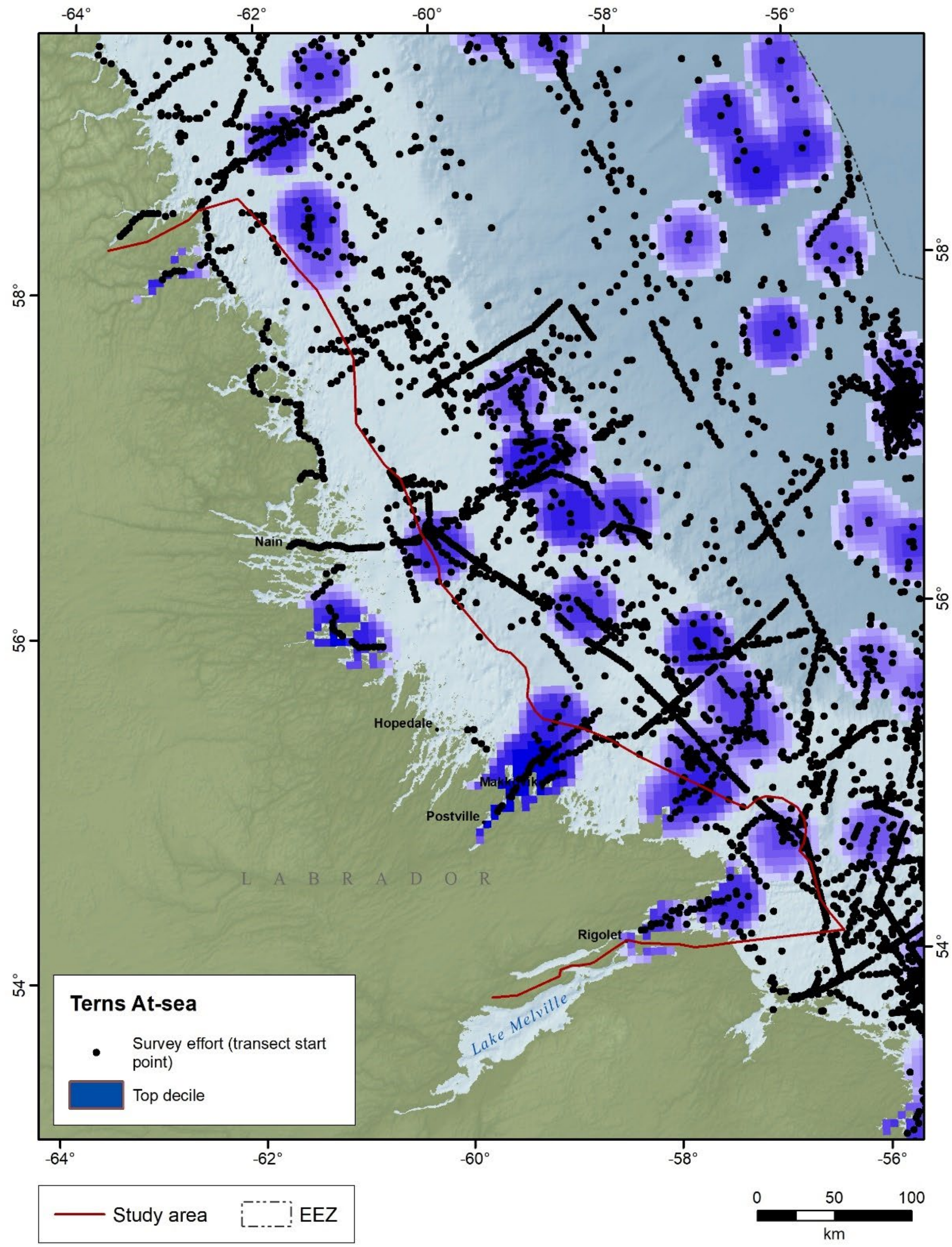


Figure 11.29: Estimated distribution and density of Terns at-sea.

Black-legged Kittiwake is the dominant small gull species in the study area. Evidence of important concentrations is apparent within southern portion of study area, along its seaward margin (Figure 11.30). However, patterns of high relative abundance appear to be most apparent outside the study area more broadly, out to the shelf break. These concentrations are particularly notable as the species is a very rare breeder in the study area.

Ivory Gull is listed under SARA as Endangered (Environment Canada 2014). Though it is not known to breed anywhere in Labrador, records exist of its occurrence along the coastline within the study area (Todd 1963), including a recent record at Rigolet of 20 individuals (eBird 2018). Top decile patterns are evident for this species outside the study area, along the shelf break (Figure 11.31).

Herring Gull occurs in important concentrations within the study area, most notably in the area southeast of Nain (Figure 11.32).

Great Black-backed Gull does not present evidence of top decile densities within the study area (Figure 11.33). Such patterns appear limited to areas offshore of Groswater Bay.

Glaucous Gull are present in the study area, but records from at-sea data were not summarized and available at the time of preparation of this research document. It is well represented in the colony survey data.

Large gulls, as a group occur in important concentrations within study area, but patterns appear as isolated and limited to northern portion of study area seaward edge (Figure 11.34). More extensive patterns located in areas outside of study area, east of its southern extent.

Northern Fulmar does not breed within study area, but occurs in important concentrations within its boundary, with evidence being most apparent in the study area northern extent and beyond its southeastern limit (Figure 11.35). Predominant patterns of important concentrations are associated with the shelf area, out to the shelf edge (1,000 m bath line).

Great Shearwater occurs within the study area, but not in important concentrations (Figure 11.36). Sooty Shearwater occurs in important concentrations within study area, especially in southern third, albeit isolated evidence is also apparent at northern extent (Figure 11.37).

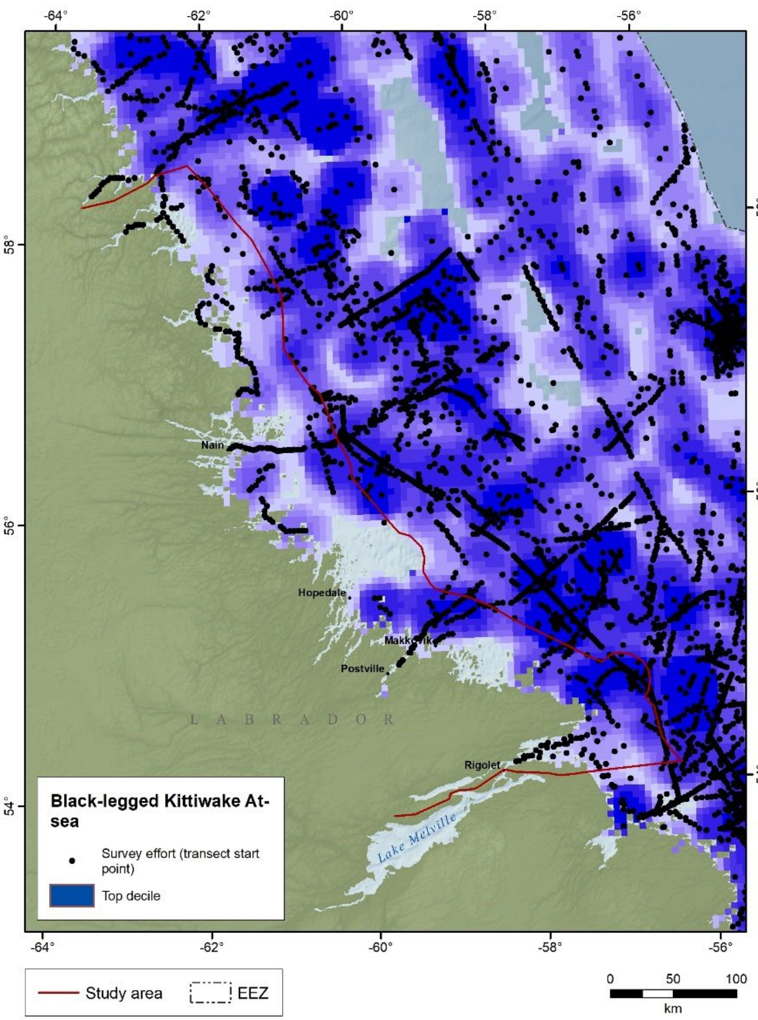


Figure 11.30: Estimated distribution and density of Black-legged Kittiwake at-sea.

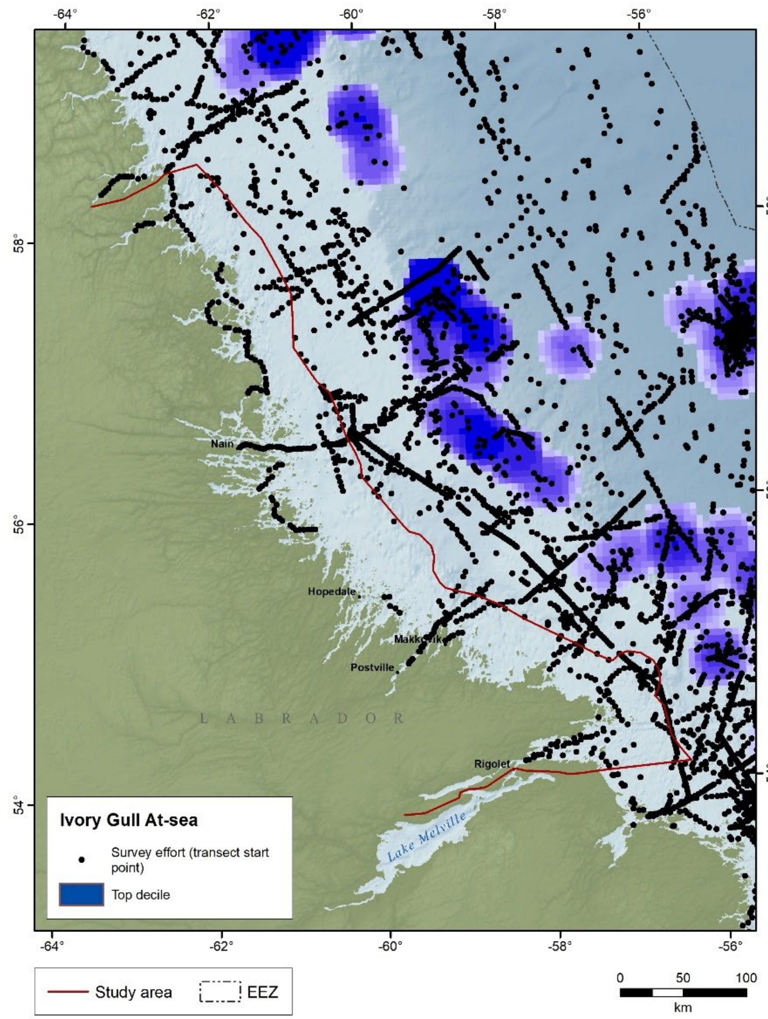


Figure 11.31: Estimated distribution and density of Ivory gull at-sea.

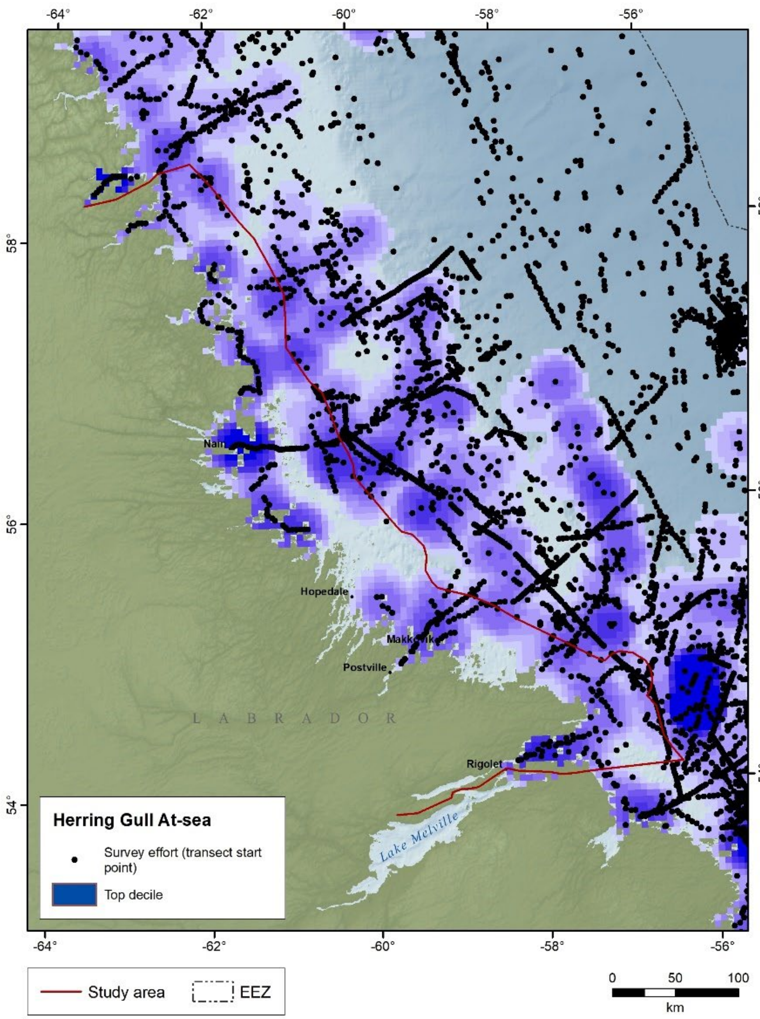


Figure 11.32: Estimated distribution and density of Herring Gull at-sea.

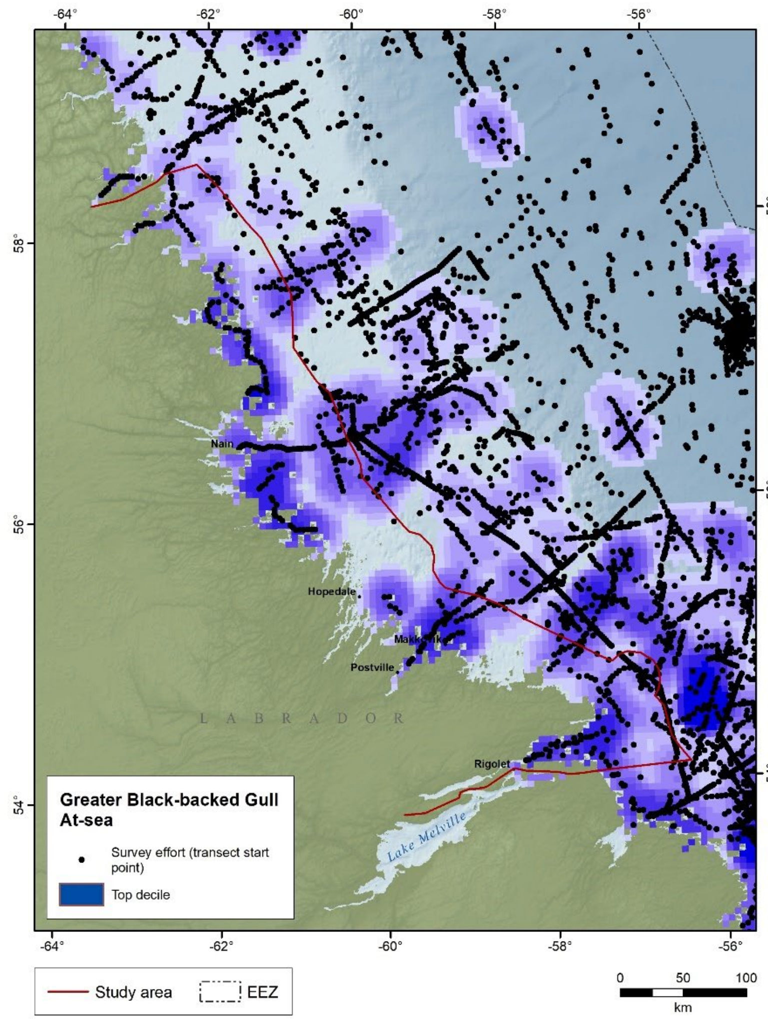


Figure 11.33: Estimated distribution and density of Great Black-backed Gull at-sea.

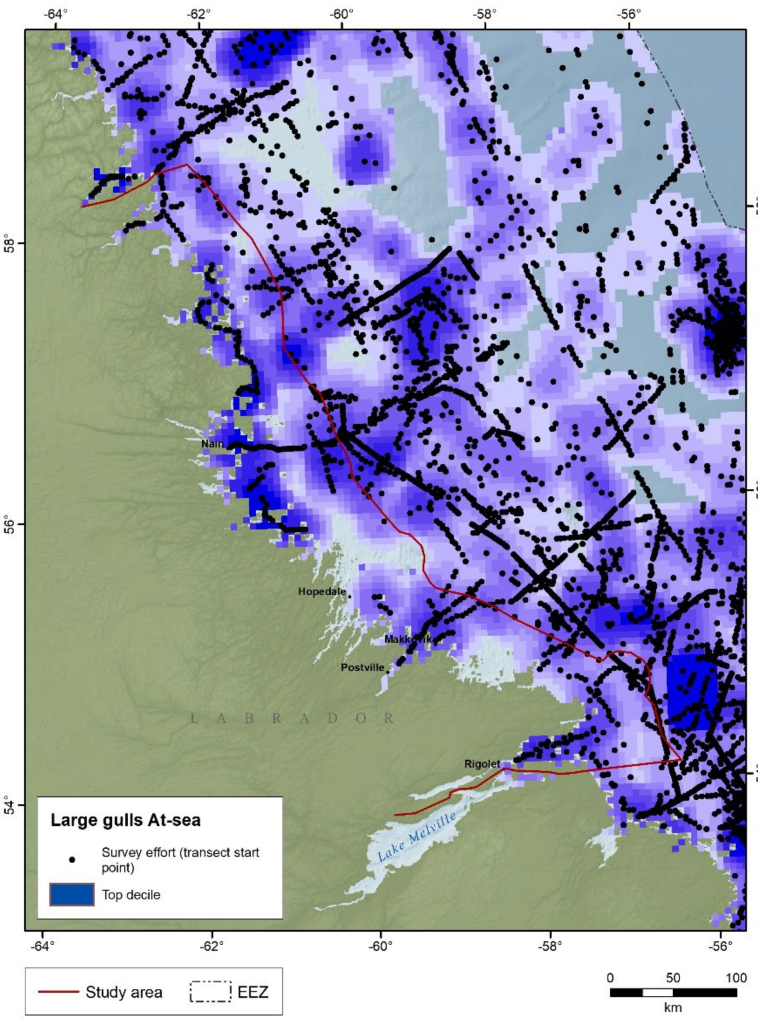


Figure 11.34: Estimated distribution and density of Large gulls at-sea.

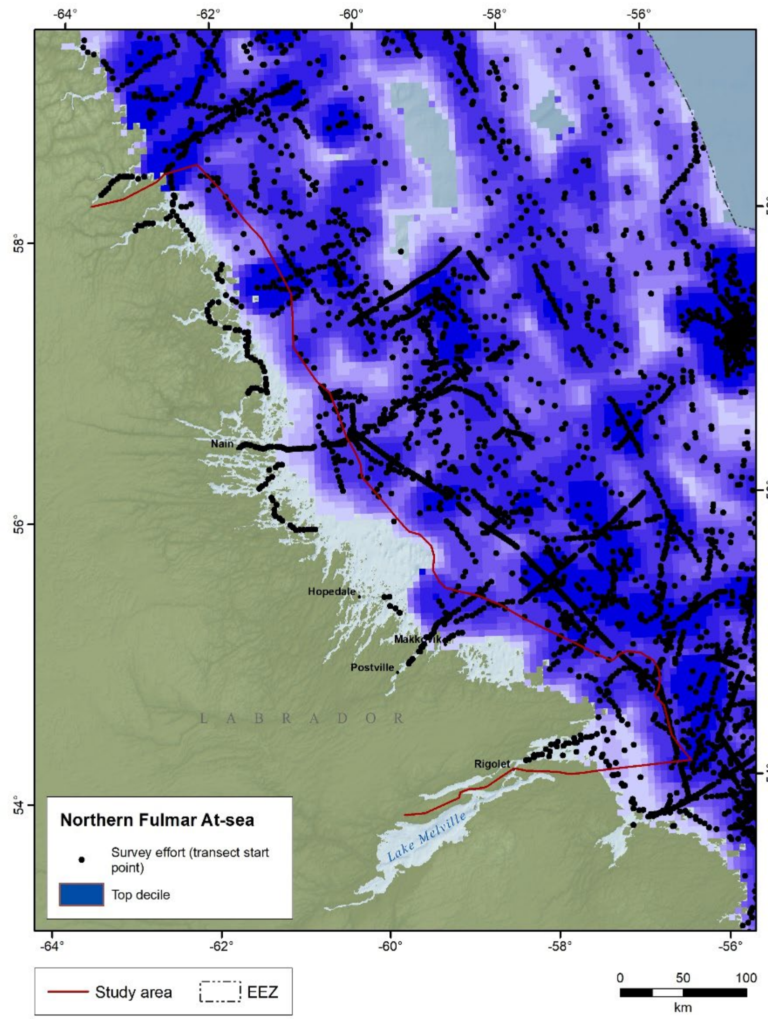


Figure 11.35: Estimated distribution and density of Northern Fulmar at-sea.

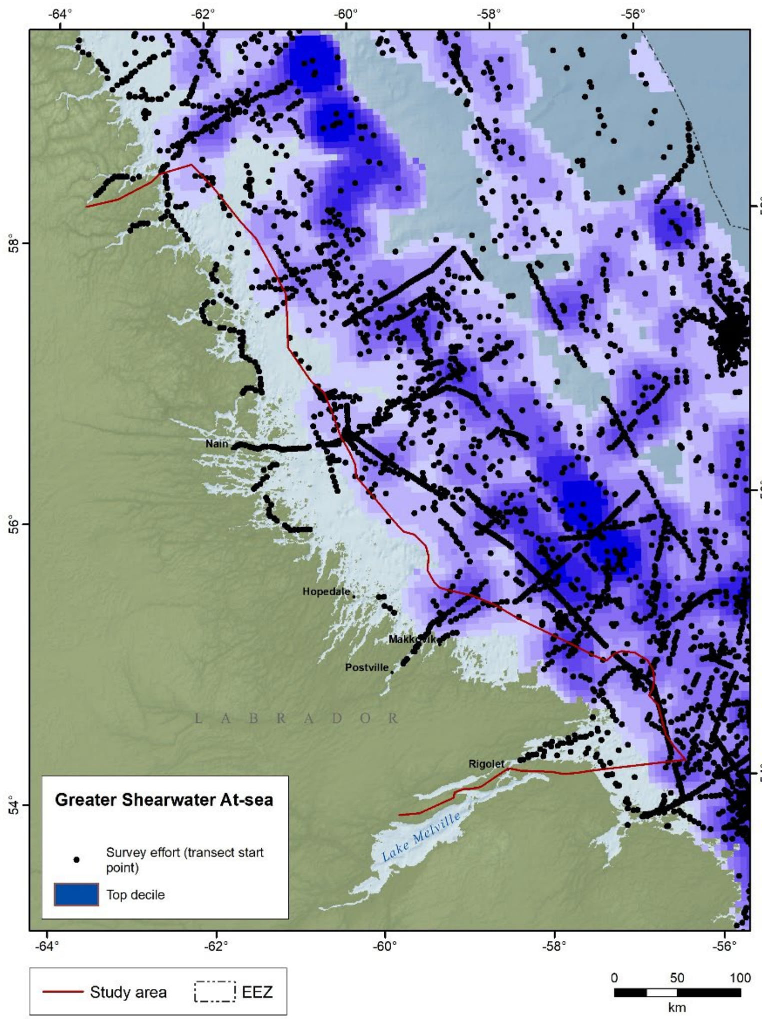


Figure 11.36: Estimated distribution and density of Great Shearwater at-sea.

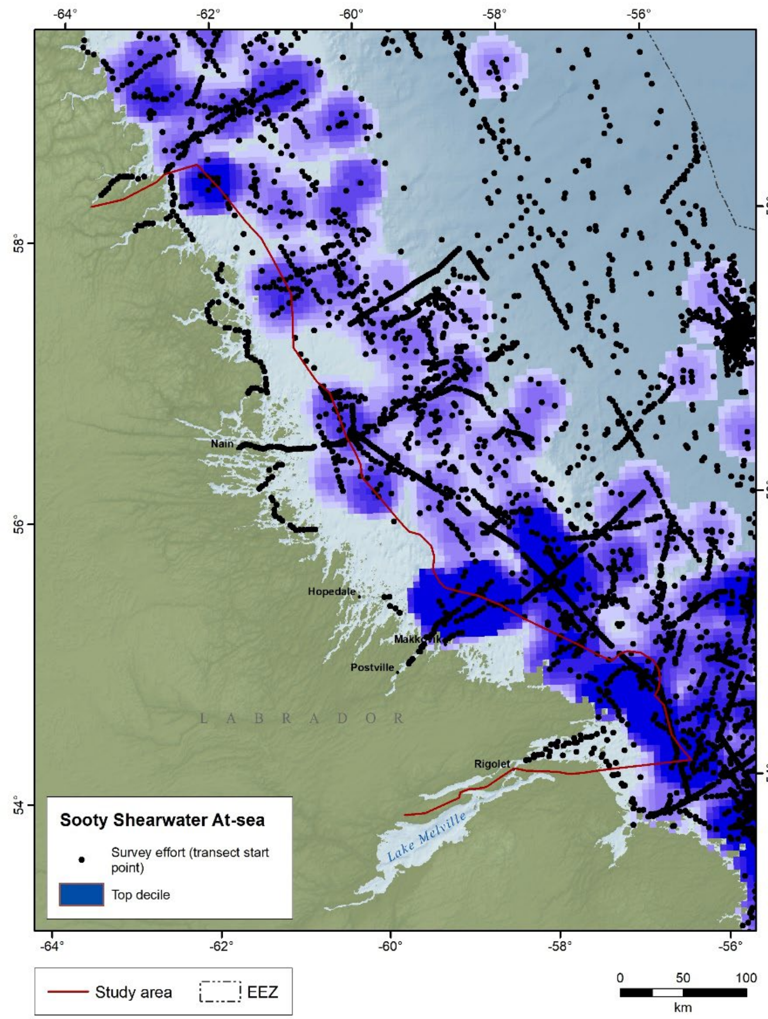


Figure 11.37: Estimated distribution and density of Sooty Shearwater at-sea.

Phalaropes are very difficult to identify to species during at-sea surveys, but available information suggests that the pattern for this group is largely dominated by observations of Red Phalarope. Phalaropes do not present evidence of top-decile concentrations within the study area (Figure 11.38). However, evidence of important concentrations around the shelf edge (1,000 m bath line) extend the length of the study area, possibly related to limit of ice extent during spring northward migration.

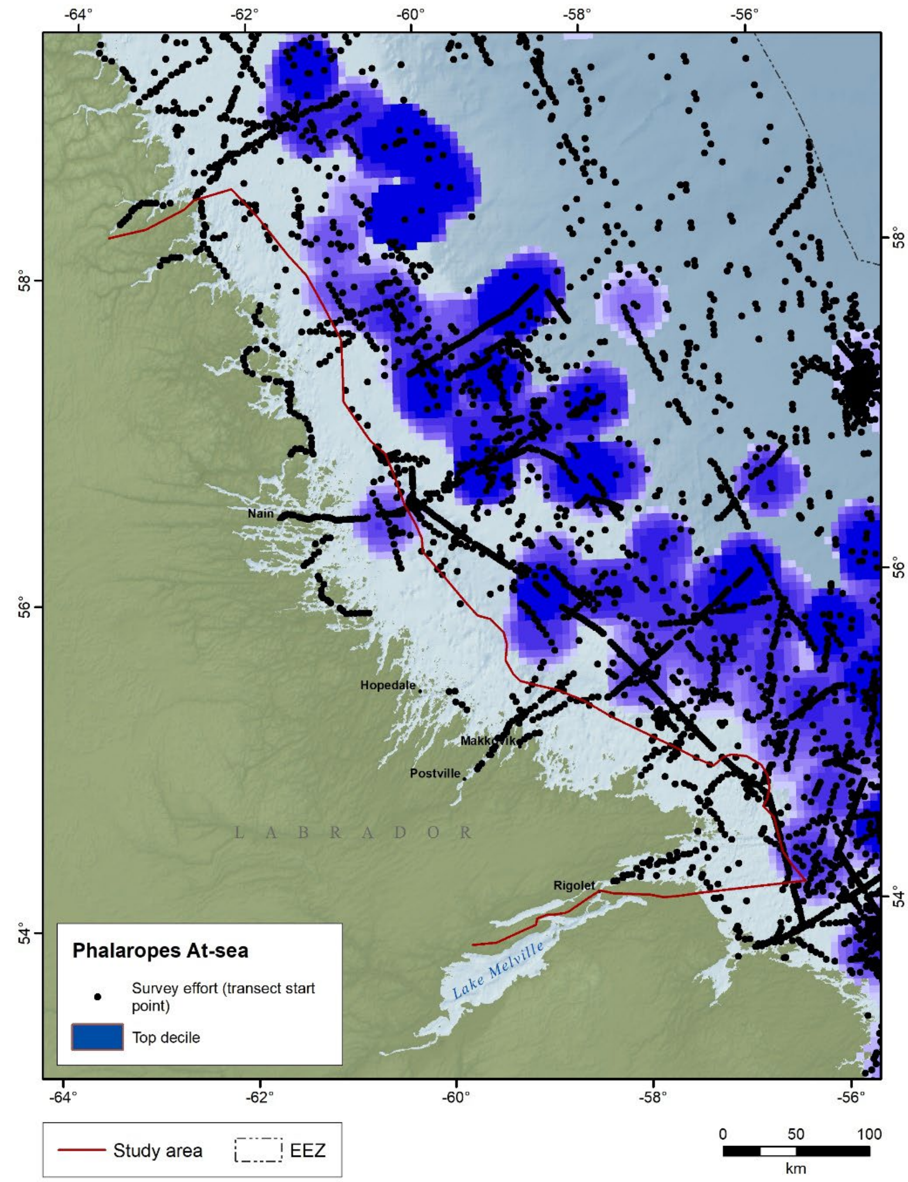


Figure 11.38: Phalaropes at-sea.

Leach's Storm-petrel occurs within the study area, however important concentrations are not apparent (Figure 11.39).

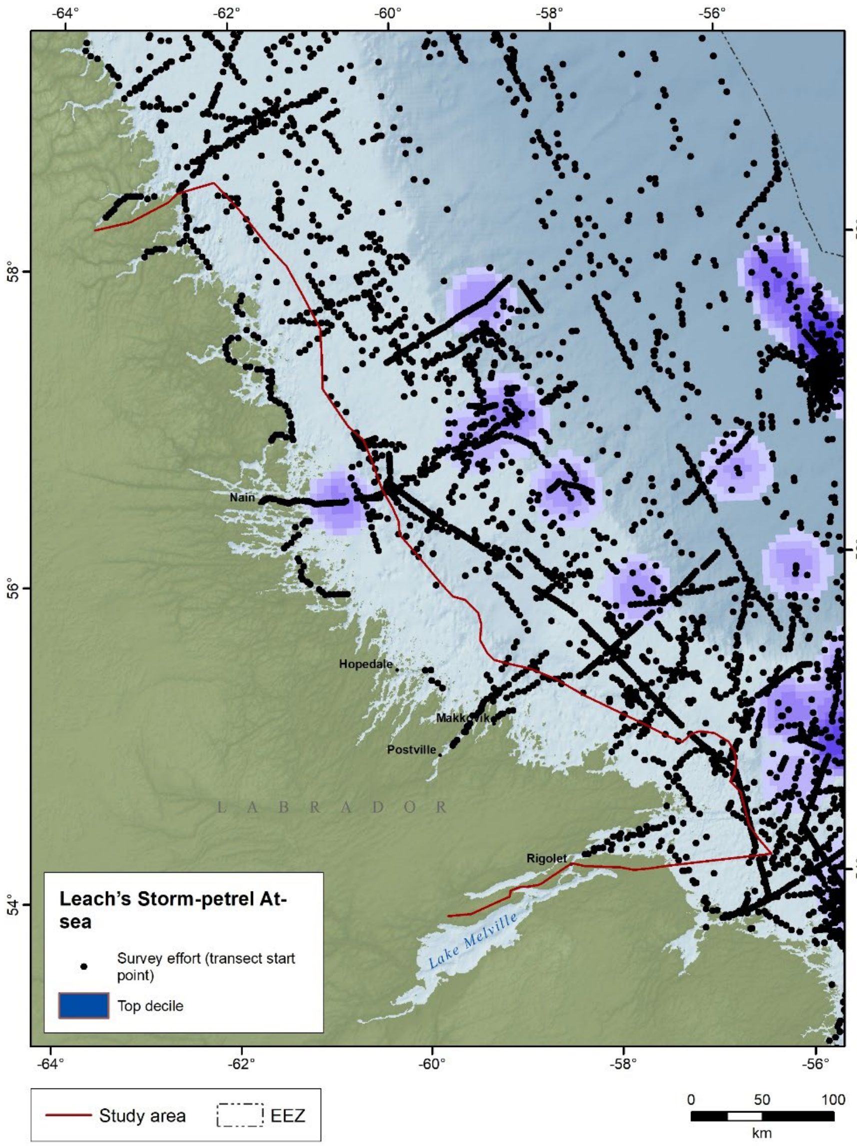


Figure 11.39: Leach's Storm-petrel at-sea.

11.3.4. Tracking Data

Remote assessment of seabird spatial and temporal occupancy patterns.

In terms of pelagic distributions, densities of marine birds recorded in the ECSAS database are generally higher in the study area in fall and winter, when compared to spring and summer (Figure 11.2). The highest concentrations are made up of Dovekie (*Alle alle*) during fall (Figure 11.40). This is corroborated by tracking studies, showing many species using the Labrador Sea and (to a lesser extent) the study area for fall migration and/or wintering. Seasonal relative species composition is presented in Table 11.5 and population estimates in Table 11.6. Historical data from the PIROP database show similar patterns and are not presented in this section.

Table 11.5: Seasonal counts of birds observed in the Labrador Sea by species group (Fifield et al. 2017).

Common Name	Spring	Summer	Fall	Winter	Total
Black-legged Kittiwake	276	933	661	144	2,014
Dovekie	698	1,609	12,489	1,287	16,083
Northern Gannet	0	3	2	0	5
Large gulls	407	66	107	147	727
Jaegers	22	28	64	1	115
Murres	536	744	2,948	989	5,217
Northern Fulmar	1,677	3,095	926	444	6,142
Other alcids	63	37	298	54	452
Phalaropes	133	245	14	0	392
Atlantic Puffin	22	217	359	15	613
Shearwaters	0	1,294	318	1	1,613
Skuas	0	4	15	2	21
Storm-petrels	27	27	1	4	59
Terns	0	12	2	0	14

Table 11.6: Seasonal densities and population estimates (to the nearest 100,000) for the Labrador Sea excluding ice-covered areas and areas of poor prediction precision (see Figure 11.2: adapted from Fifield et al. 2017).

Season	Density (CV) (95% CI) (birds·km^{-2})	Population Estimate (CV) (95% CI)
Spring	9.2 (0.26) (5.6–15.0)	2,600,000 (0.26) (1,600,000–4,300,000)
Summer	15.4 (0.25) (9.4–25.2)	6,300,000 (0.26) (3,900,000–10,300,000)
Fall	37.2 (0.25) (22.3–60.6)	9,500,000 (0.25) (5,800,000–15,400,000)
Winter	22.8 (0.35) (11.8–44.0)	4,100,000 (0.35) (2,100,000–8,000,000)

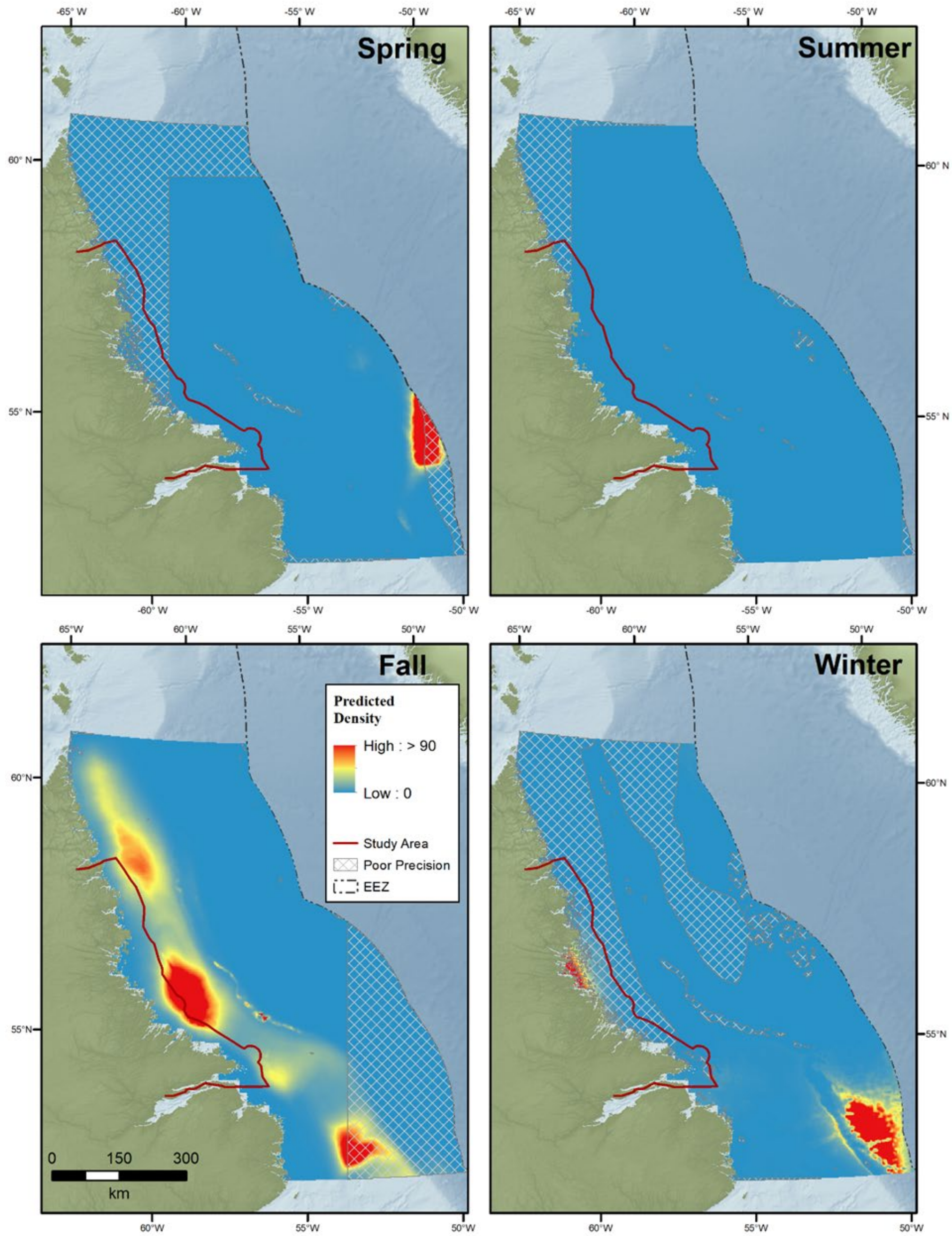


Figure 11.40: Seasonal predicted densities of Dovekie (Alle alle) in the study area and surrounding waters. Note the cross-hatched areas of poor prediction precision (Fifield et al. 2016).

Vast numbers of Dovekie, from the huge colonies in Northwest Greenland, pass through the study area on fall migration (Figure 11.40 and Figure 11.28), while others winter in northern parts of the region (Fort et al. 2013).

The Ivory Gull, an endangered species under the Species at Risk Act in Canada, and Near Threatened on the IUCN Red List, uses the waters adjacent to the study area, and regions to the north, as part of its core wintering area (Figure 11.41; Spencer et al. 2016).

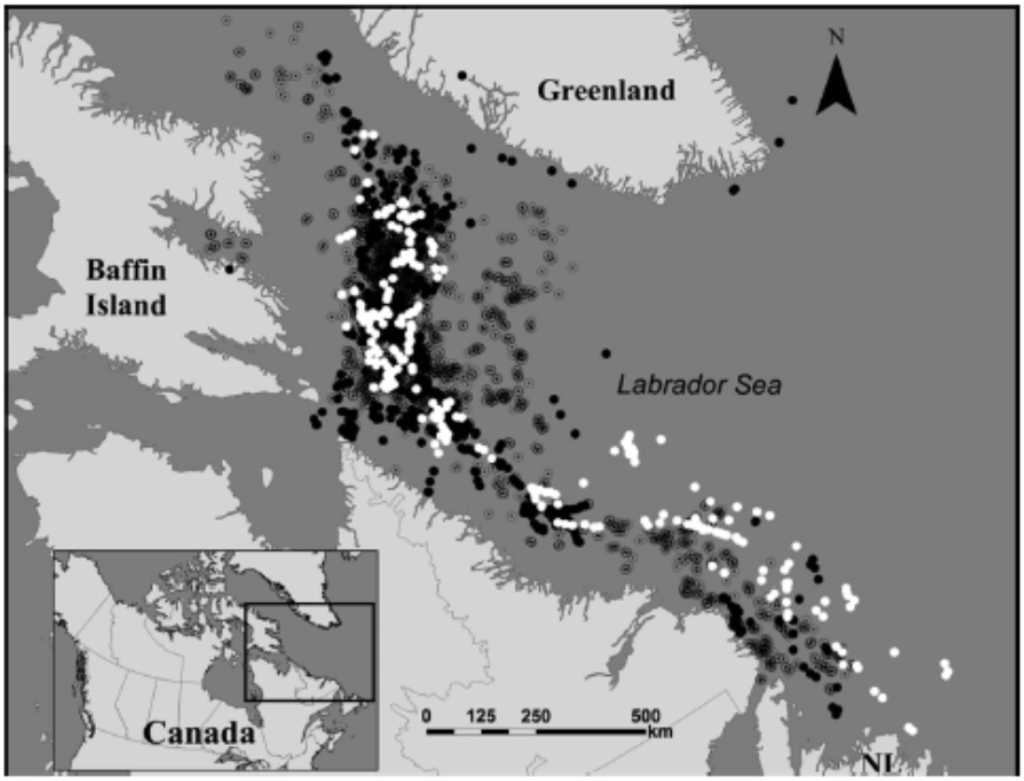


Figure 11.41: Ivory Gull non-breeding season distribution (Spencer et al. 2016). Map shows all detections of wintering satellite-tagged Ivory Gull individuals breeding on colonies in Canada (circle with dot) and Norway (black circles) over 3 years (2010–13) and observations of Ivory Gulls by at-sea surveys (PIROP, 1969–92) in Davis Strait and Labrador Sea.

Tracking studies demonstrate the importance of the Labrador Sea for non-breeding Thick-billed Murre from a range of Northwest Atlantic colonies in fall, winter and spring (McFarlane Tranquilla et al. 2013, Frederiksen et al. 2016).

The Labrador Sea is also an important area for Black-legged Kittiwake from a range of Northeast and Northwest Atlantic colonies that concentrate in the region during the non-breeding period (Frederiksen et al. 2012).

Other tracking data show that Northern Fulmar, and Atlantic Puffin are present in the study area and/or adjacent areas of the Labrador Sea at various times of year (Table 11.4).

For breeding species, tracking studies can provide valuable information relating to areas used for foraging as well as to their exposure to incompatible human activities (i.e., threats). Core foraging areas of four species of auks breeding at the Gannet Islands IBA are located in coastal shelf waters lying adjacent, and just south, of the study area during summer (Pratte et al. 2017). The Gannet Islands is a regionally significant seabird colony which hosts the largest population of Razorbill in eastern Canada. Large flocks of moulting Harlequin Duck from the eastern population (Special Concern) are also present around the islands in summer. Extension of the southern boundary of the study area could encompass foraging and moulting locations of these species (Figure 11.14).

11.3.5. Alcid colonies

The Thick-billed Murre (*Uria lomvia*) is a colonial breeder within the study area, with counts of individuals reaching top decile values (~10,000+), at Pyramid Islands and at The Castle, within the Offshore Islands Southeast of Nain IBA (Figure 11.42). Though areas southeast of Nain are the most important in Labrador, the species also nests at the Gannet Islands, south of the study area. LK of this species is mapped as Murres and comprises Thick-billed Murre and Common Murre (Figure 11.42). Although Labrador is an important breeding area for Thick-billed Murres in the context of Atlantic Canada, far larger colonies (100,000s of pairs) are present in the Canadian Arctic (Gaston et al. 2012).

The Common Murre (*Uria aalge*) also occurs as a colonial breeder within the study area, but counts are not within the top decile (~26,000+). Counts that do reach the top decile have been recorded at the Gannet Islands and Bird islands (Figure 11.42) just south of the study area.

The Atlantic Puffin (*Fractercula arctica*) occurs in numbers reaching the top decile (~23,000+) at the Herring Islands, within the Northeast Groswater Bay IBA. Counts within the top decile have also been recorded for the Gannet Islands (Figure 11.43, right panel).

The Razorbill (*Alca torda*) is a common breeding species within the study area, reaching the top decile (~1,200+) at Herring Islands and North Green Island (without including other nearby colonies). The species also reaches top-decile values at the Gannet Islands and Bird Island (Figure 11.43, left panel). Central and southern Labrador represent the core of the breeding range of this species in North America (Chapdelaine et al. 2001).

The Black Guillemot (*Cepphus grylle*) breeds throughout the study area coastline. Though specific colony locations have not been surveyed comprehensively, large breeding season concentrations (~1,000+ individuals) are observed near suitable breeding habitats suggesting the study area is important for the species at the scale of Eastern Canada. However, its distribution and abundance elsewhere in Eastern Canada and more broadly are not well known. Within the study area, available data suggest greater frequency of nesting occurrences north of Makkovik, notably in islands south of Nain (Figure 11.44).

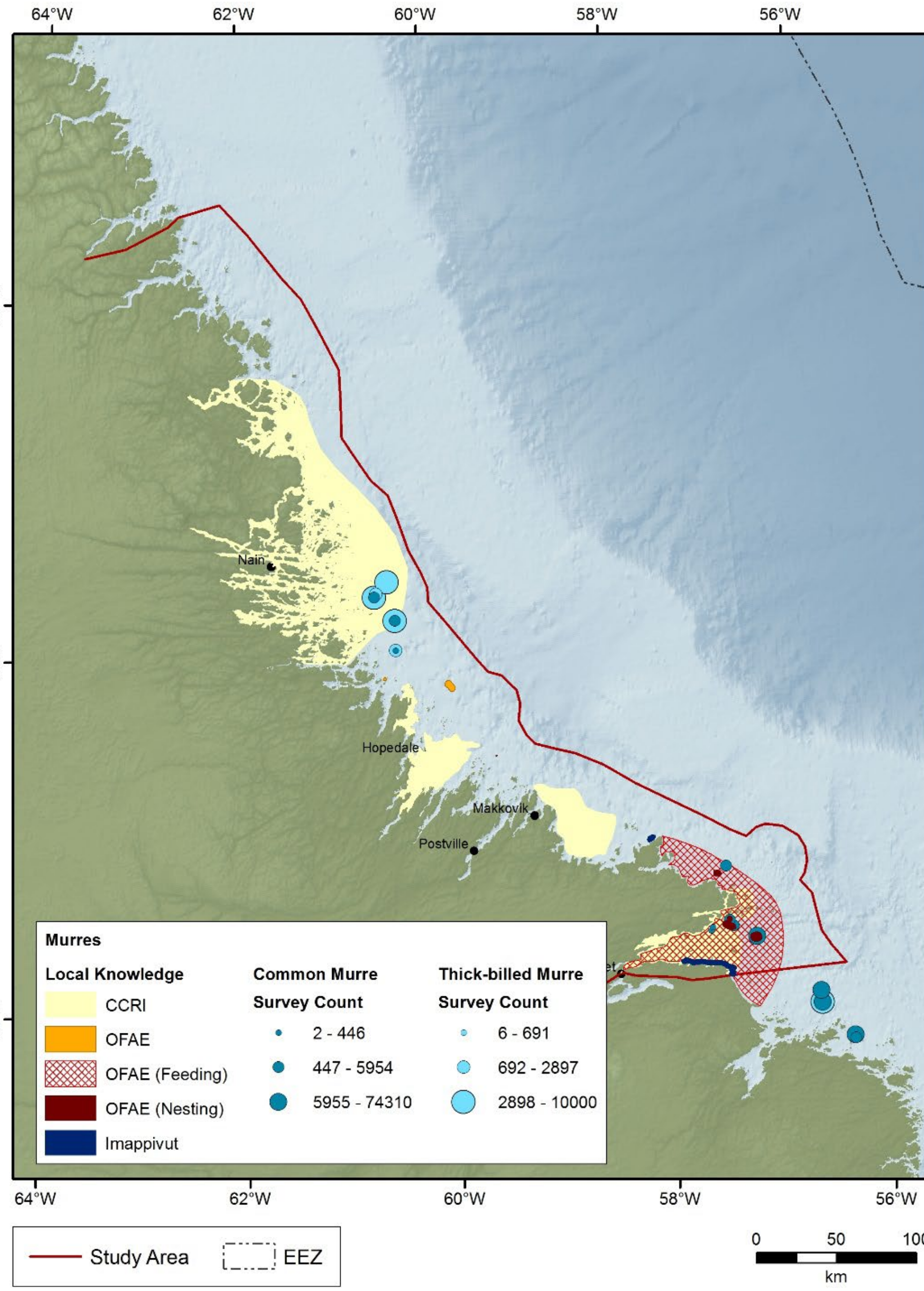


Figure 11.42: Survey counts and Local Knowledge on the distribution of Thick-billed Murre and Common Murre.

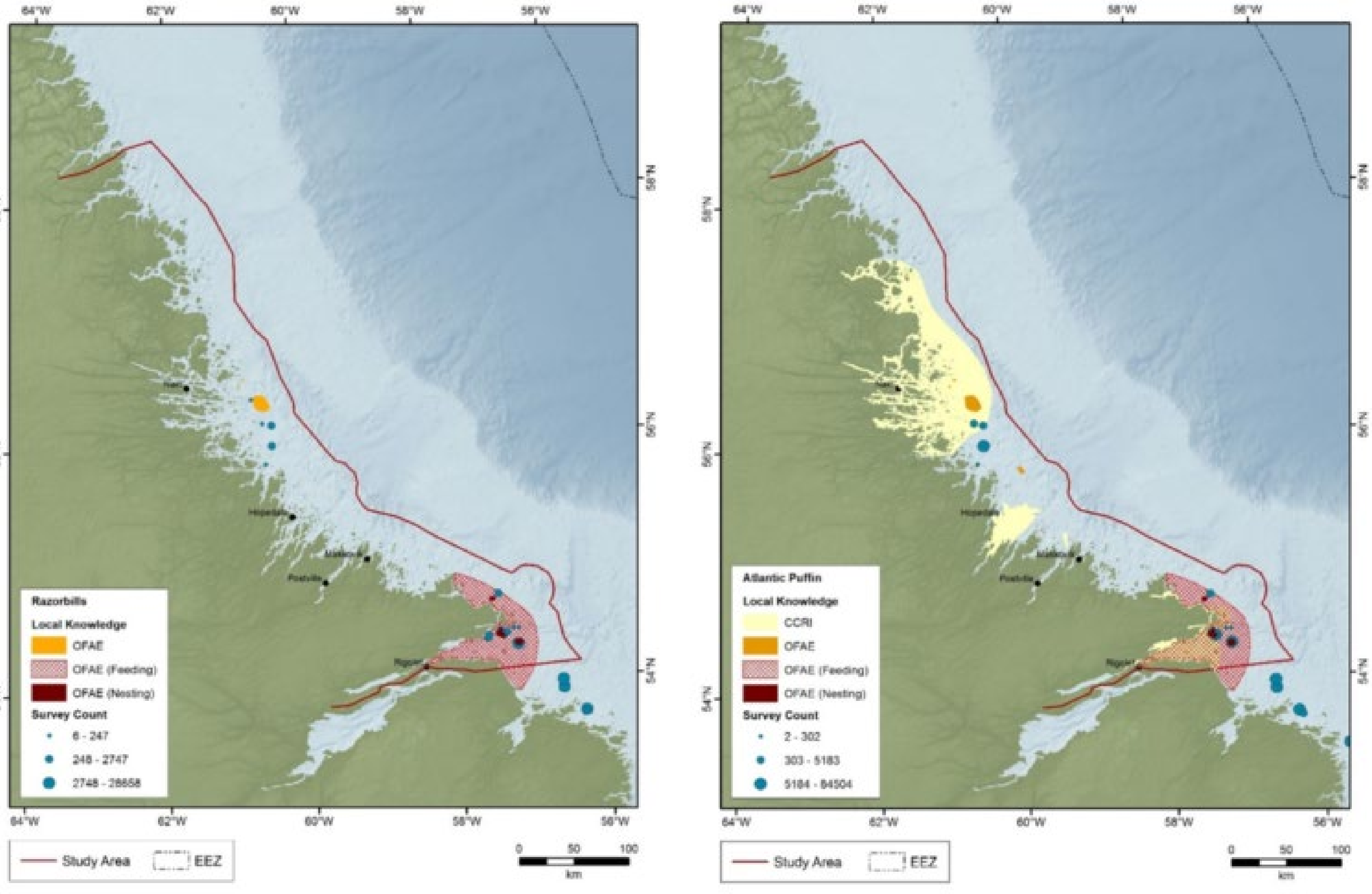


Figure 11.43: Survey counts and Local Knowledge on the distribution of Razorbill (left) and Atlantic Puffin (right).

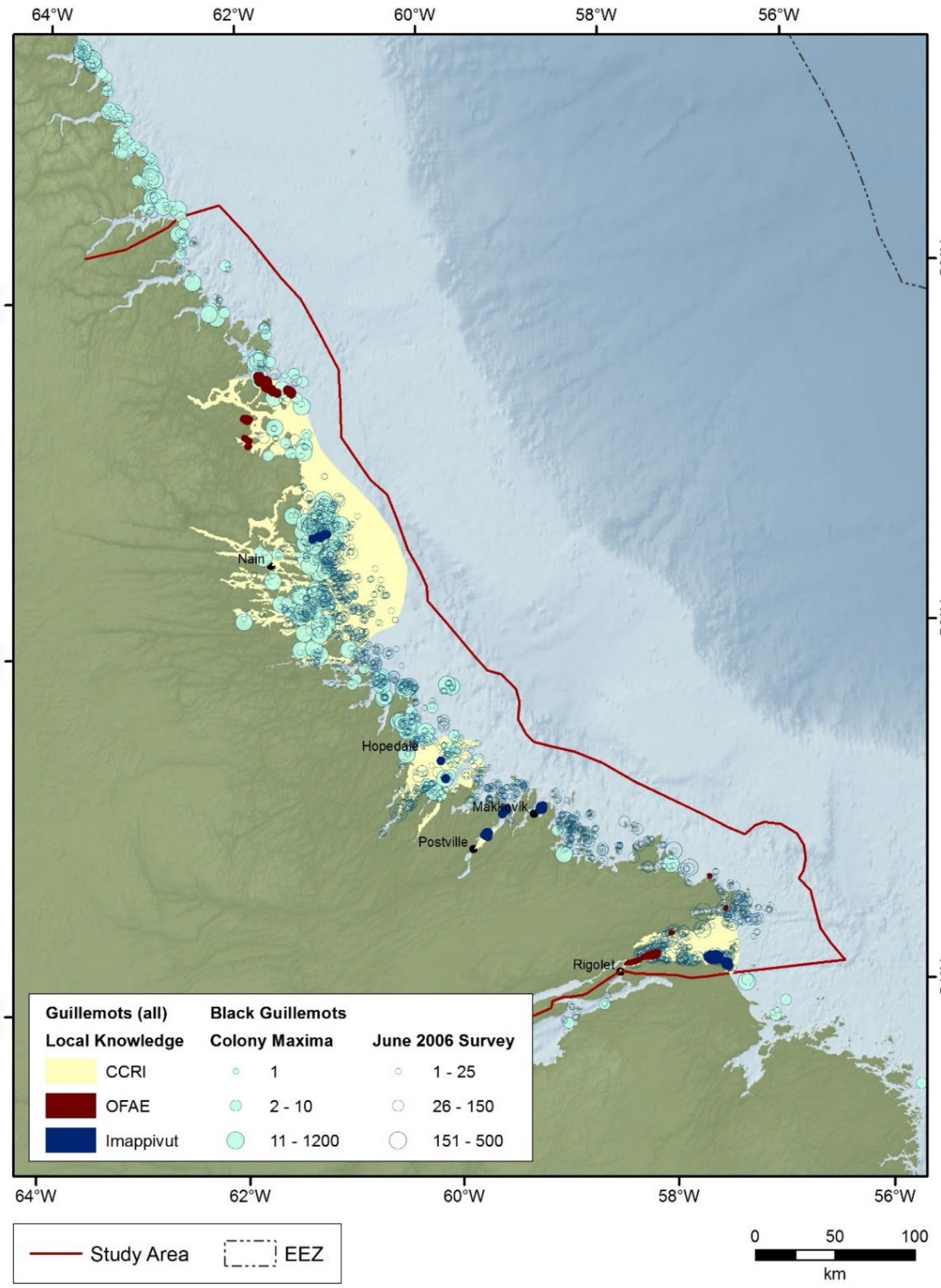


Figure 11.44: Survey counts and Local Knowledge on Guillemot distribution.

11.4. Data Gaps and Recommendations

11.4.1. Range Expansions

Two interview participants in Hopedale noted that they have seen an increase in Northern gannets (*Morus bassanus*), cormorants (*Phalacrocorax* spp.), and snow geese (*Chen caerulescens*) in recent years. Hunters throughout the study area noted observed increases in cormorants and potential impacts on habitat and other marine bird species. Future data collection should focus on identifying and understanding environmental factors that may be driving potential range expansion of marine bird species. It will also be important to understand potential environmental effects and interspecies interactions with increases in species' populations further north along the coast of Labrador.

11.4.2. Shorebirds

There is a clear need for systematic shorebird surveys, required to determine distribution and abundance, as well as patterns of use over time. The Atlantic Canada Shorebird Survey offers opportunities for interested individuals to contribute. However, logistics relating to access of certain sites for formal surveys is likely to require dedicated capacity and effort. In the interim, use of platforms such as eBird can rapidly augment the amount of data available and ultimately can help inform the process of establishment of future ACSS sites.

11.4.3. Waterfowl

Additional potential sources of information on waterfowl include shared results from ongoing tracking studies as well as compilation of data from past studies in ways that make their results available and useable. Hunter-derived band and wing recovery information are also believed to hold potential in terms of improving aspects of our understanding of waterfowl within the study area.

There remain some species-level data gaps, including Long-tailed Duck, Bufflehead.

For most species, survey effort likely is insufficient to provide insight into persistence in use. The latter, in particular, warrants further exploration.

Imappivut interview participants throughout the study area discussed the need to collect more genetic information on geese in Nunatsiavut to understand potential changes in geese species and subspecies composition. Imappivut interview participants also expressed potential conservation concerns related to migratory waterfowl, especially Canada geese. Labrador Inuit are permitted to hunt five Canada geese per person in the spring. Many interview participants discussed the importance of the spring goose hunt and expressed concerns about the long-term sustainability of the hunt, suggesting more focused population and breeding surveys to better understand goose abundance and population dynamics in the study area. A number of interview participants identified the need to better understand important nesting locations and for the Nunatsiavut Government to consider establishing bird sanctuaries to protect these areas. Some participants noted that they have observed fall seasons with apparent reductions in goose abundance and potentially attributed this to what they had perceived were increased harvests the previous spring. Interview participants also expressed concern around spring egg harvesting and the potential for this to impact bird recruitment and population levels. Labrador Inuit rely on marine birds as an important source of wild food, so any conservation measures and policies focused on birds need to consider the food security needs and Inuit harvesting rights.

11.4.4. Tracking Studies

Marine bird tracking studies are beginning to inform the annual use of the study area and adjacent waters; however, gaps remain in the species tracked and source colonies. Coverage, in terms of source colonies and numbers of birds tracked, is quite good for murres, black-legged kittiwakes and Atlantic Puffin. Only limited data are available for Northern Fulmar, a species present in high densities in the Labrador Sea, and there is no information on seasonal movement of Glaucous Gull, a species in global decline. Given the large numbers of Dovekie transiting throughout the study area, additional tracking data for that species would be useful to better understand seasonal movements and annual variation in habitat use.

Tracking studies provide data in almost real time, and do not require direct access to the study region if there is access to potential source colonies. A number of marine bird research programs based at key colonies are ongoing throughout the North Atlantic basin, and these program leads are well connected through the marine bird expert group for Conservation of Flora and Fauna, CBIRD (CAFF 1996). For some potential source colonies, additional funds for transmitters and data costs are all that would be required. For other sites not regularly visited, but thought to contribute birds to the study area, a full-scale field team deployment would be needed.

11.4.5. At-Sea Studies

In spite of recent increased pelagic seabird survey effort in the Labrador Sea (Fifield et al. 2016, 2017), temporal and spatial gaps remain. Specific to the study area, no data were collected in spring, and limited data were collected in winter due to ice. Addressing at-sea survey data gaps requires vessels transiting the study area at key times of year, and a trained seabird observer placed on the vessel. Beyond the obvious costs of the vessel itself, deploying a seabird observer is not costly. Data handling and processing would be conducted as part of ongoing ECCC programs. Implementation of dedicated aerial surveys that encompass the study area could be used to refine knowledge and address spatiotemporal gaps related to ship-availability and access (e.g., related to ice cover). Placing observers on vessels regularly transiting the Labrador coast may be a cost-effective means of filling seasonal and geographic gaps and the Nunatsiavut Government is currently exploring opportunities to initiate at-sea observation studies in collaboration with multiple partners.

Further gaps relating to speciation can be overcome at least in part through the use of digital photography. This applies especially in the case of terns, gulls, phalaropes and other ‘difficult’ species detected during surveys.

12. Ecological and Biologically Significant Areas (EBSAs)

Ecologically and Biologically Significant Areas are areas identified through science-led processes that call attention to areas of particularly high ecological or biological significance. They are meant to facilitate the provision of a greater-than-usual degree of risk aversion in management of activities in such areas (DFO 2004).

There are portions of three EBSAs within the Study Area (DFO 2013): Nain Area, Hopedale Saddle and Hamilton Inlet (Figure 12.1; Table F-1). Three EBSAs border on the study area: Northern Labrador, the Labrador Marginal Trough and Lake Melville (Figure 12.1; Table F-2). Other EBSAs that are nearby but outside the Study Area are the Outer Shelf Nain Bank and Labrador Slope EBSAs (Figure 12.1; Table F-3), which occur further offshore on the continental shelf and slope of the Labrador Sea.

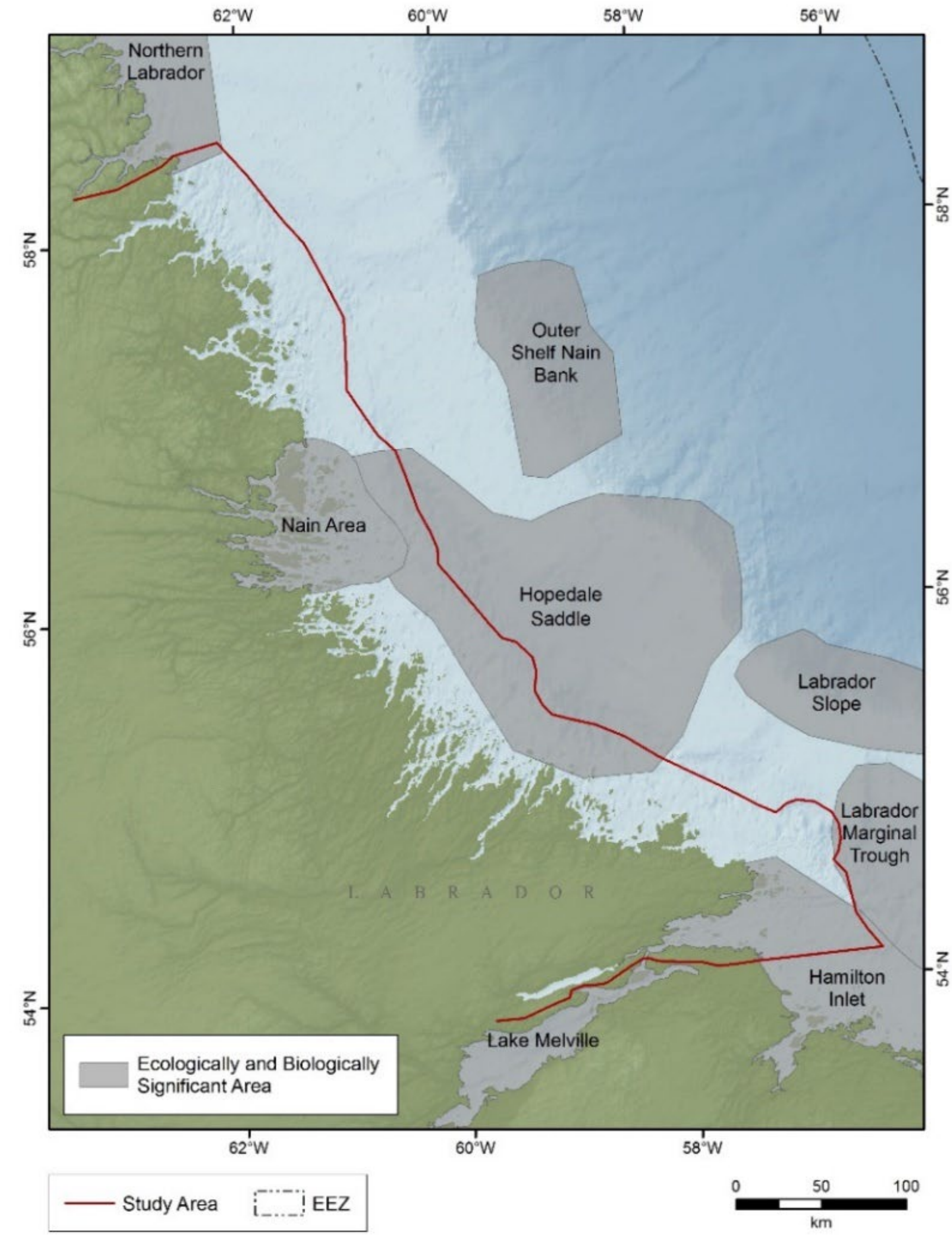


Figure 12.1. Ecologically and Biologically Significant Areas (EBSAs) that have been identified within and adjacent to the study area.

The Nain Area EBSA was identified based on the presence of seabirds and waterfowl aggregations/colonies, capelin spawning beaches, and productive Arctic Char habitat (DFO 2013). While the key feature of the Hopedale Saddle EBSA is the unique overwintering area for Eastern Hudson Bay belugas, this area also includes high concentrations or aggregations of several coral, fish, and seabird species. It's also a summer feeding area for harp seals and an area frequented by juvenile and female hooded seals (DFO 2013). The key features of the Hamilton Inlet EBSA include capelin spawning beaches and important Atlantic

Puffin and Razorbill colonies. This area is also a highly productive area for Atlantic Salmon (DFO 2013). Other features of these areas are described in detail in Wells et al. (2017).

The key features of the Northern Labrador EBSA include a unique migratory area for Eastern Hudson Bay belugas, important areas for Harlequin Duck and Barrow's Goldeneye, significant feeding and summer haul out areas for Ringed Seals and important habitat and migratory corridor for polar bears (DFO 2013). The Labrador Marginal Trough EBSA was identified because several fish and marine mammal species are found there, and potentially use the area as a migratory corridor. It's the area of highest probability of use for Harp Seal whelping and harps and cetaceans also feed here during the summer (DFO 2013). The Lake Melville EBSA is a unique habitat to the area in that it is a saltwater tidal extension of Hamilton Inlet and one of the largest fjords in eastern Canada (3,069 km^2). The Churchill River drains much of the Labrador plateau and provides 75% of the freshwater input to Lake Melville through Goose Bay. The marine influence is also strong in this system and brackish waters occur all the way up into the braided Churchill River channel beyond the inflow to the estuary (Wells et al. 2017). Several freshwater, diadromous and marine fish species are found here, and salmon are known to spawn and rear their young in this area. This is also the area where the highest counts of moulting Surf Scoters have been found in Eastern Canada. Finally, the eastern portion of the Lake is an important overwintering and breeding area for Ringed Seals, resulting in particularly high winter and early spring densities in the area. (Wells et al. 2017).

13. Inuit Use and Other Activities

The majority of Inuit in Canada in live in 53 communities across Inuit Nunangat (Figure 13.1). Inuit Nunangat is the homeland of Inuit, and this term encompasses the land, water and ice, which are all important to the culture and way of life of Inuit. Inuit Nunangat covers 35% of Canada's landmass and more than 50% of Canada's coastline.

In addition to the diverse Inuit uses of the marine environment there is also commercial (non-indigenous) fishing, oil and gas exploration, mining, and marine shipping in or near the study area. Aquatic invasive species may be introduced as a result of some of these activities and may be experiencing shifts in range and life history traits due to climate change. Contaminants have also entered the marine environment through past (e.g., construction and maintenance of military bases) and present (e.g., Voisey's Bay mine) activities.

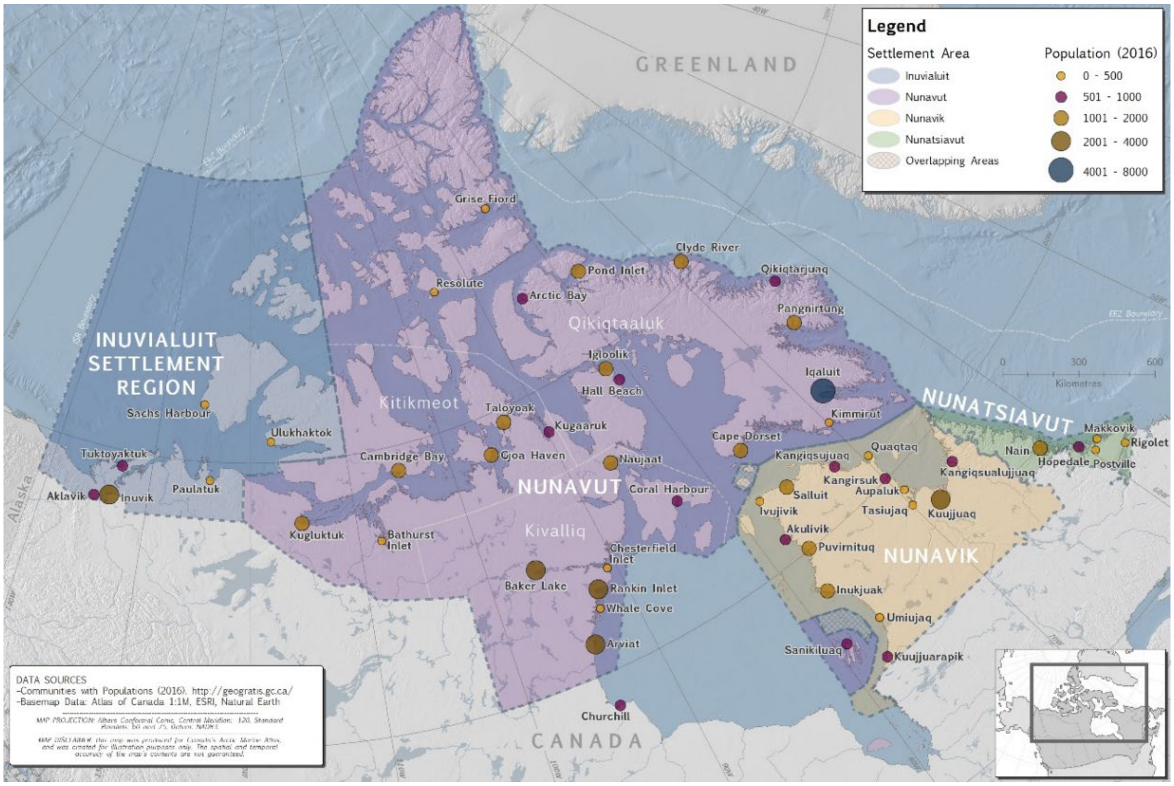


Figure 13.1: Map of Inuit Nunangat showing the 53 communities that comprise the four Inuit regions of Canada. Source: Indigenous and Northern Affairs Canada (2016).

13.1. Available Information

13.1.1. Inuit Use

There are four Inuit regions in Inuit Nunangat: the Inuvialuit Settlement Region, Nunavut, Nunavik, and Nunatsiavut. Each region was established by its own land claim and operates under unique political structures. Nunatsiavut, the homeland of Labrador Inuit, is a self-governing region that was established through the signing of the LILCA on December 1, 2005 and is represented by the Nunatsiavut Government.

Labrador Inuit have and continue to use and rely on the ocean. The ocean provides a connection to food, sustainability, economic growth, health, and culture and therefore is fundamental to Inuit survival, health and wellbeing. Labrador Inuit have traveled over, and harvested in, the marine environment in all seasons for many thousands of years.

Sea ice is critical infrastructure and is a central part of culture, community, and livelihood in Northern Labrador (Figure 13.2). Sea ice connects Inuit, allowing for travel between communities of the four Inuit regions that make up Inuit Nunangat, and to historical and culturally important areas, including cabins, seasonal camps, harvesting areas and trap lines (Angnatok and Laing 2018; Figure 13.3). Sea ice is also an important habitat for many hunted species who use ice for feeding and breeding. Therefore, sea ice is a dynamic component of the ecosystem and its use by Inuit changes throughout the seasons based on species life histories, ice conditions, and food needs.

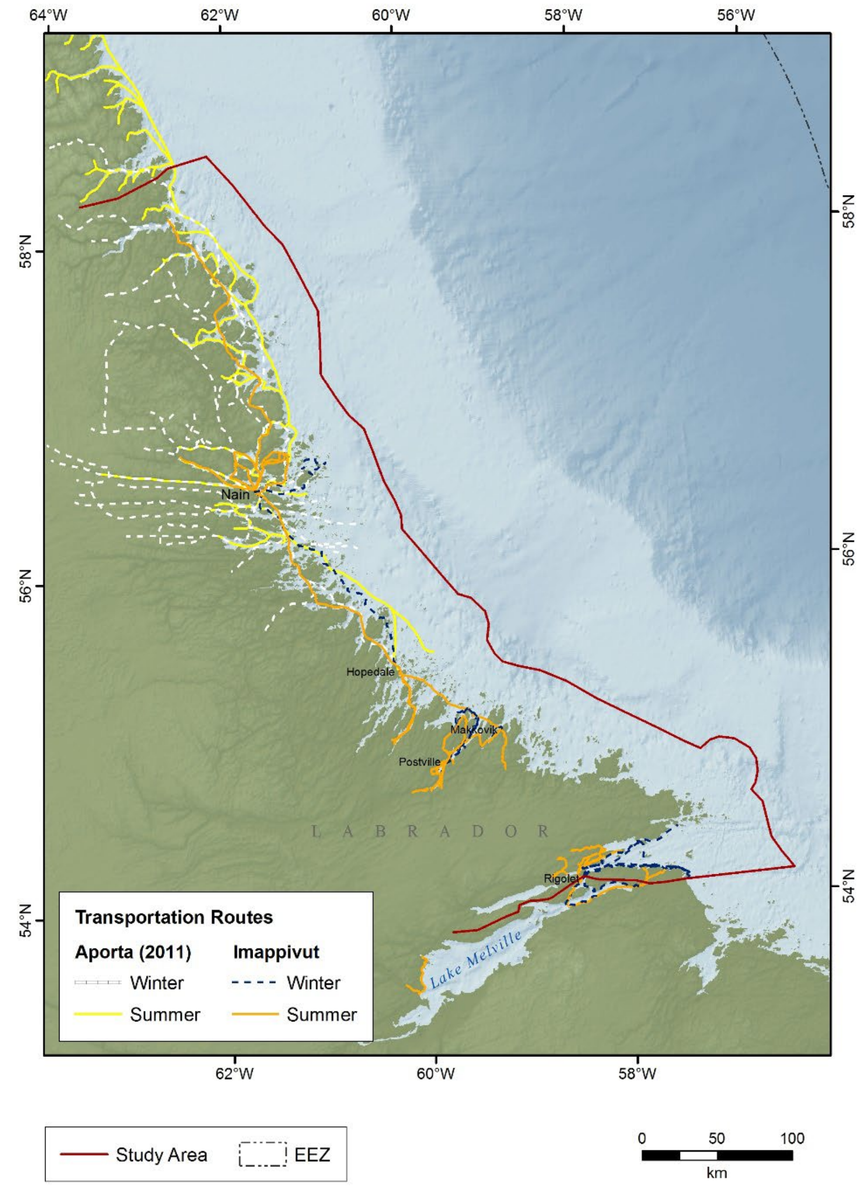


Figure 13.2: Winter (white) and summer (yellow) trails used by Labrador Inuit around Nain and north of the study area (Aporta 2011).

Figure 13.3: Hunter in Nain seal hunting at the ice edge. Photo credit: Rodd Laing

The importance of ice for Labrador Inuit is reflected in an extensive understanding of ice at each stage-including, but not limited to ice formation, solidity, stability, crystallization, and breakup (Aporta 2011). Travel on the ocean is not just considered a means to get from one place to another for Inuit; it is often for opportunistic hunting and gathering for wild foods. LK about important food sources and hunting travel routes, fishing, trapping and gathering food from various parts of the environment has been shared for generations. Labrador Inuit have lived in the study area and used these resources sustainably for thousands of years. Recent anthropogenic factors and changes in climate have had significant impacts on many species of importance for Labrador Inuit.

Commercial and community fisheries provide economic benefits for Nunatsiavut and are an important source of income and food for many residents in the region. For the community fishery, Labrador Inuit travelled hundreds of kilometers from their communities for months at a time to fish for salmon and char, but over the years this fishery has evolved, and if now made up of smaller groups fishing closer to communities. The Torngat Fish Producers Co-op is an Indigenous cooperative that operates processing plants in Makkovik (Snow Crab and Greenland halibut) and Nain (Arctic Char and scallops) for the community and commercial fisheries. The co-op reports that the landings and earnings for fishers and plant workers vary depending on the harvested species (R. Johnson, pers. comm.) and has varied over time, partially due to the decline of the cod fishery, fewer groundfish licenses, a reduction in number of fishing of vessels and restrictions on salmon harvesting.

The main commercial species caught on the Labrador Coast are: Northern shrimp, Snow Crab, Greenland Halibut, Northern cod, and Arctic Char. Over the past five years, the average landed value for all fisheries was approximately two million dollars (R. Johnson, pers. comm.). The primary species currently caught in the community fishery are Arctic Char and Icelandic scallops. The fishers are local community members who use small boats and travel short distances to fish. The community fishery provides the flexibility for fishers to sell their catch to the processing plant, or to keep and share within the community.

Inuit traditionally share food within the community, and this is reflected in the harvesting from the marine environment. Harvested food is shared among families and with elders directly as well as through community freezers. For example, the Nain Community freezer is situated in the Nunatsiavut Research Centre. Wild food is donated by harvesters and fishers and distributed to residents in Nain. Donations include marine species such as Arctic Char, Rock Cod, Polar Bear, ducks, black guillemots, geese, seal, and porpoise. Additionally, as part of a Social Fishing Enterprise, the Nunatsiavut Government purchases approximately 13,000 lbs. of char from the Torngat Fish Producers Co-op each year to be distributed amongst the community freezers in Nunatsiavut. This donation of char supplies communities with food from September to March each year. A portion of these Arctic Char are traded with NunatuKavut Community Council for cod. More than a thousand individuals visit Nunatsiavut community freezers every month and thousands of pounds of food are distributed monthly.

13.1.2. Fishing

Based on VMS records (2005–14), fisheries effort across gear types is extremely limited within the study area (Figure 13.4; Koen-Alonso et al. 2018). By gear type, the most prevalent fisheries within the study area are shrimp trawls, fixed gear for groundfish (gillnet, longline, hand line, and traps), and fixed gear for crab (traps and pots). Fishing effort can also be examined by target species; however, Treasury Board policy stipulates that in order to represent fishing activity spatially, at least five fishers, boats, and license holders must be represented in any one NAFO statistical area (referred to as the “Rule of Five”). Three species meet this “Rule of Five” and consist of both Indigenous and non-Indigenous fishing records: Greenland Halibut (gillnet and trawl), Northern Shrimp (trawl), and Snow Crab (pots) (Figure 13.5). The majority of commercial fishing occurs in the deeper waters east of the study area. Greenland halibut (Turbot) fishing is largely concentrated just outside the study area boundary near Hopedale and Makkovik, Snow Crab fishing is concentrated off Makkovik and to the southern extent of the study area, and the shrimp fishery extends across most of the latitudinal range of the study area at the shelf edge. Shrimp fishing activity also occurs inshore of the study area boundary between Nain and Hopedale and off Rigolet, though to a lesser extent than outside the study area. Fisheries for other species including cod, Capelin, mackerel, Atlantic Halibut, redfish, Icelandic scallop, and skate occur within the study area but could not be spatially represented because records for these activities did not meet the “Rule of Five”. There is also some fishing impact related to the DFO RV Survey; however, trawl sets within the boundaries of the study are relatively rare throughout the time series (Figure 13.6). Due to the lack of extensive trawling, this area represents some of the least disturbed shelf habitat in the Newfoundland and Labrador Bioregion.

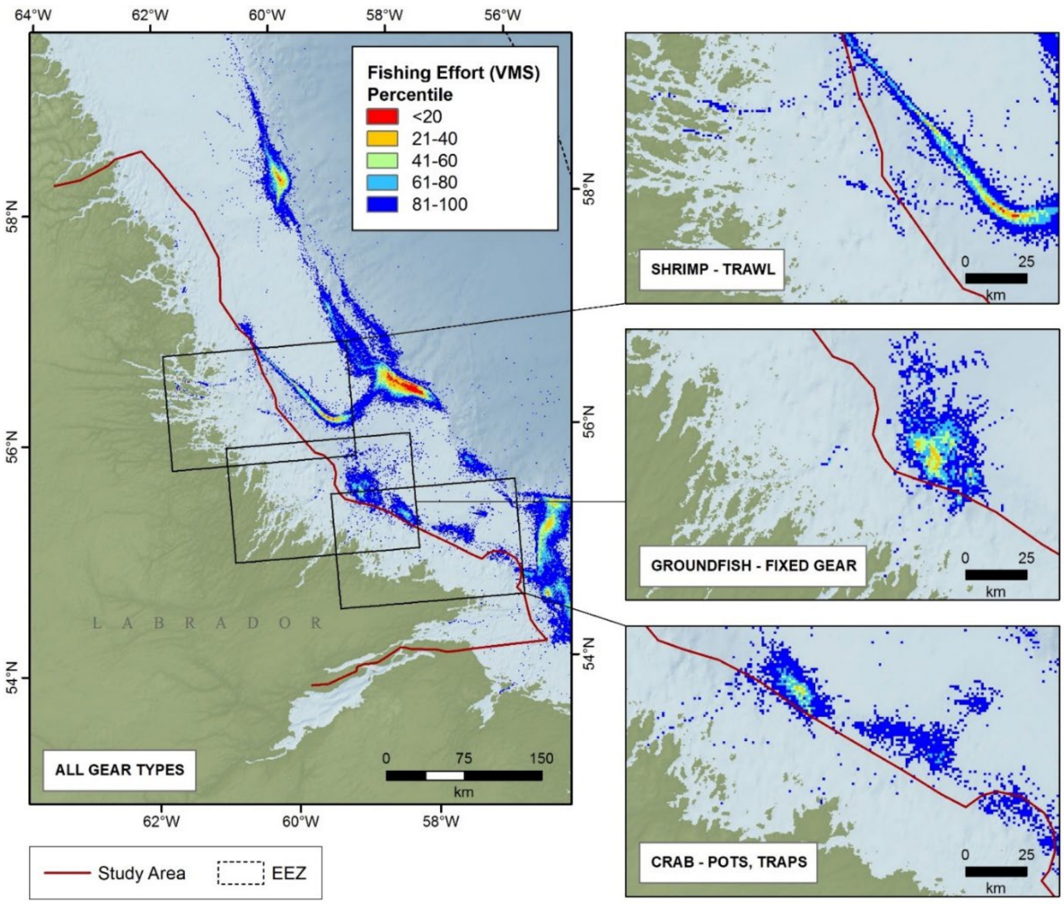


Figure 13.4: Percentile distribution of georeferenced fishing effort based on Vessel Monitoring System data (2005–14) for all fisheries/gear types (left), shrimp trawlers (top right), groundfish fixed-gear (gillnets, longlines, hand lines, and/or traps; middle right), and crab pots (bottom right; Koen-Alonso et al. 2018).

Atlantic Salmon and brook trout are also fished recreationally in the study area (DFO 2018c). Currently there are nine scheduled salmon rivers in the study area Flowers River and tributary streams, Hunt River, Adlatok River, Ujutok River and tributary streams, Little Bay River and tributary streams, Big River, Michael's River, Tom Luscombe River and tributary streams, Double Mer and tributary streams. In 2018; however, the recreational fishery for Atlantic Salmon was reduced to a catch and release fishery with a daily limit of three fish due to the predicted declines in salmon returns in many rivers in Newfoundland and Labrador (DFO 2019).

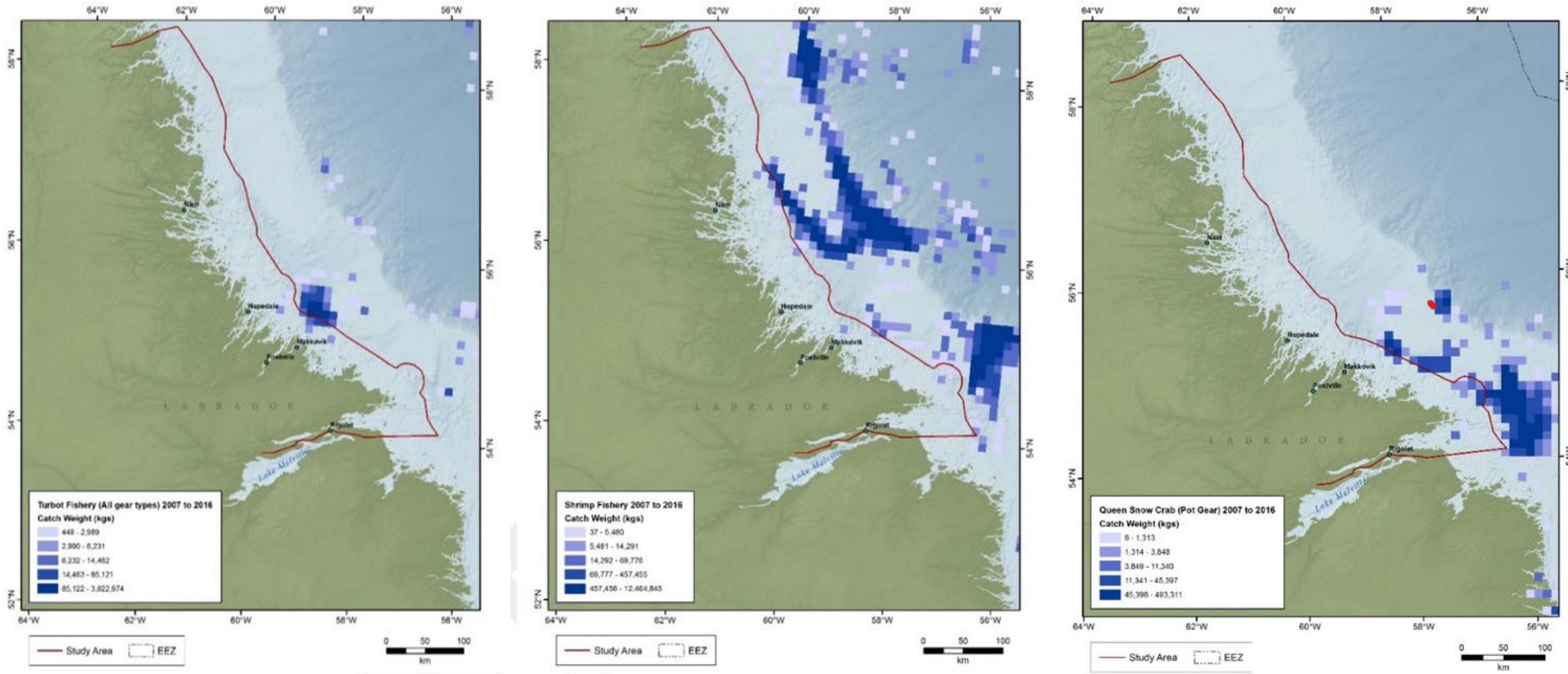


Figure 13.5: Commercial Fishing Activity (Greenland Halibut (gillnet and trawl); Northern shrimp (trawl); Snow Crab (pot)) in and adjacent to the 'Study Area' 2007–16.

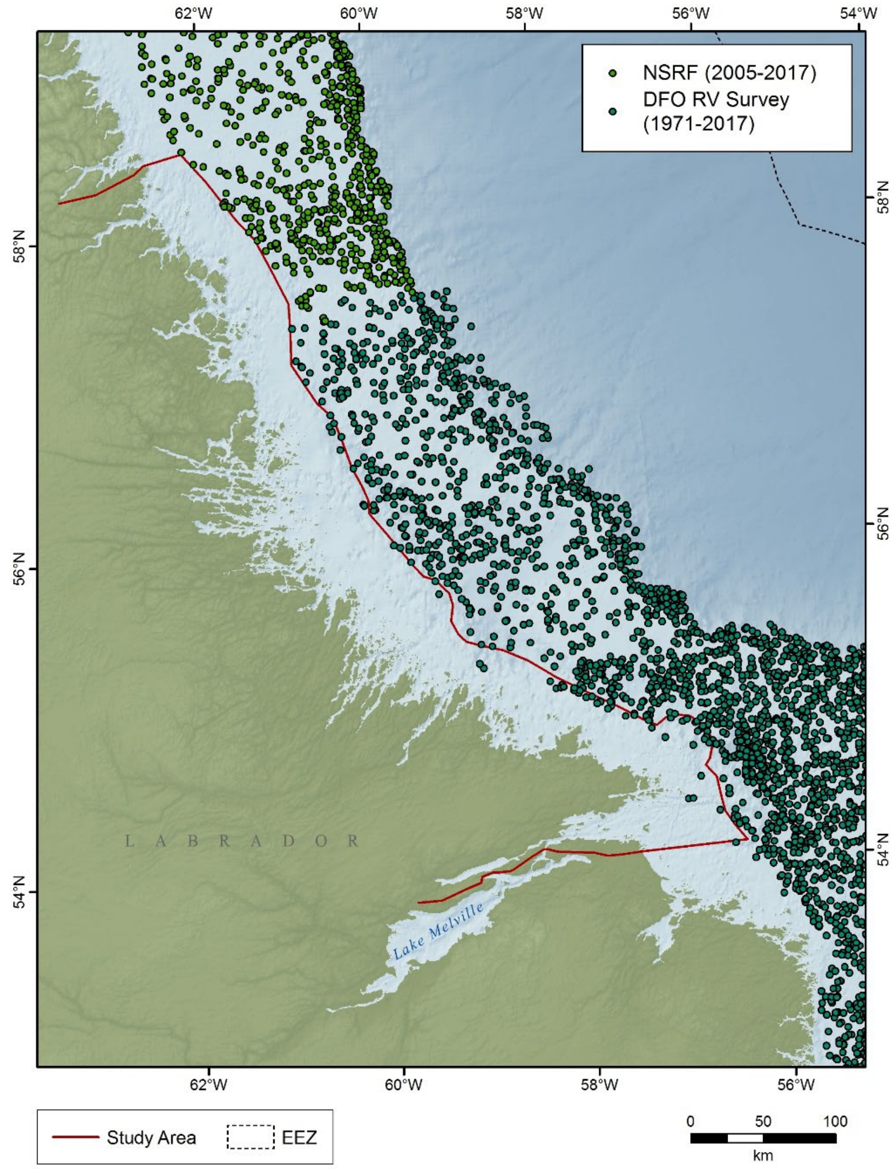


Figure 13.6: Distribution of survey trawl sets carried out by the Fisheries and Oceans RV Survey and the Northern Shrimp Survey (NSRF) from 1971–2017.

13.1.3. Oil and Gas

Interest in oil and gas exploration in the Labrador Sea has intensified in recent years. The Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB) uses AOI nominations in conjunction with internal assessments to design oil and gas Sectors - an area where the C-NLOPB will nominate future Call for Bids. Calls for Bids are parcels within the Sectors, whereby oil and gas companies may submit bids on the total amount they are willing to invest in exploration activity within the parcel. The highest bidder is then awarded an Exploration License (EL). The successful bidder is granted the exclusive right to drill and test for petroleum and has a maximum of nine years to conduct exploration activities (seismic, geotechnical, geomatics surveys etc.). Depending on the results of exploration activity, the C-NLOPB can issue further rights in the form of a Significant Discovery License (SDL) or a Production License (PL).

Seismic exploration in the Labrador Sea started in 1980 with significant coverage since 2012. Seismic surveys are largely confined to areas outside and east of the study area (Figure 13.7). No exploratory wells have been drilled within the study area to date, but some exploration activity has occurred to the east. There are five Significant Discovery Licenses for natural gas and ten Calls for Bids and a Sector adjacent to the study area (Figure 13.8).

In 2008, the C-NLOPB completed a Strategic Environmental Assessment (SEA) for an area of offshore Labrador known as the Labrador Shelf Offshore Area, which encompasses the entire study area, extending seaward to the Exclusive Economic Zone (EEZ), except in the southern portion where the boundary has been extended to Canada's continental shelf claim (Sikumiut Environmental Management Ltd. 2008). An SEA Update Report, co-chaired by the C-NLOPB and the NG, is currently underway and has convened a Working Group that consists of members from federal and provincial agencies, fishing interests groups, Indigenous organizations, academia, industry, and non-governmental organizations (C-NLOPB 2017). The purpose of the Working Group is to assist the C-NLOPB in the development of the SEA Update Report, providing technical advice regarding scope and content, the collection and analysis of Traditional Knowledge, and public consultations. The C-NLOPB has decided to defer previously scheduled Calls for Bids (CFB) until 2023 to allow sufficient time to update the SEA (C-NLOPB 2019).

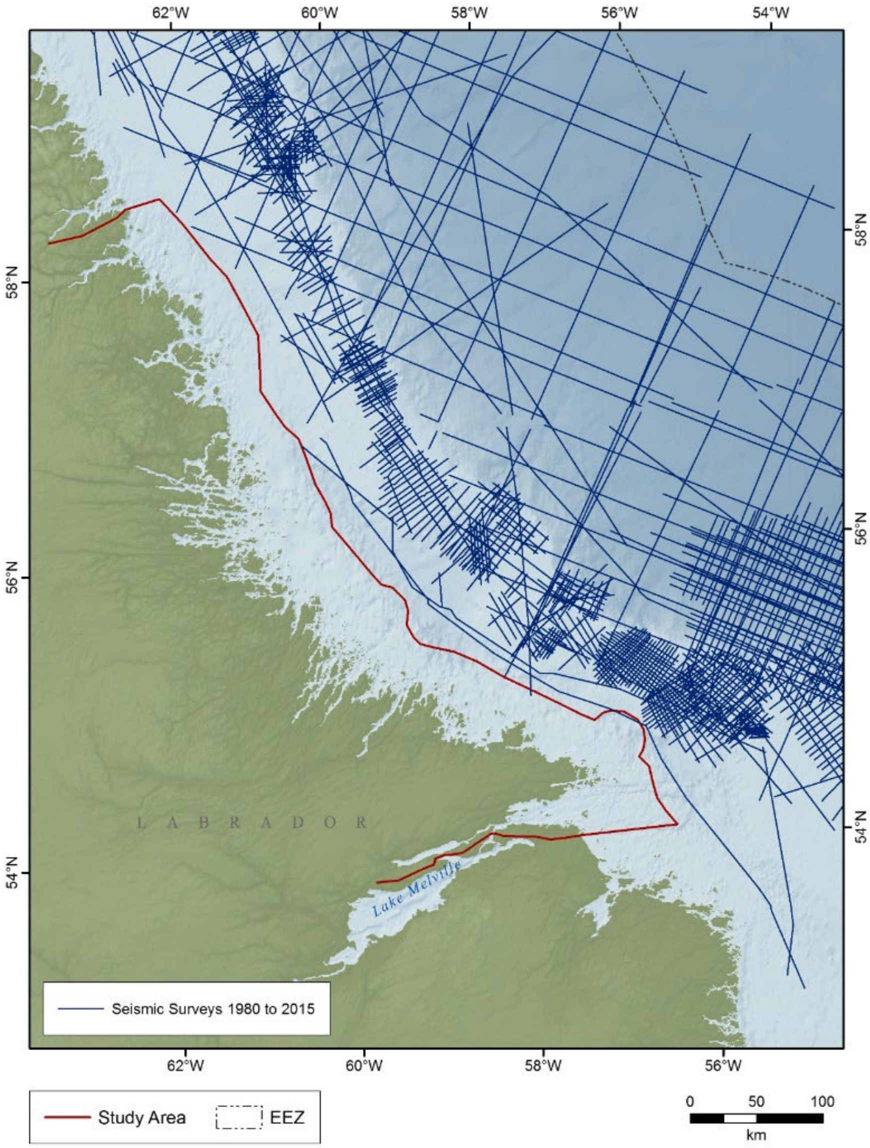


Figure 13.7: Seismic Activity 1980–2015 in and adjacent to study area (Reproduced from C-NLOPB Seismic Data Reports, Labrador North and South Regions).

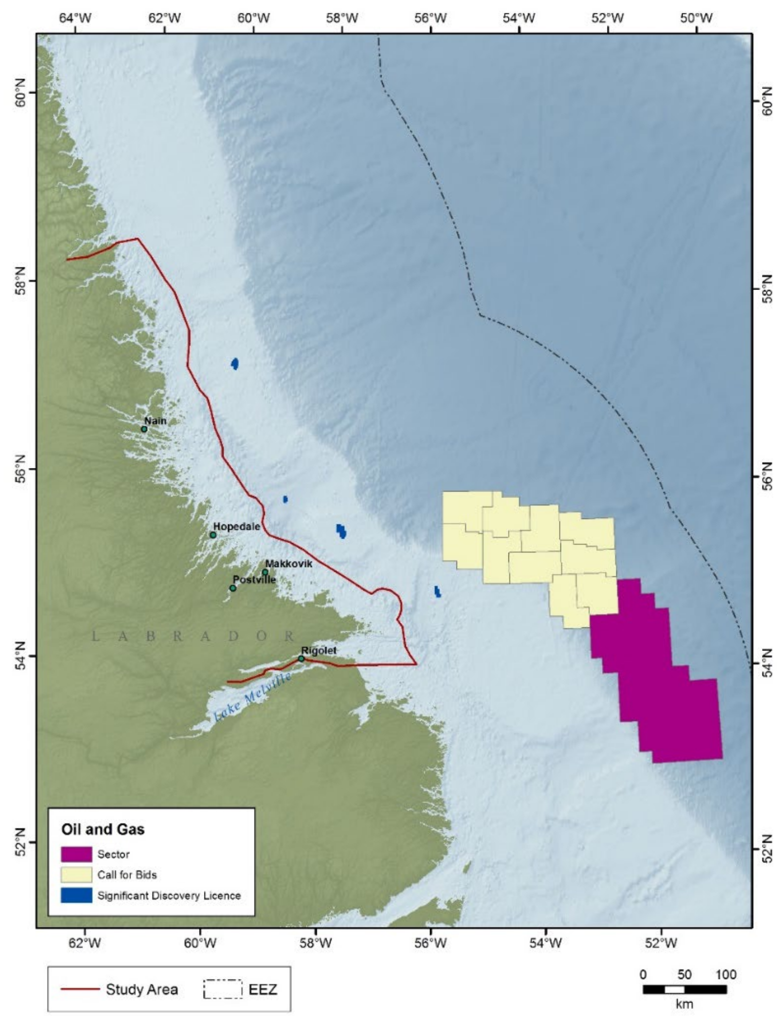
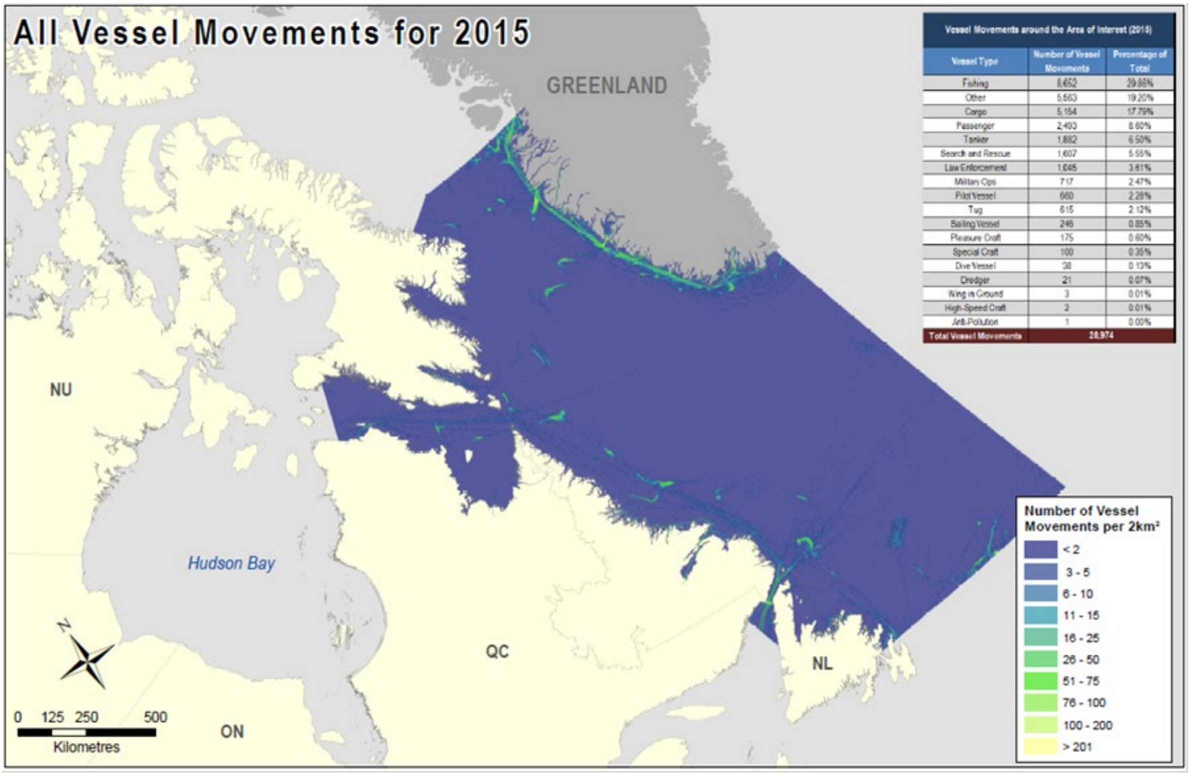


Figure 13.8: Oil and Gas Activity in area adjacent to the 'Study Area' (November 2018).

13.1.4. Vessel Traffic

Data provided by Transport Canada shows the extent of vessel movement within the study area, where a movement is defined as a unique vessel movement per day within a given grid cell (2 km^2). In order to contextualize the amount of vessel traffic in the study area, a larger region was identified that includes the offshore area extending north through Davis Strait and Hudson Strait (Figure 13.9). In 2015, there were a total of 28,974 vessel movements in the larger region, showing a distinctive fishing pattern in the area adjacent to the study area (Transport Canada 2015) (Figure 13.9). Comparatively, the marine traffic density in the study area is relatively low (910 movements in 2015). The majority of shipping traffic within the study area includes cargo supply ships, passenger ferry services, tankers, commercial fishing, search and rescue, and research vessels. The heaviest activity was associated with cargo and tanker traffic in and out of Nain and Happy Valley-Goose Bay along the coastal passenger ferry route and in fishing areas near the study area boundary (Transport Canada 2015) (Figure 13.10).



Vessel Movements around the Area of Interest (2015)		
Vessel Type	Number of Vessel Movements	Percentage of Total
Fishing	8,652	29.86%
Other	5,563	19.20%
Cargo	5,154	17.79%
Passenger	2,493	8.60%
Tanker	1,882	6.50%
Search and Rescue	1,607	5.55%
Law Enforcement	1,045	3.61%
Military Ops	717	2.47%
Pilot Vessel	660	2.28%
Tug	615	2.12%
Sailing Vessel	246	0.85%
Pleasure Craft	175	0.60%
Special Craft	100	0.35%
Dive Vessel	38	0.13%
Dredger	21	0.07%
Wing in Ground	3	0.01%
High-Speed Craft	2	0.01%
Anti-Pollution	1	0.00%
Total Vessel Movements	28,974	

Figure 13.9: 2015 Vessel Movements within and adjacent to the Study Area: Data Provided by Transport Canada: Space Based Automatic Identification System (S-AIS) (Class A Messages only) Source for 2015 data was exactEarth.

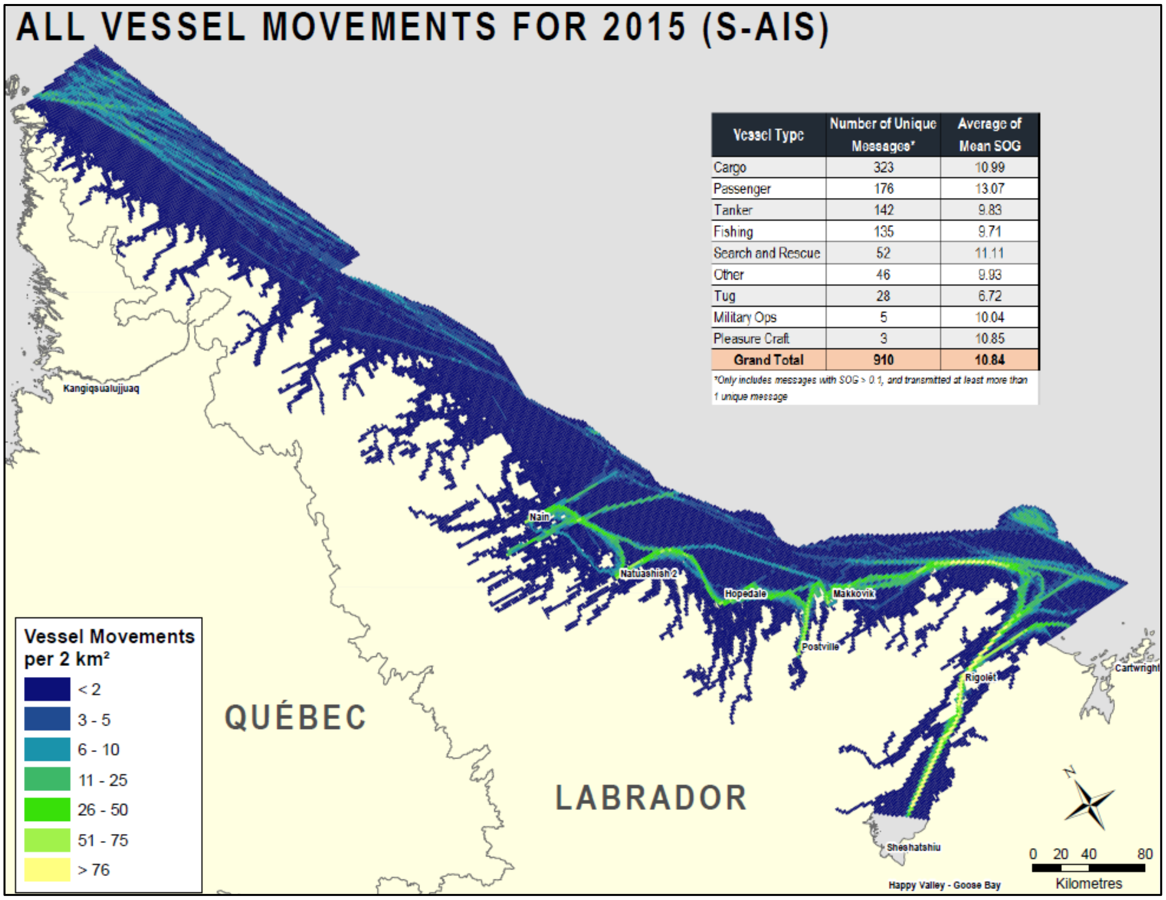


Figure 13.10: 2015 Vessel Movements within the Study Area: Data Provided by Transport Canada: Space Based Automatic Identification System (S-AIS) (Class A Messages only) Source for 2015 data was exactEarth.

Winter shipping to and from the Voisey's Bay mining site is an important issue for Labrador Inuit as they use the landfast ice for transportation and harvesting. The Impacts Benefits Agreement (IBA) between Vale Inco Newfoundland and Labrador and the NG includes provisions pertaining to the port of Edward's Cove and requirements for a winter shipping agreement to minimize ice break up. The Shipping Agreement between the NG and Vale Inco NL outlines solutions allowing shipping to occur coincident with Inuit use of the ice (e.g., shipping routes, shipping season, and winter shipping track through landfast ice, ice monitoring, ice bridges etc.).

13.1.5. Aquatic Invasive Species

Northern shipping routes may experience an increase in shipping traffic as warmer ocean temperatures reduce Arctic summer sea ice extent and timing (i.e., Northwest Passage) (Struzik 2016). This could result in increased shipping activities in the Labrador Sea as it is the Canadian gateway to the Arctic (Fort et al. 2013; VITALS 2017). This may increase the potential for the introduction of aquatic invasive species (AIS) and harmful algae as shipping is the main mechanism for AIS introductions in the marine environment through ballast water, ballast tank sediment, biofouled hulls or other wetted surfaces (International Maritime Organization [IMO] 2019). Increases in temperature and changes to salinity also affect the invasion potential of an area (Occhipinti-Ambrogi and Galil 2010; Hellmann et al. 2008).

Since September 2017, IMO regulations (IMO 2017) have required ships to use ballast exchange treatment onboard, which is intended to remove AIS from ballast water prior to discharge. However, these regulations do not apply to domestic shipping, and therefore do not manage risk of introductions from other areas within Canada. Guidelines for the control and management of ships' biofouling to minimize the transfer of aquatic invasive species were also published by the IMO in 2011 to reduce introductions from biofouling. The International Council for the Exploration of the Sea (ICES) recently released a Biofouling Viewpoint which addresses the important global issue of biofouling on commercial and recreational vessels and their role in introducing non-native species (ICES 2019).

Shipping routes within the study area include transit from Voisey's Bay to Placentia Bay, an area with several aquatic invasive species (e.g., European green crab and coffin box bryozoan) (DFO 2010a; Best et al. 2017). If AIS are introduced, they have the potential to displace native species, change community structure and food webs, and alter major ecosystem processes (e.g., nutrient cycling and sedimentation) (Molnar et al. 2008).

Additionally, harmful algae (HA), is introduced via ballast water and some species can produce toxins that contaminate shellfish and cause death of fish. These toxins are slow to depurate at low temperatures and can bio accumulate, transferring up the food chain with harmful effects for higher trophic levels (e.g., marine mammals such as cetaceans) (Lefebvre et al. 2016). In 2018, baseline AIS and HA surveys were conducted in the study area (unpublished data).

13.1.6. Contaminants

Contaminants enter the study area from local sources and via long-range atmospheric and oceanic transport. Documented local sources of contamination in the study area include two abandoned military radar sites and one operational mine (Voisey's Bay). Contaminants of particular concern are those that biomagnify and reach high concentrations in animals at the top of the food chain. These contaminants are those described as being persistent, bioaccumulative and toxic (PBT), and include polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), and organochlorine pesticides (OCPs).

PCBs represent the primary contaminant class of concern and are associated with the two former military radar sites at Saglek and Hopedale (Aivek Stantec 2015). Studies of soil, plants, and sediments in the terrestrial and adjacent marine environment at Saglek showed that PCBs from this site resulted in a halo of contamination up to 50 km in diameter (Pier et al. 2003; Kuzyk et al. 2005). The former military site at Hopedale is located near the community, and residents have raised concerns about community health, the health of country foods, and current land use and development (Bidleman and Kurt-Karakus 2013). While both sites are land-based, there is evidence that PCBs have entered the marine environment at Saglek Bay and Hopedale Harbour. Both Saglek and Hopedale have been the subject of site-specific ecological risk assessments (ERA) and human health risk assessments (HHRA). The Saglek ERA and HHRA indicated that the contamination present at the time of the assessments (late-1990s to early-2000s) were associated with ecological risks and could pose human health risks if wild foods were consumed from the area (Brown et al. 2014). Terrestrial remediation of PCBs at Saglek has taken place and long-term monitoring has shown that ecosystem recovery is underway and that the site no longer warrants a harvesting recommendation. Although PCB concentrations in the sediment have decreased substantially over the years, some longer lived benthic species may still be impacted and as such there is a recommendation that these species should be avoided or consumed in moderation.

At Hopedale, the HHRA suggests that prolonged exposure to the PCB-contaminated areas at the former military radar site may pose a health risk (Environmental Sciences Group [ESG] 2009). For example, local foods including berries, wild game, and bottom-dwelling marine species (e.g., rock cod, mussels, etc.) should not be consumed around areas with elevated PCB levels. A remedial plan for Hopedale was developed in 2010 and the Newfoundland and

Labrador government has initiated terrestrial remedial activities at the site (ESG 2009). There are currently no available solutions for effective marine remediation and the marine harvest warning will not be lifted for the Hopedale Harbour in the foreseeable future.

Voisey's Bay has been the site of an open pit nickel mine and concentrator since 2005. Two types of concentrate, nickel-cobalt-copper, and copper, are produced at the site. The nickel concentrate is processed at a processing facility in Long Harbour, Newfoundland. Background studies from the area suggest that the sediments from the Voisey's Bay region are naturally enriched in zinc (Zn), which is largely attributed to the sphalerite in the area (Veinott et al. 2001). Metals with a known point source in the area include nickel (Ni), cobalt (Co), and copper (Cu). A plan to transition the nickel mine from open-pit operations to underground is underway.

Other potential local sources of contamination in the study area include leachate and effluent from community dumpsites along the coast which could be a source of PBDEs to the terrestrial and marine ecosystems in the study area.

13.2. Sensitive Areas

There is evidence of Inuit use nearly everywhere on the central and northern Labrador coast (Brice-Bennett 1977), including traditional homesteads and culturally sensitive sites. These important sites were mentioned by most individuals interviewed during the mapping sessions conducted by the *Imappivut* team. Participants of the Imappivut Knowledge Collection interview sessions stated that many Inuit still travel from their communities during all seasons to visit some of these culturally significant areas, including Hebron, Okak and Saglek.

Significantly, Inuit consider all areas sensitive and important to cultural, health and wellbeing, including in the marine environment. The connection between environment and health is inherent for Inuit, and therefore, changes in the marine environment have direct implications for Labrador Inuit.

13.3. Data Gaps and Recommendations

Although the Imappivut Knowledge Collection Study has gathered large volumes of data about significant areas and human use, there is still a great deal of knowledge to be documented. It remains necessary to document more information for specific parts of the study area (such as the Hebron and Okak areas and Double Mer around Rigolet) that are inadequately covered by existing interviews. Filling these gaps may require targeted visits with individuals with knowledge specific to these areas. Additionally, using other documents such as OFAE has helped to address some of these gaps. Many of the inshore fisheries within the study area have limited spatial information and the Treasury Board Policy (Rule of Five) for mapping fishing activity eliminates the ability to map locational information at this time.

Finally, understanding changes in community and commercial fishery species is imperative to ensure long-term economic sustainability and ensure there are culturally important food sources available for Labrador Inuit. Some of these information gaps can be addressed directly through further collection of Local Knowledge as well as additional science research programs.

14. Protected Areas and Other Closures

There are no protected areas within the Study Area; however, the Hatton Basin Marine Refuge extends into the Northern Labrador EBSA (see Section 12), north of the study area, and the Hopedale Saddle Marine Refuge is situated farther offshore on the continental shelf and slope of the Labrador Sea (Figure 14.1, Table 14.1). Both Marine Refuges are closed to all bottom contact fishing activity under the *Fisheries Act*, contributing to the Government of Canada's MCTs as "other effective area-based conservation measures".

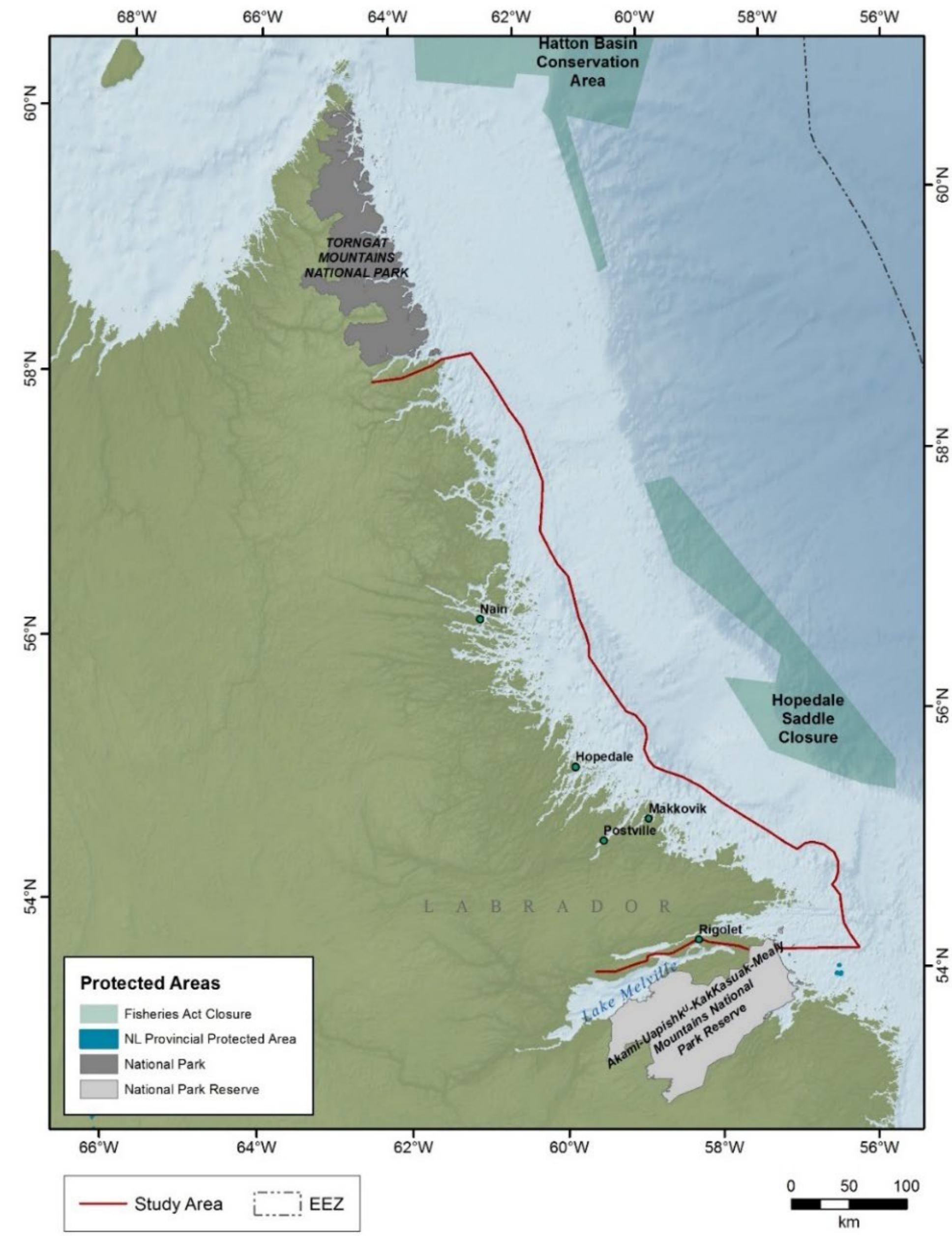


Figure 14.1 Protected Areas adjacent to the study area.

Table 14.1: Protected area adjacent to the study area.

Conservation Area	Conservation Objective	Key Ecological Features	Other Ecological Features
Hatton Basin Marine Refuge	Conserve sensitive benthic areas	Significant concentrations of small gorgonian corals (order: Alcyonacea), large gorgonian corals, and sponges	Only known overwintering area for northern Hudson Bay Narwhal (*Monodon monoceros*) Supports important habitat for other marine mammals, seals, and high densities of sea birds (including depleted species, such as the Ivory Gull [*Pagophila eburnean;* endangered under SARA])
Hopedale Saddle Marine Refuge	Protect corals and sponges and contribute to the long-term conservation of biodiversity	Cold-water corals and sponges	Supports important overwintering area for the endangered population of Eastern Hudson Bay Beluga, several depleted species, and high biological diversity

The Torngat Mountains National Park is located north of the study area and the Mealy Mountains National Park Reserve is situated to the south. These parks protect representative examples of each of Canadas' 39 terrestrial natural regions (*Canada National Parks Act*), with coastal boundaries that extend to the low water mark.

The Gannett Islands Ecological Reserve established under provincial legislation (*Wilderness and Ecological Reserves Act*) is a Seabird Ecological Reserve found south of the Study area boundary. The reserve has a 20 km^2 marine component surrounding seven low-lying islands, which support the largest and most diverse seabird breeding colony in Labrador.

SUMMARY

- The study area is dynamic; biophysical conditions and species assemblages changing seasonally and across years.
    - Local knowledge and scientific studies have noted multi-year changes in biophysical conditions (e.g., sea ice) and species assemblages related to anthropogenic climate change.
    - The strong biophysical seasonality of the study area also affects species assemblages.
    - Sea ice is an important ecological, ephemeral feature of the study area. Many species are associated with specific elements of sea ice, and their distribution is also dynamic.
- Through nutrient and contaminant transport, ocean currents and migration of species, the study area is inherently connected to adjacent marine, freshwater, and terrestrial

ecosystems. Similarly, the ecosystem is inseparable from the Labrador Inuit, their way of life and their future.

- The study area includes diverse coastal and marine habitats.
  - The inshore to offshore habitat spans habitat zones that include the intertidal, nearshore, continental shelf and continental slope.
  - The latitudinal extent is large enough that there are differences in biophysical conditions and species assemblages along a North-South gradient.
- The study area supports a relatively intact assemblage of biota that includes large marine mammals and predators and is home to species of conservation concern. It also contains many species that have been used for commercial purposes and have sustained Labrador Inuit for generations.
- The Labrador Inuit are an important part of this ecosystem; these communities are stewards and rightsholders in the study area.
- Due to a combination of factors (Labrador Inuit Land Claims Agreement exclusions, remoteness of the area, seabed that inhibits trawl activity) industrial activities like shipping, oil and gas and commercial fishing have been limited within the study area compared to other parts of the Newfoundland and Labrador shelves. However, there is substantial industrial activity occurring adjacent to the study area.
- The study area is a challenging area in which to conduct research and therefore there are few scientific studies-particularly in winter and spring when sea ice is present. The study area benefits from rich Local Knowledge of culturally important species in many parts of the coast; however, there are significant gaps in the understanding of species distributions and ecology. Some parts of the study area (e.g., shelf areas inside the limits of the Department of Fisheries and Oceans Remote Vehicle surveys and some parts of the coast less frequently used by Labrador Inuit) are particularly under-represented in existing ecological datasets.
- Some species assemblages are poorly represented in available studies, including coastal fish, marine invertebrates, and plankton communities. Furthermore, the understanding of the fine-scale oceanography of the coastal zone remains poorly understood.

RECOMMENDATIONS

- Future research should aim to provide a better understand the ecological links of the study area to adjacent areas (e.g., larval transport, nutrient sources, genetics of key species etc.). Such information will help assess the resilience of the study area's biota to shifts in climate and distributions.
- Field collections should target under-represented portions of the study area (e.g., the shelf, less used portions of the coastline) and species that are important to Labrador Inuit.
- Much of the knowledge of oceanography in the study area is derived from open ocean environments and may be less relevant to the coast. Increased effort should be made to understand the local and regional oceanographic processes in this area.
- General areas of research beyond characterizing community composition should focus on processes of productivity, trophic links (fatty acids, stable isotopes, stomach contents) and habitat-faunal relationships (e.g., currents, sea bottom).

- Ongoing work should continue to build Local Knowledge data sets to improve spatial and temporal representation and provide species-specific level information on key taxa.
- Due to anthropogenic climate change, study area ecosystems are changing. Long term monitoring of index sites should be considered to track these shifts and support predictions about future conditions. These monitoring programs should be implemented and/or supported by Nunatsiavut beneficiaries and should be locally relevant (i.e., the methods, research questions, and results are meaningful to coastal Labrador communities).
- Conservation objectives should include maintaining sustainable populations of species important to Labrador Inuit (e.g., Atlantic Salmon, Arctic Char, etc.).
- Recognizing the interdependence of the Labrador Inuit and the study area's ecosystem will be paramount to achieving conservation goals.
- The following principles are recommended when undertaking research in the study area:
    - Involve the Nunatsiavut Government in research activities, incorporate local knowledge, and build collective capacity through these partnerships;
    - Design studies according to the scales of relevant ecological processes (do not artificially confine questions to the study area);
    - Where possible, conduct research across gradients of depth, bottom types, and primary productivity;
    - Use standardized techniques to leverage data sets with small sample sizes and enable comparison of results to other regions;
    - Where possible, use less intrusive survey methods to limit damage to vulnerable benthic fauna.

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APPENDIX A – CHAPTER CONTRIBUTORS

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APPENDIX B – SEABED FEATURES

Table B-1: CHS NONNA-100 files downloaded and applied to geostatistical interpolation of bathymetry.

File Name
CA2_5300N6000W.tif
CA2_5300N6100W.tif
CA2_5400N5600W.tif
CA2_5400N5700W.tif
CA2_5400N5800W.tif
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CA2_5600N6200W.tif
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APPENDIX C – MACROALGAE

The following list of species (Table C-1) deals mainly with those which are significant components of the marine flora of Labrador and northwestern Newfoundland. Since only a few of the inconspicuous species have been included, this list should not be considered complete. There are, in addition, numerous forms that are not sufficiently represented in the collections to be mentioned and many others that require considerably more study before their identity can be established. There is also a group of undescribed species which in time will be included in a more complete tabulation of the algae of these areas.

Numerous first records for Labrador and Newfoundland are also included in this list. One asterisk designates species collected for the first time in these areas; two asterisks designate species previously unknown from arctic and subarctic regions of the Canadian northeast.

Table C-1: Species list for the coast of the Labrador Peninsula and the northwest coast of Newfoundland transcribed from Wilce (1959).

Class	Family	Species	Documented Distribution
Myxophyceae (Blue-green algae)	Chamaesiaesiphoxaceae	**Entophysalis conferta* Drouet and Daily	Hebron Fjord, Saglek Fjord, Koksoak River
	Rivulariaceae	*Calothrix scopulorum* Drouet and Daily	Common throughout the entire region.
	Scytonemataceae	*Scytonema* sp.	Fort Chimo
	Oscillatoriaceae	*Lynghya* sp.	Hebron Harbour, McLelan Strait
Chlorophyceae (Green algae)	Palmellaceae	***Gloeocystis scopulorum* Hansgirg	Hebron Harbour, Port Burwell, Nanook Pool, McLelan Strait, False River Bay
		***Urococcus foslieanus*Hansgirg)	Hebron Harbour, Port Burwell, Nanook Pool, McLelan Strait, False River Bay
	Chlorococcaceae	***Codiolum pusillum* (Lyngbyc) Kjellman	Hebron Harbour, False River Bay
	Endosphaeraceae	***Chlorochytricum schmitzii* Rosenvinge	Hebron Harbour, McLelan Strait, False River Bay
		***Chlorochytricum dermatocolax* Reinke	Hebron Harbour, Port Burwell
	Ulotrichaceae	*Ulothrix flacca* (Dillwyn) Thuret	Newfoundland, southern Labrador, and common throughout more northerly collection stations.
		***Entocladia flustrae* (Reinke) Batters	Infrequently seen north of Nain.
	Chaetophoraceae	***Pringsheimella scutata* (Reinke) Schmidt et Petrak	General throughout the area.
	Gomontiaceae	**Gomontia polyrhiza* (Lagerheim) Bornet et Flahault	Port Burwell
	Ulvaceae	***Capsosiphon fulvescens* (C. Agardh) Setchell et Gardner	Okak Bay, Hebron Harbour
		**Enteromorpha compressa* (Linnaeus) Greville	Hebron Harbour, Saglek Fjord, Port Burwell
		***Enteromorpha erecta* (Lyngbye). J. Agardh	Port Burwell

Class	Family	Species	Documented Distribution
		Enteromorpha intestinalis (Linnaeus) Link	Frenchmans Head, Port-à-Choix, Okak Bay, Hebron Fjord, Hebron Harbour, Port Bmwell, Munro Harbour, McLelan Strait, False River Bay
		Enteromorpha marginata T. Agardh	False River Bay
		Enteromorpha micrococca Kützing	Newfoundland, southern Labrador, and common throughout more northerly collection stations
		Enteromorpha minima Nageli	Frenchmans Head, Okak Bay
		***Enteromorpha plumosa** Kützing	False River Bay
		Monostroma fuscum (Pastels et Ruprecht) Wittrock f. blyttii (Areschoug) Collins	Nutak Bay, Hebron Harbour, Eastern Harbour, Port Burwell, Fox Harbour, Nanook Pool, McLelan Strait, False River Bay, Koksoak River
		Monostroma grevillei (Thuret) Wittrock	Port Saunders
		Monostroma oxyspermum (Kützing) Doty	Port-à-Choix
		Monostroma pulchrum Farlow	Frenchmans Head
		Monostroma leptoderma Kjellman	Port Burwell, Port Harvey
		***Percursaria percursa** (C. Agardh) J. Agardh	False River Bay
		Ulva lactuca Linnaeu *v. rigida* (C. Agardh) Le Jolis	Port Burwell, Port Harvey
	Praslolaceae	*Prasiola crispa* (Lightfoot) Meneghini	Throughout the entire region, less common to the south.
	Cladophoraceae	***Chaetomorpha linum** (Müller) Kützing	Amity Bay, Hebron Harbour, Eastern Harbour
		Chaetomorpha melagonium (Weber et Mohr) Kützing	Okak Bay, Amity Bay, Hebron Harbour, Eastern Harbour, Nachvak Fjord, Port Burwell, Munro Harbour, Fox Harbour, Nanook Pool, False River Bay
		Cladophora glaucescens (Griffiths et Harvey) Harvey	Port Burwell, Koksoak River, Fort Chimo
		***Cladophora rudolphiana** (C. Agardh) Harvey	Port Burwell, Koksoak River
		Cladophora rupestris (Linnaeus) Kützing	Briggs Bay
		Rhizoclonium riparium (Roth) Harvey	Napartok Bay, Hebron Fjord, Hebron Harbour, Watchman Island, Eastern Harbour, Saglek Fjord, Port Burwell, Mission Cove, Koksoak River
		Spongomorpha arcta (Dillwyn) Kützing	Hebron Harbour, Saglek Fjord, Port Burwell, Munro Harbour, Fox Harbour, Nanook Pool, throughout entire region.
		Spongomorpha lanosa (Roth) Kützing	Hebron Harbour, Eastern Harbour, Port Burwell
		Urospora penicilliformis (Roth) Areschoug	Koksoak River
	Vaucheriaceae	***Vaucheria compacta** (Collins) Collins	False River Bay, Koksoak River, Fort Chimo
		***Vaucheria sphaerospora** Nordstedt	False River Bay, Koksoak River, Fort Chimo
		***Vaucheria submarina** Berk *sensu* De Wildeman	False River Bay, Koksoak River, Fort Chimo
Phaeophyceae (Brown algae)	Ectocarpaceae	*Pylaiella littoralis* (Linnaeus) Kjellman	Common at all stations throughout the region
		Ectocarpus confervoides (Roth) Le Jolis	Cooks Brook to Frenchmans Head, Okak Bay, Hebron Harbour, Saglek Fjord, False River Bay
		***Ectocarpus dasycarpus** Kuckuck	Port Burwell

Class	Family	Species	Documented Distribution
		***Ectocarpus fasciculatus* (Griffiths) Harvey	Port Burwell
		**Ectocarpus siliculosus* (Dillwyn) Lyngbye	Port Burwell, False River Bay, Koksoak River
		Ectocarpus tomentosoides Farlow	Infrequent, general distribution
		***Giffordia ovata* (Kjellman) Kylin	Port Burwell
		***Streblonema oligosporum* Stromfelt	Hebron Fjord, Hebron Harbour
		***Streblonema fasciculatum* Thuret	Hebron Harbour, Saglek Bay entrance
		Streblonema accidioides (Rosenv.) Foslie	Port Burwell, Munro Harbour
		***Streblonema stilophore* Crouan	Port Burwell
	Sphacelariaceae	**Chaetopteris plumosa* (Lyngbye) Kützing	Kai-Kai Inlet, Hebron Fjord, Hebron Harbour, Eastem Harbour, Kangalaksiorvik Fjord, Port Burwell, Munro Harbour, Fox Harbour, Nanook Pool
		**Halopteris scoparia* (Linnaeus) Savageau	Northern Newfoundland (north of Brigg Bay)
		**Sphacelaria radicans* (Dillwyn) C. Agardh	Hebron Harbour
		Sphacelaria arctica Greville	Common throughout the entire region
	Ralfsiaceae	***Ralfsia clavata* (Carmichael) Crouan *sensu* Farlow	Port Burwell
		**Ralfsia fungiformis* (Gunner) Setchell et Gardner	Collected at all stations north of Nain
		Ralfsia verrucosa (Areschoug) J. Agardh	Hebron Fjord, Hebron Harbour, Port Burwell, Nanook Pool
	Lithodermataceae	**Lithoderma extensum* (Crouan) Hamel	Hebron Fjord, Port Burwell, Munro Harbour, Fox Harbour
		**Sorapion kjellmanni* (Wille) Rosenvinge	Hebron Harbour, Port Burwell, mouth of False River Bay.
	Elachistaceae	**Elachistea fucicola* (Velley) Areschoug	Common throughout the entire region.
	Chordariaceae	***Leptonema fasciculatum* Reinke	Common at most sheltered stations
		***Eudesme virescens* (Carmichael) J. Agardh	Hebron Harbour, Saglek Fjord, False River Bay, Koksoak River
		Sphaerotrichia divaricata (C. Agardh) Kylin	Hebron Harbour, Nachvak Fjord
		Chordaria flagelliformis (Müller) C. Agardh	Common throughout the entire region
	Desmarestiaceae	*Desmarestia aculeata* (Linnaeus) Lamouroux	Common throughout the entire region
		Desmarestia viriclis (Müller) Lamouroux	Amity Harbour, False River Bay, Koksoak River
	Striariaciaceae	***Isthmoplea sphaerospora* (Carmichael) Kjellman	Saglek Fjord, Port Burwell, False River Bay, Koksoak River
		***Stictyosiphon tortilis* (Ruprecht) Reinke	Frenchmans Head, Reel Bay, Amity Harbour, Hebron Fjord, Hebron Harbour, Saglek Bay entrance, Eastern Harbour, Nachvak Fjord, Port Burwell, Munro Harbour, Fox Harbour, False River Bay, Koksoak River
	Puntarlarceae	***Delamarea attenuata* (Kjellman) Rosevinge	Hebron Harbour, Saglek Fjord
		**Litosiphon filiformis* (Reinke) Batters	Port Burwell, Port Harvey, McLelan Strait
		***Litosiphon pusillus* (Carmichael) Harvey	Hebron Harbour
		**Petalonia fascia* (0. F. Müller) Kuntze	Frenchmans Head, Port-à-Choix, Hebron Fjord, Hebron Harbour, Saglek Fjord, Eastern Harbour, Nachvak Fjord, Port Burwell, False River Bay, Koksoak River
		***Punctaria latifolia* Greville	Hebron Fjord

Class	Family	Species	Documented Distribution
		***Punctaria plantaginea* (Roth) Greville	Nachvak Fjord
		***Scytosiphon lomentaria* (Lyngbye) C. Agardh	Hebron Harbour, Eastern Harbour, Saglek Fjord, Port Burwell, Port Harvey, False River Bay, Koksoak River
	Dictyosiphonaceae	***Coilodesme bulligera* Strömfelt	Port Harvey
		Dictyosiphon foeniculaceus (Hudson) Greville	Nain, Kai-Kai Inlet, Hebron Fjord, Hebron Harbour, Eastern Harbour, Saglek Fjord, Nachvak Fjord, Kangalaksiorvik Fjord, Port Burwell, False River Bay, Koksoak River
	Laminariaceae	*Agarum cribrosum* (Mertens) Bory	Common throughout the entire region
		**Alaria grandifolia* J. Agardh	Common throughout the entire region
		**Chorda filum* (Linnaeus) Lamouroux	Nutak Bay, Hebron Fjord, Hebron Harbour, Saglek Fjord, Nachvak Fjord
		**Chorda tomentosa* Lyngbye	Frenchmans Head, Hebron Harbour, Saglck Fjord, False River Bay, Koksoak River
		**Laminaria cuneifolia* J. Agardh	False River Bay, Koksoak River
		**Laminaria groenlandica* Rosenvinge	Hebron Fjord, Hebron Harbour, Port Burwell, Fox Harbour, Nanook Pool, Port Harvey
		Laminaria longicruris De la Pylaie	Common throughout the entire region
		**Laminaria nigripes* J. Agardh	Red Bay, Hebron Fjord, Hebron Harbour, Watchman Island, Saglek Fjord, Port Burwell, Munro Harbour, Fox Harbour, Nanook Pool, Port Harvey, McLelan Strait, east coast of Ungava Bay, False River Bay, Koksoak River
		Laminaria saccharina (Linnaeus) Lamouroux	Red Bay, Amity Harbour, Hebron Fjord, Hebron Harbour, Port Burwell, Nanook Pool, False River Bay, Koksoak River
		**Laminaria solidungula* J. Agardh	Okak Bay, Nutak Bay, Napartok Bay, Hebron Fjord, Hebron Harbour, Watchman Island, Eastern Harbour, Port Burwell, Fox Harbour, Nanook Pool, McLelan Strait, False River Bay, Koksoak River, Fort Chimo
		Laminaria sp.	Throughout southeastern Ungava Bay
		Laminaria sp.	Hebron Harbour, drift from deep water
		Saccorhiza dermatodea (De la Pylaie) J. Agardh	Red Bay, Okak Bay, Nutak Bay, Hebron Fjord, Hebron Harbour, Cape Morhardt, Saglek Fjord, Port Burwell, Fox Harbour, Munro Harbour, Nanook Pool, Port Harvey
	Fucaceae	*Ascophyllum nodosum* (Linnaeus) Le Jolis	Brigg Bay, Okak Bay, Kai-Kai Inlet, Hebron Fjord, Port Burwell, Nanook Pool, east coast of Ungava Bay, False River
		**Fucus distichus* Linnaeus subsp. *distichus*	Common throughout the entire region
		**Fucus distichus* Linnaeus subsp. *anceps* (Harvey et Ward ex Carruthers) Powell, n. comb.	Near mouths of Koksoak and False rivers
		**Fucus distichus* Linnaeus subsp. *edentatus* (De la Pylaie) Powell, n. comb.	Red Bay, Saglek Bay
		Fucus distichus Linnaeus subsp. *evanescens* (C. Agardh) Powell, n. comb.	Common throughout the entire region.

Class	Family	Species	Documented Distribution
		Fucus vesiculosus Linnaeus	Common throughout the entire region
Rhodophyceae (Red algae)	Bangiaceae	*Bangia fuscopurpurea* (Dillwyn) Lyngbye	Frenchmans Head
		***Porphyra miniata* (Lyngbye) C. Agardh	Saglek Fjord, Kangalaksiorvik Fjord, McLelan Strait, Koksoak River
	Achrochaetiaceae	**Rhodochorton penicilliforme* (Kjellman) Rosenvinge	Port Burwell
		**Rhodochorton purpureum* (Lightfoot) Rosenvinge	Hebron Fjord, Hebron Harbour, Watchman Island, Cape Morhardt, Saglek Fjord, Eastern Harbour, Port Burwell, Nanook Pool, McLelland, Strait, False River Bay, Koksoak River
	Dumontiaceae	*Dilsea integra* (Kjellman) Rosenvinge	Nutak Bay, Amity Bay, Napartok Bay, Hebron Fjord, Hebron Harbour, Eastern Harbour, Port Burwell, Munro Harbour, Koksoak River
		**Dumontia incrassata* (0. F. Müller) Lamouroux	Frenchmans Head
	Rhizophyllidaceae	***Polyides caprinus* (Gunnerus) Papenfuss	Hebron Harbour
	Squamariaceae	*Hildenbranclia prototypus* Nardo	Common throughout the entire region
		***Peyssonnelia rosenvingii* Schmitz	Southern Labrador and northwestern Newfoundland
	Corallinaceae	***Lithothamnium lenormandi* (Areschoug) Foslie	Southern Labrador and northwestern Newfoundland
		Lithothamnium laeve (Strömfelt) Foslie	Northwestern Newfoundland
		Lithothamnium glaciale Kjellman	Common throughout the entire region
		Lithothamnium sp.	Southern Labrador and northwestern Newfoundland
		Corallina officinalis Linnaeus	Southern Labrador and northwestern Newfoundland
	Kallymieniaceae	*Euthora cristata* (Linnaeus ex Turner) J. Agardh	Red Bay, Amity Bay, Hebron Harbour, Saglek Fjord. Eastern Harbour, Port Burwell, Nanook Pool, Port Harvey
		**Kallymenia schmitzii* De Toni	Amity Bay, False River Bay, Koksoak River
	Choreocolacaceae	**Ceratocolax hartzii* Rosenvinge	Hebron Harbour, False River Bay, Koksoak River
		***Harveyella mirabilis* (Reinsch) Schmitz et Reinke	Port Burwell, False River Bay, Koksoak River
	Rhodophyllidaceae	*Rhodophyllis dichotoma (Lepeschkin) Gobi	Hebron Harbour, Saglek Fjord, Eastern Harbour. Port Burwell, Munro Harbour, Port Harvey, False River Bay
	Phyllophoraceae	*Ahnfeltia plicata* (Hudson) Fries	Cooks Brook to Frenchmans Head, Brigg Bay, Hebron Fjord. Hebron Harbour, Kangalaksiorvik Fjord, Port Burwell, Munro Harbour
		**Phyllophora brodiaei* (Turner). J. Agardh	Nutak Bay, Eastern Harbour, False River Bay
		Phyllophora interrupta (Greville) J. Agardh	Nutak Bay, Amity Bay, Hebron Fjord, Hebron Harbour, Eastern Harbour, False River Bay, Koksoak River
		**Phyllophora membranifolia* (Goodenough et Woodward) J. Agardh	Southern Labrador and northwestern Newfoundland
	Gigartinaceae	*Chondrus crispus* Stackhouse	Northern Newfoundland
	Rhodymeniaceae	*Halosaccion ramentaceum* (Linnaeus) J. Agardh	Common throughout the entire region
		Rhodymenia palmata lLinnaeus) Greville	Common throughout the entire region

Class	Family	Species	Documented Distribution
	Ceramiaceae	**Antithamnion boreale* (Gobi) Kjellman	Seen commonly at all stations north of Hebron
		Ceramium rubrum (Hudson) C. Agardh	Infrequent throughout the entire region
		Ceramium sp.	Hopedale, Amity Bay, Kai-Kai Inlet, Hebron Harbour, Saglek Fjord,Eastern Harbour
		***Ptilota plumosa* (Hudson) C. Agardh	Port Burwell, Munro Harbour
		Ptilota serrata Kutzing	Common throughout the entire region
		Trailliella intricata (J. Agardh) Batters	Frenchmans Head
		Membranoptera alata (Hudson) Stackhouse	Hebron Fjord, Hebron Harbour, Eastern Harbour, Port Burwell, Munro Harbour, Nanook Pool, Port Harvey, False River Bay, Koksoak River
		Membranoptera denticulata (Montagne) J. Agardh	False River Bay, Koksoak River
		**Pantoneura baerii* (Postels et Ruprecht) Kylin	False River Bay, Koksoak River
		Phycodrys rubens (Hudson) Batters	Red Bay, Nutak Bay, Amity Bay, Hebron Fjord, Hebron Harbour, Port Burwell, Munro Harbour, Nanook Pool, False River Bay, Koksoak River
	Rhodomelaceae	*Odonthalia dentata* (Linnaeus) Lyngbye	Nutak Bay, Hebron Harbour, Port Burwell, Munro Harbour, Fox Harbour, Nanook Pool, False River Bay, Koksoak River
		**Polysiphonia arctica* J. Agardh	Amity Bay, Hebron Fjord, Hebron Harbour, Port Burwell, Munro Harbour, Nanook Pool, False River Bay, Koksoak River
		**Polysiphonia urceolata* (Lightfoot) Greville	Port-à-Choix, Hebron Harbour, Eastem Harbour, Port Burwell, Nanook Pool, False River Bay
		Rhodomela confervoides (Hudson) Silva	Common throughout the entire region
		***Rhodomela lycopodioides* (Linnaeus) C. Agardh f. *flagellaris* Kjellman	Kai-Kai Inlet, Hebron Harbour, Port Burwell, Munro Harbour, Nanook Pool, False River Bay, Koksoak River

Table C-2: Dominant macroalgae by habitat identified by Wilce (1959) along the Labrador Coast. Taxonomy follows Wilce (1959), but it should be noted that taxonomic designation of many algae has changed significantly since this report was published (Lane et al. 2006). Identification of the kelps in particular is complicated by their extreme polymorphism that appears to be in part habitat dependant (Wilce 1959). Orders reported are abbreviated as M- Myxophycea, X-Xanthophycea, C-Chlorophycea, P-Phaeophyceae, R-Rhodophyceae.

Habitat	Zone	Most Abundant Species	Species Per Order Reported
Mud flats	Littoral	*Vaucheria sphaerospora*	M- 2 X- 3 C- 12 P- 16 R- 3
	Boulder barricade	*Fucus vesiculosus* *Fucus distichus* *Ascophyllum nodosum* *Ralfsia fungiformis*	M- 0 X- 0 C- 0 P- 4 R- 2
	Sub-littoral Sampled as drift	*Agarum cribosum* *Laminaria sp.* *Alaria esculenta*	M- 0 X- 0 C- 4 P- 18 R- 21
Protected Shallows	Littoral	*Calothrix scopulorum* *Ascophyllum nodosum* *Petalonia fascia* *Enteromorpha intestinalis* *Pylaiella littoralis* *Chorda tomentosa* *Fucus vesiculosus* *Chordaria flagelliiformis* *Elachistea fucicola*	M- 1 X- 0 C- 13 P- 16 R- 4
	Sub-littoral	Mostly soft substrates with few algae	
Moderately exposed coasts	-	*Calothrix scopulorum* *Ulothrix flacca* *Monostroma fuscum* *Prasiola crispa* *Pylaiella littoralis* *Desmarestia aculeata* *Petalonia fascia* *Laminaria longicruris* *Laminaria nigripes* *Laminaria saccharina* *Fucus distichus* *Halosaccion ramentaceum* *Rhodymenia palmata* *Ptilota serrata* *Rhodomela confervoides*	M- 4 X- 0 C- 19 P- 33 R- 30
Fully exposed coasts	-	*Calothrix scopulorum* *Prasiola crispa* *Pylaiella littoralis* *Ralfsia fungifoormis* *Chordaria flagelliformis* *Petalonia fascia* *Laminaria groenlandica* *Laminaria nigripes* *Fucus distichus* *Hildenbrandia prototypus* *Liththamnion sp. Halosaccion ramentaceum*	M- 1 X- 0 C- 10 P- 19 R- 20

Habitat	Zone	Most Abundant Species	Species Per Order Reported
		Rhodymenia palmata *Rhodomela lycopodioides*	
Tide pools	-	*Calothrix scopulorum* *Enteromorpha intestinalis* *Monostroma fuscum* *Spongomorpha arcta* *Pylaiella littoralis* *Ralfsia verrucosa* *Chordaria flagelliformis* *Alaria grandifolia* *Laminaria saccharina* *Laminaria nigripes* *Fucus distichus* *Hildenbrandia prototypus* *Ahnfeltia plicata* *Halosaccion ramentaceum* *Rhodomela confervoides*	M- 1 X- 0 C- 13 P- 22 R- 23

Table C-3: Species collected on the central Labrador coast (Hooper and Whittick, 1984). Taxonomic authorities according to South (1976). A + indicates a new record for the Labrador coast.

Chlorophyta	Phaeophyta	Rhodophyta
Acrochaete parasitica +	*Agarum cribrosum*	*Ahnfeltia plicata*
A. repens +	*Alaria esculenta*	*Antithamnion boreale*
Blidingia minima	*Ascophyllum nodosum*	*Antithamnionella floccosa*
Bolbocoleon piliferum +	*Chorda filum*	*Audouinella alariae +*
Capsosiphon fulvescens	*Chorda tomentosa*	*A. membranacea +*
Chaetomorpha capillaris	*Chordaria flagelliformis*	*A. microscopica +*
C. linum	*Cladosiphon zosterae*	*A. purpurea +*
C. melagonium	*Coilodesme bulligera*	*A. spetsbergensis +*
Chlorochytrium sp.	*Delamarea attenuata*	*Bangia atropurpurea*
Codiolum pusillum	*Desmarestia aculeata*	*Callophyllis cristata*
Ectochaete wittrockii +	*D. viridis*	*Ceramium rubrum*
Enteromorpha intestinalis	*Dictyosiphon foeniculaceus*	*Ceratocolax hartzii*
E. linza +	*D. macounii +*	*Clathromorphum circumscriptum*
E. prolifera	*Ectocarpus fasciculatus*	*C. compactum*
Entocladia flustrae	*£ siliculosus*	*Corallina officinalis*
E. viridis +	*Elachista fucicola*	*Cystoclonium purpureum +*
Eugomontia sacculata +	*E. lubrlca*	*Devaleraea ramentaceum*
Gomontia polyrhiza	*Entonema aecidioides*	*Goniotrichum alsidii +*
Monostroma grevillei	*E. alariae*	*Halosacciocolax kiellmanii*
M. undulatum +	*Eudesme virescens*	*Harveyella mirabilis*
Ostreobium quekettii	*Fucus edentatus*	*Hildenbrandia rubra*
f'ercursaria percursa	*F. evanescens*	*Kvaleya epilaeve*
Prasiola crispa	*F. spiralis +*	*Leptophytum foecundum*
P. stipitata +	*F. vesiculosus*	*L. laeve*
Pringshelimiella scutata	*Giffordia ovata*	*Lithothamnium glaciale*
Pseudendoclonium submarinum +	*Haptospora globosa*	*L. lemoineae*
	Isthmoplea sphaerophora	*L tophiforme*
Pseudopringsheima confluens +	*I.aminaria digitata*	*Membranoptera alata*
P. fucicola +	*L longicruris*	*Neodilsea integra*
Rhizoclonium riparium	*L saccharina*	*Odonthalia dentata*

Chlorophyta	Phaeophyta	Rhodophyta
Rosenvingiella polyrhiza + *Spongomorpha arcta* *S. aeruginosa* *S. spinescens +* *Ulothrix flacca* *Ulva tactuca* *Ulvaria obscura* *Urospora penicilliformis* *U. wormskioldli +*	*L solidungula* *Laminariocolax tomentosoides* *Leptonematella fasciculata* *Lithoderma fatiscens* *Litosiphon filiformis* *Melanosiphon intestinalis +* *Microspongium globosum +* *Papenfussiella callitricha +* *Petalonia fascia* *P. zosterifolia +* *Petroderma maculiforme* *Pilayella littoralis* *Porterinema fluviatilis +* *Pseudolithoderma extensum* *Punctaria latifolia* *P. plantaginea* *Ralfsia clavata* *R. fungiformis* *R. verrucosa* *Saccorhiza dermatodea* *Scytosiphon tomentaria* *Sorapion kjellmanii* *Sphacelaria arctica* *S. plumosa* *S. radicans* *Stictyosiphon tortilis*	*Palmaria palmata* *Pantoneura baerii* *Peyssonnelia rosenvingii* *Phycodrys rubens* *Phyllophora truncata* *Phymatolithon laevigatum +* *Polyides rotundus* *Polysiphonia arctics* *P. flexicaulis* *P. urceotata* *Porphyra linearis* *P. miniata* *P. umbilicalis* *Ptilota serrata* *Rhodomela confervoides* *Rhodophyllis dichotoma* *Tumerella pennyi*

Table C-4: Rhodolith/maerl-forming species of coralline algae from Hernandez-Kantun et al. 2017.

Leptophytum foecundum (Kjellman) Adey
Lithothamnion glaciale (Kjellman)
Lithothamnion tophiforme (Esper) Unger

Table C-5: Labrador pecies sampled for genetic analysis by Bringloe and Saunders (2018). Genetic analyses indicate that the taxanomic designation of some species is still uncertain.

Battersia arctica	*Planosiphon zosterifolius*	*Rhodomela sp.*
Battersia racemose	*Palaiella washingtoniensis*	*Saccharina latissimi*
Chaetopterus plumose	*Scytosiphon canaliclatus*	*Coccotylus truncates*
Chorda sp.	*Tilopteridalean sp.*	*Leptosiphonia flexicaulis*
Chordaria flagelliformis	*Agarum clathratum*	*Peysonnelia rosenvingei*
Desmarestia sp.	*Ahnfeltia plicata*	*Phycodris fimbriata*
Dictyosiphon foeniculaceus	*Ceramium virgatum*	*Polyostea arctica*
Eudesme virescens	*Dilsea socialis/carnosa*	*Ptilota serrata*
Petalonia filiformis	*Euthora cristata*	*Scagelia pylaisa*
	Rhodomela lycopodiodes	

Table C-6: Species listed in the "Marine Algae of the Northeastern Coast of North America" with Labrador collection sites (Taylor 1957). Note that only species that included specific mention of specimens collected from Labrador are included in this list.

Cholorophycea	Phaeophyceae	Rhodophyceae
Monostroma fuscum (Postels et Ruprecht) Whittrock f. blytii (Areschoug) Collins Chaetomorpha melagonum (Weber et Mohr) Kützing Rhizoclonium riparium (Roth) Harvey Cladophora glaucescens (Griffiths et Harvey) Harvey Spongomorpha arcta (Dillwyn) Kützing	*Pylaiella littoralis* (Linnaeus) Kjellman *Chaetopteris plumosa* (Lyngbye) Kützing *Ralfsia fungiformis* (Gunner) Setchel et Gardner *Eudesme virescens* (Carmichael) J. Agardh *Spaerotrichia divaricata* (C. Agardh) Kylin *Chordaria flagelliformis* (Müller) C. Agardh *Desmarestia viridis* (Müller) Lamoureux *Desmarestia aculeata* (Linnaeus) Lamoureux *Isthmoplea sphaerophora* (Carmichael) Kjellman *Stictyosiphon tortilis* (Ruprecht) Reinke *Punctaria plantaginea* (Roth) Greville *Scytosiphon lomentaria* (Lyngbye) C. Agardh *Dictyosiphon foeniculaceus* (Hudson) Greville *Chorda tomentosa* Lyngbye *Chorda filum* (LInnaeus) Lamoureux *Sacchorhiza dermatodea* (De la Pylaie) J. Agardh *Laminaria agardhii* Kjellman *Laminaria saccharina* (Linnaeus) Lamoureux *Laminaria groenlandica* Rosenvinge *Laminaria solidungula* J. Agardh *Laminaria nigripes* (J. Agardh) Rosenvinge *Fucus filiformis* Grelin *Fucus evanescens* C. Agardh *Ascophyllum nodosum* (Linnaeus) Le Jolis	*Porphyra miniata* (Lyngbye) C. Agardh *Dilsea integra* (Kjellman) Rosenvinge *Polyides caprinus* (Gunnerus) Papenfuss *Lithothamnion* glaciale Kjellman *Euthora cristata* (Linnaeus ex Turner) J. Agardh *Kallymenia schmitzii* De Toni *Turnerella pennyi* (Harvey) Schmitz *Rhodophyllis dichotoma* (Lepesckin) Gobi *Antithamnion americanum* (Harvey) Farlow in Kjellman *Antithamnion pylaisaei* (Montagne) Kjellman *Ptilota serrata* Kützing *Pantoneura baerii* (Postels et Ruprecht) Kylin *Membranoptera alata* (Hudson) Stackhouse *Membranoptera denticulata* (Montagne) Kylin *Phycodris rubens* (Hudson) Batters *Polysiphonia arctica* J. Agardh *Rhodomela lycopodiodes* (Linnaeus) J. Agardh *Rhodomela confervoides* (Hudson) Silva *Odonthalia dentata* (Linnaeus) Lyngbye

Records for macroalgal specimens collected along the Labrador coastline on September 7-12, 2014 are described in Tables C-7.1 through C-7.3. Species identifications were facilitated using several genetic markers, including the 5' end of the cytochrome c oxidase subunit I gene (COI-5P), full or partial reads of the ribulose-1 5-biphosphate carboxylase gene (rbcL-3P and rbcL), the Internal Transcribed Spacer (ITS), and the elongation factor tufA. GenBank accession numbers are provided for published sequences. BOLD ID stands for Barcode of Life Data System. Note that taxonomic work is ongoing, and that informal names have been applied in some cases. This work was part of a larger project assessing post glacial history in Arctic marine macroalgae (Bringloe and Saunders 2018), conducted by The Saunders Lab at the University of New Brunswick.

Table C-7.1: Ulvophyceae (green algae) collected along the Labrador coast in 2014.

Species	GenBank	BOLD	tufA	Lat, Lon	Habitat	Location
Monostroma sp.	GWS039298	ULVA1634-14	MH308605	60.23386, -64.34144	Subtidal (4 m) on rock	Duck Islands, Torngat
Acrosiphonia sonderi	GWS039361	ULVA1627-14	MH308590	59.29849, -63.52443	Subtidal (3 m) on rock	Evans Bight, Torngat
	GWS039362	ULVA1628-14	-	59.29849, -63.52443		
Ulva prolifera	GWS039308	ULVA1635-14	MH308492	60.23386, -64.34144	Upper intertidal pool on rock	Duck Islands, Torngat
	GWS039309	ULVA1636-14	MH308554	60.23386, -64.34144	Mid intertidal pool on rock	
Ulvaria obscura	GWS039347	ULVA1637-14	MH308575	59.42878, -63.7148	Subtidal (3 m) on rock	Hogg Island, Torngat

Table C-7.2: Phaeophyceae (brown algae) collected along the Labrador coast in 2014.

Species	GenBank	BOLD	COI-5P	Lat, Lon	Habitat	Location
Desmarestia sp.	GWS039330	MACRO3713-14	MH308831	59.42878, -63.7148	Subtidal (5 m) on rock	Hogg Island, Torngat
	GWS040355	MACRO3715-14	MH309760	55.08429, -59.16566	Subtidal (12 m) on rock	Makkovik Harbour
Acinetosporaceae sp.	GWS039332	MACRO3738-14	MH309283	59.42878, -63.7148	Subtidal (5 m) on alga	Hogg Island, Torngat
Pylaiella washingtoniensis	GWS039280	MACRO3781-14	MH309954	60.23386, -64.34144	Subtidal (4 m) on Fucus	Duck Islands, Torngat
	GWS039305	MACRO3783-14	-	60.23386, -64.34144	Drift on Fucus	
	GWS039311	MACRO3719-14	-	60.23386, -64.34144	Mid intertidal pool on rock	

Species	GenBank	BOLD	COI-5P	Lat, Lon	Habitat	Location
	GWS039387	MACRO3784-14	MH309519	56.76594, -61.31059	Subtidal (2 m) on Rhodomela (GWS039386)	Black Harbour
	GWS040267	MACRO3724-14	MH309317	59.29849, -63.52443	Mid intertidal on rock	Evans Bight, Torngat
	GWS040269	MACRO3725-14	MH309293	59.29849, -63.52443	Mid intertidal on rock	
	GWS040276	MACRO3726-14	MH308785	59.29849, -63.52443	Upper intertidal on rock	
	GWS040306	MACRO3740-14	-	56.76594, -61.31059	Subtidal (2 m) on Fucus	Black Harbour
	GWS040369	MACRO3729-14	-	55.10165, -59.18001	Upper intertidal on Fucus (GWS040366)	Makkovik Lighthouse
	GWS040381	MACRO3733-14	-	55.10165, -59.18001	Mid intertidal on Fucus (GWS040380)	
	GWS040382	MACRO3734-14	MH309639	55.10165, -59.18001		
	GWS040383	MACRO3735-14	MH308740	55.10165, -59.18001		
	GWS040384	MACRO3736-14	MH309152	55.10165, -59.18001		
Chordaria chordaeformis	GWS040252	MACRO3744-14	MH309001	59.42878, -63.7148	Subtidal (3 m) on rock	Hogg Island, Torngat
	GWS040331	MACRO3745-14		56.76594, -61.31059	Subtidal (2 m) on rock	Black Harbour
Chordaria flagelliformis	GWS039284	MACRO3746-14	MH309291	60.23386, -64.34144	Subtidal (4 m) on rock	Duck Islands, Torngat
	GWS039285	MACRO3747-14	MH309490	60.23386, -64.34144		
	GWS039293	MACRO3748-14	MH309392	60.23386, -64.34144		
	GWS039294	MACRO3749-14	MH309998	60.23386, -64.34144		
	GWS039297	MACRO3750-14	MH308843	60.23386, -64.34144		
	GWS039388	MACRO3751-14	MH309717	56.76594, -61.31059	Subtidal (2 m) on rock	Black Harbour
	GWS039390	MACRO3752-14	MH308811	56.76594, -61.31059		
	GWS040265	MACRO3754-14	MH309666	59.29849, -63.52443	Mid intertidal on rock	Evans Bight, Torngat
	GWS040417	MACRO3755-14	MH308739	55.10165, -59.18001	Low intertidal on rock	Makkovik Lighthouse
	GWS040421	MACRO3757-14	MH308747	55.10165, -59.18001	Low intertidal on rock	
	GWS040319	MACRO3839-14	MH309600	56.76594, -61.31059	Subtidal (2 m) on cobble	
Eudesme virescens	GWS039445	MACRO3758-14	MH309437	55.10165, -59.18001	Subtidal (6 m) on shells	Makkovik Lighthouse
	GWS040314	MACRO3834-14	MH309548	56.76594, -61.31059	Subtidal (2 m) on cobble	Black Harbour
	GWS040315	MACRO3835-14	MH308883	56.76594, -61.31059		
	GWS040323	MACRO3843-14	MH309566	56.76594, -61.31059		
	GWS040329	MACRO3759-14	MH309768	56.76594, -61.31059		
	GWS040330	MACRO3760-14	MH308798	56.76594, -61.31059		

Species	GenBank	BOLD	COI-5P	Lat, Lon	Habitat	Location
Halothrix lumbricalis	GWS039291	MACRO3796-14	MH308980	60.23386, -64.34144	Subtidal (4 m) on Devaleraea	Duck Islands, Torngat
	GWS039313	MACRO3797-14	MH309433	59.42878, -63.7148	Subtidal (5 m) on Devaleraea	Hogg Island, Torngat
Heterosaundersella sp.	GWS040333	MACRO3768-14	MH309329	56.76594, -61.31059	Subtidal (2 m) on Chordaria	Black Harbour
Delamarea sp.	GWS040470	MACRO3883-14	-	55.08414, -59.17248	Lower mid intertidal on rock	Makkovik Wharf Beach
	GWS040471	MACRO3884-14	-	55.08414, -59.17248		
Dictyosiphon foeniculaceus	GWS039389	MACRO3761-14	MH309219	56.76594, -61.31059	Subtidal (2 m) on Chordaria	Black Harbour
	GWS039391	MACRO3762-14	MH309613	56.76594, -61.31059		
	GWS039411	MACRO3763-14	MH309798	55.10165, -59.18001	Low intertidal on Chordaria	Makkovik Lighthouse
	GWS040393	MACRO3769-14		55.10165, -59.18001		
	GWS040414	MACRO3770-14	MH309895	55.10165, -59.18001	Low intertidal on rock	
	GWS040415	MACRO3771-14	-	55.10165, -59.18001		
	GWS040418	MACRO3773-14	-	55.10165, -59.18001	Low intertidal on Chordaria	
	GWS040420	MACRO3775-14	-	55.10165, -59.18001	Low intertidal on rock	
	GWS040452	MACRO3777-14	MH309130	55.08414, -59.17248	Low intertidal on Scytosiphon	Makkovik Wharf Beach
	GWS040454	MACRO3778-14	MH309989	55.08414, -59.17248	Low intertidal on rock	
	GWS040463	MACRO3877-14	MH308741	55.08414, -59.17248	Low intertidal on Fucus	
	GWS040482	MACRO3756-14	MH309008	55.08414, -59.17248	Drift	
Dictyosiphon sp.	GWS040484	MACRO3779-14	-	55.08414, -59.17248	Lower mid intertidal on Scytosiphon	Makkovik Wharf Beach
Ectocarpus sp.	GWS039299	MACRO3782-14	MH309234	60.23386, -64.34144	Subtidal (4 m) on *Saccharina latissima*	Duck Islands, Torngat
Ectocarpus sp. (1siliculosus)	GWS039435	MACRO3720-14	-	55.10165, -59.18001	Subtidal (6 m) on rock	Makkovik Lighthouse
	GWS039440	MACRO3721-14	-	55.10165, -59.18001		
	GWS039447	MACRO3722-14	-	55.10165, -59.18001	Subtidal (6 m) on algae	
	GWS040404	MACRO3785-14	-	55.10165, -59.18001	Low intertidal on Chorda	
	GWS040411	MACRO3786-14	-	55.10165, -59.18001		
	GWS040413	MACRO3737-14	-	55.10165, -59.18001		
Ectocarpus sp. (4GWS)	GWS039448	MACRO3723-14	-	55.10165, -59.18001	Subtidal (6 m) on Agarum	Makkovik Lighthouse
	GWS040372	MACRO3730-14	-	55.10165, -59.18001	Mid intertidal on Fucus	
Elachista fucicola	GWS040363	MACRO3787-14	-	55.10165, -59.18001	Upper intertidal on Fucus	Makkovik Lighthouse
	GWS040365	MACRO3788-14	-	55.10165, -59.18001		

Species	GenBank	BOLD	COI-5P	Lat, Lon	Habitat	Location
	GWS040373	MACRO3789-14	-	55.10165, -59.18001	Mid intertidal on Fucus	
	GWS040375	MACRO3790-14	-	55.10165, -59.18001		
	GWS040386	MACRO3791-14	-	55.10165, -59.18001	Upper intertidal on Fucus	
	GWS040387	MACRO3792-14	-	55.10165, -59.18001		
	GWS040390	MACRO3793-14	-	55.10165, -59.18001		
	GWS040392	MACRO3794-14	-	55.10165, -59.18001		
	GWS040464	MACRO3795-14	-	55.08414, -59.17248	Low intertidal on rock	
Punctaria sp. (2GWS)	GWS040254	MACRO3799-14	MH308812	59.42878, -63.7148	Subtidal (3 m) on rock	Hogg Island, Torngat
Petalonia fascia	GWS040251	MACRO3810-14	MH309285	59.42878, -63.7148	Subtidal (3 m) on rock	Hogg Island, Torngat
	GWS040264	MACRO3811-14	MH309962	59.29849, -63.52443	Mid intertidal on cobble/rock	Evans Bight, Torngat
	GWS040268	MACRO3812-14	MH309521	59.29849, -63.52443		
	GWS040270	MACRO3802-14	-	59.29849, -63.52443		
	GWS040277	MACRO3813-14	MH310041	59.29849, -63.52443	Upper intertidal on rock	
	GWS040278	MACRO3814-14	MH309345	59.29849, -63.52443		
	GWS040279	MACRO3815-14	MH309267	59.29849, -63.52443		
	GWS040320	MACRO3840-14	MH309420	56.76594, -61.31059	Subtidal (2 m) on cobble	Black Harbour
	GWS040324	MACRO3844-14	MH309181	56.76594, -61.31059		
	GWS040326	MACRO3846-14	MH309896	56.76594, -61.31059		
Petalonia filiformis	GWS040245	MACRO3804-14	MH309765	59.42878, -63.7148	Subtidal (3 m) on rock	Hogg Island, Torngat
	GWS040246	MACRO3805-14	MH309150	59.42878, -63.7148		
	GWS040247	MACRO3806-14	MH308913	59.42878, -63.7148		
	GWS040248	MACRO3807-14	MH309143	59.42878, -63.7148		
	GWS040249	MACRO3808-14	MH309587	59.42878, -63.7148		
	GWS040250	MACRO3809-14	MH309491	59.42878, -63.7148		
	GWS040308	MACRO3828-14	MH309809	56.76594, -61.31059	Subtidal (2 m) on cobble	Black Harbour
	GWS040309	MACRO3829-14	MH309456	56.76594, -61.31059		
	GWS040310	MACRO3830-14	MH309605	56.76594, -61.31059		
	GWS040311	MACRO3831-14	MH309155	56.76594, -61.31059		
	GWS040312	MACRO3832-14	MH308876	56.76594, -61.31059		
	GWS040313	MACRO3833-14	MH309446	56.76594, -61.31059		
	GWS040316	MACRO3836-14	MH309091	56.76594, -61.31059		
	GWS040317	MACRO3837-14	-	56.76594, -61.31059		
Petalonia filiformis	GWS040318	MACRO3838-14	MH309339	56.76594, -61.31059	Subtidal (2 m) on cobble	Black Harbour
	GWS040321	MACRO3841-14	MH309688	56.76594, -61.31059		
	GWS040325	MACRO3845-14	MH310004	56.76594, -61.31059		

Species	GenBank	BOLD	COI-5P	Lat, Lon	Habitat	Location
	GWS040327	MACRO3847-14	MH308743	56.76594, -61.31059		
	GWS040395	MACRO3848-14	MH308997	55.10165, -59.18001	Low intertidal on rock	Makkovik Lighthouse
	GWS040396	MACRO3849-14	MH309240	55.10165, -59.18001		
	GWS040397	MACRO3850-14	MH309166	55.10165, -59.18001		
	GWS040401	MACRO3854-14	MH309948	55.10165, -59.18001		
	GWS040405	MACRO3856-14	MH308735	55.10165, -59.18001		
	GWS040446	MACRO3863-14	MH309439	55.08414, -59.17248	Low intertidal on rock	Makkovik Wharf Beach
	GWS040448	MACRO3865-14	MH308907	55.08414, -59.17248		
	GWS040449	MACRO3866-14	MH309635	55.08414, -59.17248		
	GWS040455	MACRO3869-14	MH309368	55.08414, -59.17248		
	GWS040456	MACRO3870-14	MH309263	55.08414, -59.17248		
	GWS040457	MACRO3871-14	MH308845	55.08414, -59.17248		
	GWS040458	MACRO3872-14	MH309825	55.08414, -59.17248		
Petalonia filiformis	GWS040459	MACRO3873-14	MH309189	55.08414, -59.17248	Lower-mid intertidal on rock	Makkovik Wharf Beach
	GWS040460	MACRO3874-14	MH309907	55.08414, -59.17248		
	GWS040461	MACRO3875-14	MH309274	55.08414, -59.17248		
	GWS040462	MACRO3876-14	MH309105	55.08414, -59.17248		
	GWS040468	MACRO3881-14	MH309824	55.08414, -59.17248		
	GWS040472	MACRO3885-14	MH309000	55.08414, -59.17248		
Planosiphon zosterifolius	GWS040263	MACRO3824-14	-	59.29849, -63.52443	Mid intertidal on cobble	Evans Bight, Torngat
	GWS040280	MACRO3827-14	MH308896	59.29849, -63.52443	Upper intertidal on rock	
	GWS040400	MACRO3853-14	MH309192	55.10165, -59.18001	Low intertidal on rock	Makkovik Lighthouse
	GWS040402	MACRO3855-14	MH309096	55.10165, -59.18001		
	GWS040465	MACRO3878-14	MH309559	55.08414, -59.17248	Lower mid intertidal on rock	Makkovik Wharf Beach
	GWS040466	MACRO3879-14	MH309174	55.08414, -59.17248		
	GWS040467	MACRO3880-14	MH309466	55.08414, -59.17248		
Scytosiphon canaliculatus	GWS040275	MACRO3826-14	MH309284	59.29849, -63.52443	Upper intertidal on rock	Evans Bight, Torngat
	GWS040447	MACRO3864-14	MH309966	55.08414, -59.17248	Low intertidal on rock	Makkovik Wharf Beach
	GWS040473	MACRO3886-14	MH309915	55.08414, -59.17248	Lower mid intertidal on rock	
	GWS040474	MACRO3887-14	MH309806	55.08414, -59.17248		
	GWS040475	MACRO3888-14	-	55.08414, -59.17248		
Scytosiphon canaliculatus	GWS040476	MACRO3889-14	MH309371	55.08414, -59.17248	Lower mid intertidal on rock	Makkovik Wharf Beach
	GWS040478	MACRO3891-14	-	55.08414, -59.17248		
	GWS040479	MACRO3892-14	MH308890	55.08414, -59.17248		
Scytosiphon sp. (GroupJ)	GWS040322	MACRO3842-14	-	56.76594, -61.31059	Subtidal (2 m) on cobble	Black Harbour

Species	GenBank	BOLD	COI-5P	Lat, Lon	Habitat	Location
Ascophyllum nodosum	GWS039304	MACRO3894-14	MH309506	60.23386, -64.34144	Drift	Duck Islands, Torngat
Fucus distichus	GWS040272	MACRO3898-14	-	59.29849, -63.52443	Mid intertidal on rock	Evans Bight, Torngat
	GWS040360	MACRO3899-14	-	55.10165, -59.18001	Mid intertidal on rock	Makkovik Lighthouse
	GWS040366	MACRO3909-14	-	55.10165, -59.18001	Upper intertidal on rock	
	GWS040370	MACRO3901-14	-	55.10165, -59.18001	Mid intertidal on rock	
	GWS040371	MACRO3902-14	-	55.10165, -59.18001		
	GWS040374	MACRO3903-14	-	55.10165, -59.18001		
	GWS040380	MACRO3906-14	-	55.10165, -59.18001		
Fucus spiralis	GWS040389	MACRO3912-14	-	55.10165, -59.18001	Upper intertidal on rock	Makkovik Lighthouse
Fucus vesiculosus	GWS040361	MACRO3900-14	-	55.10165, -59.18001	Mid intertidal on rock	Makkovik Lighthouse
	GWS040362	MACRO3907-14	-	55.10165, -59.18001	Upper intertidal on rock	
	GWS040364	MACRO3908-14	-	55.10165, -59.18001		
	GWS040385	MACRO3910-14	-	55.10165, -59.18001		
	GWS040388	MACRO3911-14	-	55.10165, -59.18001		
	GWS040391	MACRO3913-14	-	55.10165, -59.18001		
	GWS040485	MACRO3914-14	-	55.08414, -59.17248	Lower mid intertidal on rock	Makkovik Wharf Beach
Petroderma sp. (1Arc)	GWS040486	MACRO3953-14	-	55.08414, -59.17248	Lower mid intertidal on cobble	Makkovik Wharf Beach
Agarum clathratum	GWS039257	MACRO3929-14	MH308782	60.23386, -64.34144	Subtidal (8 m) on rock	Duck Islands, Torngat
	GWS039404	MACRO3930-14	MH309734	55.08429, -59.16566	Subtidal (12 m) on rock	Makkovik Harbour
	GWS040357	MACRO3932-14	MH308773	55.10165, -59.18001	Subtidal (6 m) on rock	Makkovik Lighthouse
Alaria esculenta	GWS039275	MACRO3916-14	KY572326	60.23386, -64.34144	Subtidal (4 m) on rock	Duck Islands, Torngat
	GWS039286	MACRO3917-14	KY572198	60.23386, -64.34144		
	GWS040256	MACRO3920-14	KY572403	59.29849, -63.52443	Subtidal (3 m) on rock	Evans Bight, Torngat
Saccharina latissima	GWS040244	MACRO3943-14	KY572575	60.23386, -64.34144	Subtidal (8 m) on rock	Duck Islands, Torngat
	GWS040255	MACRO3944-14	KY572765	59.42878, -63.7148	Subtidal (5 m) on rock	Hogg Island, Torngat
	GWS040260	MACRO3945-14	KY572669	59.29849, -63.52443	Subtidal (6 m) on rock	Evans Bight, Torngat

Species	GenBank	BOLD	COI-5P	Lat, Lon	Habitat	Location
	GWS040307	MACRO3946-14	KY572144	56.76594, -61.31059	Drift	Black Harbour
Saccharina nigripes	GWS039258	MACRO3936-14	MH309117	60.23386, -64.34144	Subtidal (8 m) on rock	Duck Islands, Torngat
	GWS039276	MACRO3937-14	MH310020	60.23386, -64.34144	Subtidal (4 m) on rock	
	GWS039306	MACRO3933-14	MH309593	60.23386, -64.34144	Drift	
	GWS039343	MACRO3942-14	MH309630	59.42878, -63.7148	Subtidal (5 m) on rock	Hogg Island, Torngat
	GWS040257	MACRO3939-14	MH309211	59.29849, -63.52443	Subtidal (3 m) on rock	Evans Bight, Torngat
	GWS040259	MACRO3940-14	MH309500	59.29849, -63.52443	Subtidal (6 m) on rock	
Chorda sp. (1filum)	GWS039348	MACRO3924-14	MH309102	59.42878, -63.7148	Subtidal (3 m) on rock	Hogg Island, Torngat
	GWS039351	MACRO3925-14	MH309713	59.42878, -63.7148		
	GWS040406	MACRO3921-14	MH309350	55.10165, -59.18001	Low intertidal on rock	Makkovik Lighthouse
	GWS040407	MACRO3922-14	MH308783	55.10165, -59.18001		
Laminaria solidungula	GWS039273	MACRO3934-14	MH309367	60.23386, -64.34144	Subtidal (8 m) on rock	Duck Islands, Torngat
	GWS040258	MACRO3935-14	MH310019	59.29849, -63.52443	Subtidal (6 m) on rock	Evans Bight, Torngat
Battersia artica	GWS040437	MACRO3959-14	MH309733	55.08414, -59.17248	Low intertidal on rock	Makkovik Wharf Beach
	GWS040435	MACRO3958-14	MH309784	55.08414, -59.17248		
Chaetopteris plumosa	GWS039385	MACRO3956-14	MH308959	56.76594, -61.31059	Subtidal (2 m) on rock	Black Harbour
	GWS039395	MACRO3957-14	MH309140	56.76594, -61.31059		
Tilopteridalean sp. (1GWS)	GWS040242	ABMMC20434-14	MH309646	60.23386, -64.34144	Subtidal (8 m) on cobble	Duck Islands, Torngat
	GWS040243	ABMMC20435-14	MH309383	60.23386, -64.34144		
	GWS040304	ABMMC20466-14	-	59.42878, -63.7148		Hogg Island, Torngat
	GWS040429	ABMMC20481-14	MH309129	55.10165, -59.18001	Subtidal (6 m) on rock	Makkovik Lighthouse

Table C-7.3: Rhodophyceae (red algae) collected along the Labrador coast in 2014.

Species	No.	BOLD	COI-5P	Lat, Lon	Habitat	Location
Pyropia njordii	GWS039412	ABMMC20218-14	-	55.10165, -59.18001	Low intertidal on rock	Makkovik Lighthouse
	GWS039413	ABMMC20219-14	-	55.10165, -59.18001		
	GWS039414	ABMMC20220-14	-	55.10165, -59.18001		
	GWS039415	ABMMC20221-14	-	55.10165, -59.18001		

Species	No.	BOLD	COI-5P	Lat, Lon	Habitat	Location
	GWS039416	ABMMC20222-14	-	55.10165, -59.18001		
Wildemania miniata	GWS039274	ABMMC20212-14	MH309447	60.23386, -64.34144	Subtidal (4 m) on rock and/or fucus	Duck Islands, Torngat
	GWS039287	ABMMC20213-14	MH309379	60.23386, -64.34144		
	GWS039289	ABMMC20214-14	MH309682	60.23386, -64.34144		
	GWS039314	ABMMC20215-14	MH309598	59.42878, -63.7148	Subtidal (5 m) on Palmaria	Hogg Island, Torngat
	GWS039315	ABMMC20216-14	MH309390	59.42878, -63.7148		
	GWS039316	ABMMC20217-14	MH309820	59.42878, -63.7148		
Ahnfeltia borealis	GWS039320	ABMMC20224-14	MH143555	59.42878, -63.7148	Subtidal (5 m) on rock	Hogg Island, Torngat
	GWS039323	ABMMC20225-14	MH309308	59.42878, -63.7148	Subtidal (5 m) on rock	
	GWS039334	ABMMC20226-14	MH308766	59.42878, -63.7148	Subtidal (5 m) on rock	
	GWS039338	ABMMC20229-14	MH310015	59.42878, -63.7148	Subtidal (5 m) on rock	
	GWS039349	ABMMC20230-14	MH309549	59.42878, -63.7148	Subtidal (3 m) on rock	
	GWS039368	ABMMC20231-14	MH309257	59.29849, -63.52443	Subtidal (3 m) on rock	Evans Bight, Torngat
	GWS040262	ABMMC20228-14	MH309358	59.29849, -63.52443	Subtidal (6 m) on rock	
	GWS040299	ABMMC20461-14	MH309144	59.42878, -63.7148	Subtidal (8 m) on cobble	Hogg Island, Torngat
	GWS040303	ABMMC20465-14	MH309977	59.42878, -63.7148	Subtidal (8 m) on cobble	
Clathromorphum compactum	GWS040286	ABMMC20235-14	MH309911	59.29849, -63.52443	Subtidal (6 m) on cobble	Evans Bight, Torngat
Clathromorphum sp. (9GWS)	GWS040336	ABMMC20238-14	-	56.76594, -61.31059	Subtidal (10 m) on rock	Black Harbour
Lithothamnion glaciale	GWS040334	ABMMC20236-14	-	56.76594, -61.31059	Subtidal (2 m) on rock	Black Harbour
	GWS040341	ABMMC20239-14	-	56.76594, -61.31059	Subtidal (10 m) on bottom	
	GWS040342	ABMMC20240-14	-	56.76594, -61.31059		
	GWS040345	ABMMC20241-14	-	56.76594, -61.31059	Subtidal (10 m) on shell	
	GWS040347	ABMMC20243-14	-	56.76594, -61.31059	Subtidal (10 m) on cobble	
	GWS040356	ABMMC20246-14	-	56.76594, -61.31059	Subtidal (12 m) on barnacle test	
	GWS040423	ABMMC20248-14	-	55.08429, -59.16566	Subtidal (6 m) on rock	Makkovik Lighthouse
Lithothamnion lemoineae	GWS040335	ABMMC20237-14	MH308969	56.76594, -61.31059	Subtidal (10 m) on bottom	Black Harbour
	GWS040346	ABMMC20242-14	-	56.76594, -61.31059	Subtidal (10 m) on crustose coralline	

Species	No.	BOLD	COI-5P	Lat, Lon	Habitat	Location
	GWS040432	ABMMC20249-14	-	55.10165, -59.18001	Subtidal (6 m) on rock	Makkovik Lighthouse
Hildenbrandia rubra	GWS040394	ABMMC20252-14	-	55.10165, -59.18001	Upper intertidal pool on rock	Makkovik Lighthouse
	GWS040487	ABMMC20253-14	-	55.08414, -59.17248	Lower mid intertidal on cobble	Makkovic Wharf Beach
Hildenbrandia sp. (1Arct)	GWS040282	ABMMC20446-14	MH308965	59.29849, -63.52443	Subtidal (6 m) on cobble	Evans Bight, Torngat
	GWS040285	ABMMC20448-14	MH309380	59.29849, -63.52443		
	GWS040287	ABMMC20449-14	MH309757	59.29849, -63.52443		
	GWS040292	ABMMC20454-14	MH310027	59.29849, -63.52443		
Hildenbrandia sp. (40GWS)	GWS040425	ABMMC20477-14	-	55.10165, -59.18001	Subtidal (2 m) on rock	Makkovik Lighthouse
	GWS040427	ABMMC20479-14	-	55.10165, -59.18001		
Hildenbrandia sp. (73GWS)	GWS040424	ABMMC20476-14	-	55.10165, -59.18001	Subtidal (2 m) on rock	Makkovik Lighthouse
	GWS040426	ABMMC20478-14	-	55.10165, -59.18001		
Rhodochorton purpureum	GWS039310	ABMMC20258-14	-	60.23386, -64.34144	Mid intertidal pool on rock	Duck Islands, Torngat
	GWS040261	ABMMC20260-14	-	59.29849, -63.52443	Subtidal (6 m) on cobble	Evans Bight, Torngat
Rhodophysemopsis hyperborea	GWS040281	ABMMC20445-14	KY205173	59.29849, -63.52443	Subtidal (6 m) on limpet	Evans Bight, Torngat
Devaleraea ramentacea	GWS039277	ABMMC20267-14	MF543930	60.23386, -64.34144	Subtidal (4 m) on rock	Duck Islands, Torngat
	GWS039281	ABMMC20268-14	MF543942	60.23386, -64.34144	Subtidal (8 m) on rock	
	GWS039283	ABMMC20269-14	MF543937	60.23386, -64.34144	Subtidal (8 m) on rock	
	GWS039312	ABMMC20270-14	-	59.42878, -63.7148	Subtidal (5 m) on rock	Hogg Island, Torngat
Palmaria palmata	GWS039259	ABMMC20271-14	KY572809	60.23386, -64.34144	Subtidal (8 m) on Saccharina latissima stipe	Duck Islands, Torngat
	GWS039300	ABMMC20272-14	KY572535	60.23386, -64.34144		
	GWS039342	ABMMC20273-14	KY572563	59.42878, -63.7148	Subtidal (5 m) on rock	Hogg Island, Torngat
Ceramium virgatum	GWS039372	ABMMC20284-14	-	56.76594, -61.31059	Subtidal (2 m) on rock	Black Harbour
	GWS039379	ABMMC20285-14	-	56.76594, -61.31059	Subtidal (2 m) on Rhodomela	
	GWS039382	ABMMC20286-14	KY572323	56.76594, -61.31059		
	GWS039399	ABMMC20287-14	-	56.76594, -61.31059		
	GWS039427	ABMMC20290-14	KY572480	55.10165, -59.18001	Subtidal (6 m) on rock	Makkovik Lighthouse
Scagelia pylaisaei	GWS039319	ABMMC20291-14	-	59.42878, -63.7148		

Species	No.	BOLD	COI-5P	Lat, Lon	Habitat	Location
	GWS039322	ABMMC20292-14	-	59.42878, -63.7148	Subtidal (5 m) on Ahnfeltia	Hogg Island, Torngat
	GWS039331	ABMMC20293-14	MH309517	59.42878, -63.7148	Subtidal (5 m) on Agarum	
	GWS039369	ABMMC20294-14	MH310033	56.76594, -61.31059	Subtidal (8 m) on rock	Black Harbour
	GWS039370	ABMMC20276-14	MH309504	56.76594, -61.31059	Subtidal (8 m) on invert	
	GWS039371	ABMMC20295-14	MH308871	56.76594, -61.31059	Subtidal (8 m) on rock	
	GWS039373	ABMMC20277-14	MH308802	56.76594, -61.31059	Subtidal (2 m) on Ceramium or Rhodomela	
	GWS039376	ABMMC20278-14		56.76594, -61.31059		
	GWS039377	ABMMC20279-14	MH310038	56.76594, -61.31059		
	GWS039384	ABMMC20280-14	-	56.76594, -61.31059		
	GWS039434	ABMMC20296-14	-	55.10165, -59.18001	Subtidal (6 m) on invert	Makkovik Lighthouse
	GWS039449	ABMMC20281-14	MH309201	55.10165, -59.18001	Subtidal (6 m) on Phycodrys	
	GWS039455	ABMMC20282-14	-	55.10165, -59.18001	Subtidal (6 m) on Ptilota	
	GWS039458	ABMMC20283-14	MH309318	55.10165, -59.18001	Subtidal (6 m) on Agarum	
	GWS040340	ABMMC20297-14	MH308823	56.76594, -61.31059	Subtidal (10 m) on invert	Black Harbour
Membranoptera carpophylla	GWS039353	ABMMC20376-14	MH143535	59.29849, -63.52443	Subtidal (6 m) on rock	Evans Bight, Torngat
Membranoptera fabriciana	-	ABMMC20300-14	MH309840	60.23386, -64.34144	Subtidal (8 m) on Ptilota	Duck Islands, Torngat
	GWS039272	ABMMC20301-14	MH309636	60.23386, -64.34144		
	GWS039288	ABMMC20302-14	MH143536	60.23386, -64.34144		
	GWS039327	ABMMC20303-14	MH309041	59.42878, -63.7148	Subtidal (5 m) on red alga	Hogg Island, Torngat
	GWS039335	ABMMC20304-14	MH308865	59.42878, -63.7148	Subtidal (5 m) on alga	
Phycodrys fimbriata	GWS039262	ABMMC20305-14	MH143554	60.23386, -64.34144	Subtidal (8 m) on Ptilota	Duck Islands, Torngat
	GWS039270	ABMMC20306-14	MH309516	60.23386, -64.34144	Subtidal (8 m) on rock	
	GWS039318	ABMMC20307-14	MH309796	59.42878, -63.7148	Subtidal (5 m) on rock	Hogg Island, Torngat
	GWS039326	ABMMC20308-14	-	59.42878, -63.7148		
	GWS039333	ABMMC20309-14	-	59.42878, -63.7148		
	GWS039355	ABMMC20310-14	-	59.29849, -63.52443	Subtidal (6 m) on rock	Evans Bight, Torngat
	GWS039405	ABMMC20312-14	MH309863	55.08429, -59.16566		Makkovik Harbour

Species	No.	BOLD	COI-5P	Lat, Lon	Habitat	Location
	GWS039408	ABMMC20311-14	MH309220	55.08429, -59.16566	Subtidal (12 m) on invert	
	GWS039428	ABMMC20313-14		55.10165, -59.18001	Subtidal (6 m) on rock	Makkovik Lighthouse
	GWS039431	ABMMC20314-14	MH309942	55.10165, -59.18001	Subtidal (6 m) on coralline crust	
	GWS039443	ABMMC20315-14	MH309794	55.10165, -59.18001	Subtidal (6 m) on barnacle	
	GWS039450	ABMMC20316-14	MH310061	55.10165, -59.18001	Subtidal (6 m) on rock	
	GWS039451	ABMMC20317-14	MH309112	55.10165, -59.18001		
Leptosiphonia flexicaulis	GWS039380	ABMMC20332-14	-	56.76594, -61.31059	Subtidal (2 m) on Rhodomela	Black Harbour
	GWS039381	ABMMC20333-14	-	56.76594, -61.31059		
	GWS039396	ABMMC20335-14	-	56.76594, -61.31059	Subtidal (2 m) on rock	
	GWS039397	ABMMC20336-14	-	56.76594, -61.31059	Subtidal (2 m) on Sphacelaria	
	GWS039398	ABMMC20337-14	-	56.76594, -61.31059	Subtidal (2 m) on Rhodomela	
	GWS039409	ABMMC20338-14	-	55.08429, -59.16566	Subtidal (12 m) on invert	Makkovik Harbour
	GWS039410	ABMMC20339-14	-	55.08429, -59.16566		
	GWS039419	ABMMC20340-14	-	55.10165, -59.18001	Low intertidal on rock	Makkovik Lighthouse
	GWS040409	ABMMC20358-14	-	55.10165, -59.18001	Low intertidal on Chorda	
	GWS040412	ABMMC20360-14	-	55.10165, -59.18001		
	GWS040440	ABMMC20380-14	-	55.08414, -59.17248	Low intertidal on rock	Makkovik Wharf Beach
	GWS040483	ABMMC20367-14	-	55.08414, -59.17248	Drift	
Odonthalia dentata	GWS039265	ABMMC20321-14	KY572275	60.23386, -64.34144	Subtidal (8 m) on rock	Duck Islands, Torngat
	GWS039360	ABMMC20322-14	KY572840	59.29849, -63.52443	Subtidal (6 m) on rock	Evans Bight, Torngat
Polysiphonia sp. (1stricta)	GWS039422	ABMMC20341-14	-	55.10165, -59.18001	Low intertidal on rock	Makkovik Lighthouse
	GWS039423	ABMMC20342-14	-	55.10165, -59.18001		
	GWS039424	ABMMC20343-14	-	55.10165, -59.18001		
	GWS039432	ABMMC20345-14	-	55.10165, -59.18001	Subtidal (6 m) on coralline crust	
	GWS039454	ABMMC20354-14	-	55.10165, -59.18001	Subtidal (6 m) on barnacle	
	GWS039456	ABMMC20355-14	-	55.10165, -59.18001	Subtidal (6 m) on rock	
	GWS040433	ABMMC20361-14	-	55.10165, -59.18001	Low intertidal on rock	

Species	No.	BOLD	COI-5P	Lat, Lon	Habitat	Location
	GWS039394	ABMMC20334-14	-	56.76594, -61.31059	Subtidal (2 m) on Rhodomela	Black Harbour
	GWS039436	ABMMC20346-14	-	55.10165, -59.18001	Subtidal (6 m) on rock	Makkovik Lighthouse
	GWS039442	ABMMC20349-14	-	55.10165, -59.18001	Subtidal (6 m) on barnacle	
	GWS039444	ABMMC20350-14	-	55.10165, -59.18001	Subtidal (6 m) on coralline crust	
	GWS039446	ABMMC20351-14	-	55.10165, -59.18001		
	GWS039457	ABMMC20356-14	-	55.10165, -59.18001	Subtidal (6 m) on rock	
	GWS039461	ABMMC20357-14	-	55.10165, -59.18001		
	GWS040434	ABMMC20362-14	-	55.08414, -59.17248	Low intertidal on rock	Makkovik Wharf Beach
	GWS040436	ABMMC20363-14	-	55.08414, -59.17248		
	GWS040453	ABMMC20365-14	-	55.08414, -59.17248		
Rhodomela lycopodioides	GWS039374	ABMMC20368-14	KY572815	56.76594, -61.31059	Subtidal (2 m) on rock	Black Harbour
	GWS039383	ABMMC20371-14	KY572582	56.76594, -61.31059		
	GWS039421	ABMMC20373-14	KY572726	55.10165, -59.18001	Low intertidal on rock	Makkovik Lighthouse
	GWS039433	ABMMC20374-14	KY572161	55.10165, -59.18001	Subtidal (6 m) on rock	
	GWS039462	ABMMC20375-14	KY572462	55.10165, -59.18001		
Rhodomela sp. (1virgataGWS)	GWS039346	ABMMC20331-14	MH309651	59.42878, -63.7148	Subtidal (3 m) on rock	Hogg Island, Torngat
	GWS039375	ABMMC20369-14	MH308768	56.76594, -61.31059	Subtidal (2 m) on rock	Black Harbour
	GWS039378	ABMMC20370-14	MH308828	56.76594, -61.31059	Subtidal (2 m) on rock	
	GWS039386	ABMMC20372-14	MH308866	56.76594, -61.31059	Subtidal (2 m) on rock	
	GWS039417	ABMMC20288-14	MH309624	55.10165, -59.18001	Low intertidal on rock	Makkovik Lighthouse
	GWS039418	ABMMC20379-14	MH308815	55.10165, -59.18001	Low intertidal on rock	
	GWS039420	ABMMC20289-14	MH143563	55.10165, -59.18001	Low intertidal on rock	
Rhodomela virgata	GWS039329	ABMMC20381-14	-	59.42878, -63.7148	Subtidal (5 m) on rock	Hogg Island, Torngat
Savoiea arctica	GWS039437	ABMMC20347-14	KU564409	55.10165, -59.18001	Subtidal (6 m) on coralline crust	Makkovik Lighthouse
	GWS039452	ABMMC20352-14	KU564375	55.10165, -59.18001	Subtidal (6 m) on rock	
	GWS039453	ABMMC20353-14	KU564364	55.10165, -59.18001		
Ptilota serrata	GWS039256	ABMMC20386-14	-	60.23386, -64.34144	Subtidal (8 m) on rock	Duck Islands, Torngat
	GWS039260	ABMMC20387-14	KU381891	60.23386, -64.34144	Subtidal (8 m) on rock	
	GWS039261	ABMMC20388-14	-	60.23386, -64.34144	Subtidal (8 m) on rock	
	GWS039266	ABMMC20389-14	KU381962	60.23386, -64.34144	Subtidal (8 m) on rock	
	GWS039339	ABMMC20392-14	KU381878	59.42878, -63.7148	Subtidal (5 m) on rock	Hogg Island, Torngat

Species	No.	BOLD	COI-5P	Lat, Lon	Habitat	Location
	GWS039365	ABMMC20394-14	-	59.29849, -63.52443	Subtidal (6 m) on rock	Evans Bight, Torngat
	GWS039367	ABMMC20395-14	KU381969	59.29849, -63.52443	Subtidal (6 m) on rock	
	GWS039429	ABMMC20396-14	KU381818	55.10165, -59.18001	Subtidal (6 m) on rock	Makkovik Lighthouse
	GWS039430	ABMMC20397-14	KU381861	55.10165, -59.18001	Subtidal (6 m) on rock	
Fimbrifolium dichotomum	GWS039254	ABMMC20401-14	MH309268	60.23386, -64.34144	Subtidal (8 m) on rock	Duck Islands, Torngat
	GWS039263	ABMMC20402-14	MH309676	60.23386, -64.34144	Subtidal (8 m) on Ptilota	
	GWS039264	ABMMC20403-14	MH309401	60.23386, -64.34144		
	GWS039268	ABMMC20404-14	MH309667	60.23386, -64.34144		
	GWS039271	ABMMC20405-14	MH309199	60.23386, -64.34144		
	GWS039278	ABMMC20406-14	-	60.23386, -64.34144		
	GWS039324	ABMMC20407-14	MH309754	59.42878, -63.7148	Subtidal (5 m) on rock	Hogg Island, Torngat
	GWS039357	ABMMC20408-14	MH309668	59.29849, -63.52443	Subtidal (6 m) on rock	Evans Bight, Torngat
Dilsea socialis	GWS039344	ABMMC20412-14	KY572718	59.42878, -63.7148	Subtidal (3 m) on rock	Hogg Island, Torngat
	GWS039345	ABMMC20413-14	KY572628	59.42878, -63.7148		
	GWS039400	ABMMC20414-14	KY572139	55.08429, -59.16566	Subtidal (12 m) on rock	Makkovik Harbour
	GWS039401	ABMMC20415-14	KY572322	55.08429, -59.16566		
Waernia mirabilis	GWS040240	ABMMC20432-14	MH310013	60.23386, -64.34144	Subtidal (8 m) on cobble	Duck Islands, Torngat
	GWS040288	ABMMC20450-14	MH309929	59.29849, -63.52443	Subtidal (6 m) on cobble	Evans Bight, Torngat
	GWS040289	ABMMC20451-14	MH308902	59.29849, -63.52443		
	GWS040290	ABMMC20452-14	MH309469	59.29849, -63.52443		
	GWS040291	ABMMC20453-14	MH309947	59.29849, -63.52443		
	GWS040293	ABMMC20455-14	MH308974	59.29849, -63.52443		
Turnerella sp. (1Atl)	GWS039269	ABMMC20418-14	-	60.23386, -64.34144	Subtidal (8 m) on rock	Duck Islands, Torngat
	GWS039354	ABMMC20442-14	-	59.29849, -63.52443	Subtidal (6 m) on rock	Evans Bight, Torngat
	GWS039358	ABMMC20419-14	-	59.29849, -63.52443		
	GWS039366	ABMMC20421-14	-	59.29849, -63.52443	Subtidal (3 m) on rock	
Euthora cristata	GWS039255	ABMMC20299-14	KY572287	60.23386, -64.34144	Subtidal (8 m) on rock	Duck Islands, Torngat
	GWS039325	ABMMC20437-14	KY572359	59.42878, -63.7148	Subtidal (5 m) on Fimbrifolium	Hogg Island, Torngat
	GWS039356	ABMMC20438-14	KY572175	59.29849, -63.52443	Subtidal (6 m) on rock	Evans Bight, Torngat

Species	No.	BOLD	COI-5P	Lat, Lon	Habitat	Location
	GWS039406	ABMMC20439-14	KY572159	55.08429, -59.16566	Subtidal (12 m) on invert	Makkovik Harbour
Coccotylus truncatus	GWS039301	ABMMC20490-14	MH309814	60.23386, -64.34144	Subtidal (8 m) on rock	Duck Islands, Torngat
	GWS039303	ABMMC20484-14	-	60.23386, -64.34144		
	GWS039328	ABMMC20491-14	MH309640	59.42878, -63.7148	Subtidal (5 m) on rock	Hogg Island, Torngat
	GWS039363	ABMMC20492-14	MH309694	59.29849, -63.52443	Subtidal (6 m) on rock	Evans Bight, Torngat
	GWS039402	ABMMC20485-14	MH309772	55.08429, -59.16566	Subtidal (12 m) on rock	Makkovik Harbour
	GWS039403	ABMMC20486-14	-	55.08429, -59.16566		
	GWS039407	ABMMC20493-14	MH308967	55.08429, -59.16566		
Peyssonnelia rosenvingei	GWS040337	ABMMC20468-14	MH308924	56.76594, -61.31059	Subtidal (10 m) on cobble	Black Harbour
	GWS040338	ABMMC20469-14	MH309314	56.76594, -61.31059		
	GWS040348	ABMMC20470-14	MH309133	56.76594, -61.31059		
	GWS040349	ABMMC20471-14	MH309324	56.76594, -61.31059		
	GWS040350	ABMMC20472-14	MH308894	56.76594, -61.31059		
	GWS040351	ABMMC20473-14	MH309488	56.76594, -61.31059		
	GWS040352	ABMMC20474-14	MH309583	56.76594, -61.31059		
	GWS040358	ABMMC20475-14	MH309062	55.10165, -59.18001	Subtidal (6 m) on cobble	Makkovik Lighthouse
	GWS040430	ABMMC20482-14	MH309677	55.10165, -59.18001	Subtidal (6 m) on rock	
	GWS040431	ABMMC20483-14	MH308839	55.10165, -59.18001		

APPENDIX D – FISH

Table D-1: List of highlighted species that are known to occur within the study area and their associated biological/ecological/influencing factors, distribution, COSEWIC status, abundance and biomass, population trends, and importance to the fishery.

Species	Biology/Ecology/Influencing Factors	Distribution	Status, Abundance and Biomass, Trends, Commercial/Cultural Importance
Greenland Halibut (Turbot) (*Reinhardtius hippoglossoides*)	**Biology:** - Maximum longevity of the species in the Arctic and Northwest Atlantic is at least 30 years (Dwyer et al. 2013). - Maximum length and weight are 120 cm and 45 kg (Munroe et al. 2015). - Males reach sexual maturity at 36 cm; Females reach sexual maturity at 46 cm (Dwyer et al. 2013). - Spawning occurs January-March (Dwyer et al. 2013). - 7,000–140,000 eggs (size dependent) (Munroe et al. 2015). - Larvae remain pelagic for several months (Munroe et al. 2015). **Ecology:** - Diet varies by size, with individuals <20 cm consuming zooplankton, krill, and other invertebrates (DFO 2018e). - Larger individuals consume mainly fish and shrimp (DFO 2018e). **Abiotic/Biotic Factors:** - Inhabit depths from 200–2,000 m; commonly found between 500 and 1,000 m (Morgan 2018). - Fall surveys in division 2J indicate that most of the biomass is located between 200–750 m depth (Morgan 2018).	**Global:** - *R. hippoglossoides* is distributed in a nearly continuous manner along the continental slopes throughout the northwest and northeast Atlantic Ocean at depths of 200 m to 1,500 m. In the northwest, largest concentrations extend from southwest Greenland to the southern face of the Grand Banks and Flemish Pass, particularly within deep-water channels formed along the continental shelf. In the northeast, the species is observed from the coast of Norway, north to Svalbard, and east towards Russia (Bowering and Nedreaas 2000). **Regional:** - Highest density catches observed during RV multispecies trawl surveys are located within Hopedale Saddle and along the shelf edge. However, the species has been observed across the continental shelf in divisions 2HJ.	**COSEWIC Status:** - No status **Abundance and Biomass:** - Greenland Halibut biomass for 2J3K in 2017 was at the second lowest point in the time series (Morgan 2018). - Estimates for the Fall 2017 survey of 2J indicate a biomass of 34,729 t (Morgan 2018). - Estimates for the Fall 2017 survey of 3K indicate a biomass of 88,094 t (Morgan 2018). - Abundance estimates for divisions 2J3K declined in 2012 and have remained at low levels (Morgan 2018). **Population Trends:** - Fall RV trawl surveys indicate that the biomass index in 2J3K has declined steadily since 2014 (Morgan 2018). **Commercial/Cultural Importance:** - Subject to mortality through commercial (subarea 2 + divisions 3KLMNO) and recreational fisheries as well as non-directed fisheries as by-catch (DFO 2018e).

Species	Biology/Ecology/Influencing Factors	Distribution	Status, Abundance and Biomass, Trends, Commercial/Cultural Importance
	- Found in temperatures from -1.0–10°C, but most abundant from -0.5–3.0°C (Munroe et al. 2015). - Generally associated with channels where the sediments are fine and consolidated (DFO 2018e). - Natural mortality resulting from predation by Harp, Grey, and Hooded Seals, as well as Atlantic Halibut (DFO 2018e).		
Arctic Cod (*Boreogadus saida*)	**Biology:** - Maximum age is 5–7 years (Fernandes et al. 2015; Wienerroither et al. 2011); but Labrador fish seldom live beyond 6 years (Scott and Scott 1988). - Reach sexual maturity at 2+ years (Wienerroither et al. 2011). - Fecundity is low compared to *G. morhua,* with females producing 9,000–21,000 eggs (Wienerroither et al. 2011). **Ecology:** - Species can be found associated with sea ice but appear in higher densities in open habitats (Renaud et al. 2012). - Diet primarily consists of planktonic copepods and amphipods (Fernandes et al. 2015; Hop and Gjøsæter 2013). - The species is an important component of arctic marine food webs, acting as a food source for fish, marine mammals, and birds (Scott and Scott 1988; Wienerroither et al. 2011; Fernandes et al. 2015). **Abiotic/Biotic Factors:** - Optimal temperature range is from 0–4°C (Scott and Scott 1988).	**Global:** - *B. saida* prefers colder temperatures, occupying Canadian waters from the Beaufort Sea south to the Grand Banks of Newfoundland. This species also exhibits a circumpolar distribution in arctic regions outside of the Northwest Atlantic (Fernandes et al. 2015). **Regional:** - Highest density catches observed during RV multispecies trawl surveys are located on medium to high relief areas of the continental shelf. However, the species has been observed in varying densities across much of the continental shelf in divisions 2HJ.	**COSEWIC Status:** - No Status **Abundance and Biomass:** - Information not available. **Population Trends:** - Information not available. **Commercial/Cultural Importance:** - This species is not a major commercial species but has been subject to a directed fishery in the USSR, and by Norway, Danish, and German vessels (Fernandes et al. 2015).

Species	Biology/Ecology/Influencing Factors	Distribution	Status, Abundance and Biomass, Trends, Commercial/Cultural Importance
	- Depth range of 0–400 m (Froese and Pauly 2016); with highest densities at 100–300 m (Scott and Scott 1988). - Warming temperatures resulting from global warming are likely to impact the distribution of this species (Hop and Gjøsæter 2013).		
Capelin (*Mallotus villosus*)	**Biology:** - The species has a relatively short lifespan (6 years or less in Newfoundland and Labrador waters) and exhibits variable levels of recruitment (DFO 2018d, F. Mowbray, pers. comm.). - Size of adult capelin ranges from 12–23 cm (DFO 2018d). - Historical spawning age of capelin was three-four years; however, since the early-1990s, capelin mature earlier and spawn at 2–3 years (DFO 2018d). - Historically, spawning occurred in June on beaches or at demersal offshore spawning sites (DFO 2018d). - Since 1991, spawning has been delayed by up to 4 weeks to July-August, which is likely related to cooler water temperatures and younger, smaller spawners (Carscadden et al. 1997). - Eggs adhere to sediment at spawning sites and remain until hatched, which can range from one-three weeks depending on temperature (Carscadden and Vilhjálmsson 2002). - Larval survival is linked to wind direction and prey availability (Frank and Legett 1981; Murphy et al. 2018).	**Global** - *M. villosus* exhibit a circumpolar distribution and are also found throughout the North Pacific Ocean (Rose 2005). In Newfoundland and Labrador, the species are found in major bays, and on the northern Grand Bank and northeastern Newfoundland Shelf (DFO 2015). **Regional:** - Highest density catches have been observed along the continental shelf in NAFO div. 2J; however, some observations have also been made across the continental shelf in div. 2H as well. The species has been observed most often in the southern portion of the study area.	**COSEWIC Status:** - No Status **Abundance and Biomass:** - Spring acoustic surveys in 3KL indicate that abundance ranged from 53-122 billion between 2013–2015 (DFO 2018d). - More recent surveys indicated that abundance has declined to ~20 billion (DFO 2018d). **Population Trends:** - During the 1990s and early-2000s capelin abundance estimates for 2J3KL were very low (DFO 2018d). - Between 2007 and 2012 indices increased slightly (DFO 2018d). - From 2013–2015 estimates were the highest recorded since 1990 and were 25% of the 1980s estimates (DFO 2018d). - The 2017 survey indicates significant declines matching those of the early 2000s (DFO 2018d). **Commercial/Cultural Importance:** - The species was targeted by a directed foreign offshore fishery in

Species	Biology/Ecology/Influencing Factors	Distribution	Status, Abundance and Biomass, Trends, Commercial/Cultural Importance
	- Adult survival is linked to the timing of ice-mediated spring blooms (Buren et al. 2014a). **Ecology:** - Capelin stocks in Subarea 2 + Divisions 3KL are distributed in major bays and offshore areas (DFO 2018d). - Individuals undergo lengthy migrations from wintering to spawning sites (Nakashima 1992). - In NL, capelin diet consists primarily of copepods (O'Driscoll et al. 2012). - They are consumed by many predators making them a key forage species in the food web (DFO 2018d). **Abiotic/Biotic Factors:** - Capelin have been observed feeding at depths up to 450 m in NL (Rose 2005). - They inhabit water temperatures -1.5–6°C but are largely concentrated between -1°C and 2°C (Rose 2005). - Stocks undergo boom and bust cycles associated with environmental conditions and prey availability (DFO 2018d; Buren et al. 2014a). - Spawning appears to be related to water temperature, with delayed spawning post-1991 being attributed to cold water temperatures (DFO 2018d).		2J3KL that was closed in 1992 (DFO 2018d). - Currently capelin are subject to commercial harvest in divisions 2J3KLPs, with landings of 25,000 t on average from 1991–2017 (DFO 2018d).
Atlantic Cod Northern Cod (*Gadus morhua*)	**Biology:** - Maximum age of 29 years, but cod older than 20 years are considered rare (Scott and Scott 1988).	**Global:** - *G. morhua* are found along the continental shelves on the eastern and western boundaries of the North Atlantic. Along the western coast the distribution extends from the	**COSEWIC Status:** - Endangered (Newfoundland and Labrador Population). **Abundance and Biomass:** - Recent stock assessments in divisions 2J3KL produced

Species	Biology/Ecology/Influencing Factors	Distribution	Status, Abundance and Biomass, Trends, Commercial/Cultural Importance
	- Since the late-1980's, female have been reaching sexual maturity at five years in NL (DFO 2018f). - Cod in NL grow more slowly and are typically less productive compared to populations further south (DFO 2018f). - Size at maturity is 35–85 cm (COSEWIC 2010a). - Females can produce 300,000–several million eggs (COSEWIC 2010a). - Batch spawners that spawn over a period of <3 months at varying depths (COSEWIC 2010a). - Spawning periods last 3–6 weeks (COSEWIC 2010a). - Reproductive parameters vary based on stock, depth, temperature, condition of the fish, and area (COSEWIC 2010a). **Ecology:** - Larvae feed on phytoplankton and small zooplankton at water depths of 10–50 m (COSEWIC 2010a). - Juveniles settle on the bottom at depths up to 150 m, where they remain for 1–4 years (COSEWIC 2010a). - Juveniles tend to favour complex 3-dimensional benthic environments which reduce the risk of predation (COSEWIC 2010a). - Adults consume numerous fish species, as well as squid, and a variety of benthic organisms (COSEWIC 2010a). - Capelin and shrimp are particularly important prey species (DFO 2018f).	southern side of Georges Bank, northward to Baffin Island. In the east, the range extends from the North Sea following the coast to northern Russia. Populations are also found in the strait between Norway and Sweden, along Denmark, as well as in the southern Baltic Sea (COSEWIC 2010a). **Regional:** - The species has been observed relatively consistently across the continental shelf in NAFO Divs. 2HJ, with some high density catches occurring along the edge of the shelf.	abundance and biomass estimates of 795 million fish and 467,000 t, respectively (DFO 2018f). **Population Trends:** - In the NAFO div 2J3KL, Atlantic Cod populations declined 97–99% in the past three generations (Brattey et al. 2018). - Recent surveys of divisions 2J3KL indicated increases in biomass between 2005–17, with a decline from 639,000 t to 467,000 t observed in 2018 (DFO 2018f). - Abundance also increased from 2005 to 2015, after which it saw declines (DFO 2018f). **Commercial/Cultural Importance:** - Threats to Atlantic Cod populations include exploitation through recreational and stewardship fisheries, as well as bycatch in undirected fisheries (COSEWIC 2010a). - Commercial fishing in 2GHJ3KL is currently under a moratorium (COSEWIC 2010a).

Species	Biology/Ecology/Influencing Factors	Distribution	Status, Abundance and Biomass, Trends, Commercial/Cultural Importance
	- The species undergoes seasonal migrations attributed to geographical and seasonal differences in water temperature, food supply, and possibly spawning grounds (COSEWIC 2010a). **Abiotic/Biotic Factors:** - Cod are generally found in water 2–11°C; however, in NL they can survive in water as cool as -1.5°C (COSEWIC 2010a). - Threats to Atlantic Cod populations include exploitation through directed fisheries, recreational fisheries, and bycatch in undirected fisheries as well as alterations to bottom habitats resulting from fishing gear (COSEWIC 2010a). - Climate change has also been linked to direct and indirect changes in population dynamics in other areas of the North Atlantic (Mieszkowska et al. 2007). - From 1985-2007, capelin availability was a significant driver of biomass dynamics (DFO 2018f). Harp seals are a key predator, but they have not been found to be an important driver of the stock (Buren et al. 2014b).		
Mailed Sculpin (NS) (*Triglops* sp.)	**Biology:** - Occupy benthic habitats (Scott and Scott 1988). - Lifespan approximately 10 years (Wienerroither et al. 2011). - Max length is approximately 17 cm (Scott and Scott 1988). - Sexual maturity is species dependent and ranges from 2–7 years (Wienerroither et al. 2011).	**Global:** - Of the nine *Triglops* spp. found throughout the world, two are more commonly found in the study area: *T. murrayi* and *T. nybelini.* The species' combined range extends from Baffin Bay to the White Sea, and as far south as Maine (Scott and Scott 1988). **Regional:**	**COSEWIC Status:** - No Status. **Abundance and Biomass:** - Not well known. **Population Trends:** - Trends produced for the Flemish Cap indicate that biomass of *T. murrayi* declined from the early-2000s to 2008 (Pérez-Rodriguez et al. 2012).

Species	Biology/Ecology/Influencing Factors	Distribution	Status, Abundance and Biomass, Trends, Commercial/Cultural Importance
	- Females have been observed with as many as 2,739 eggs (Scott and Scott 1988). - Spawning is species dependent but occurs from late summer to winter (Wienerroither et al. 2011). **Ecology:** - Diet consists primarily of amphipods, mysids, and crustaceans (Scott and Scott 1988). **Abiotic/Biotic Factors:** - Prefer soft bottom habitats (Froese and Pauly 2016). - Found at depths up to 930 m, but most common in waters <600 m (Scott and Scott 1988). - Occur at temperatures from 0–12°C (Froese and Pauly 2016) but prefer 0–3°C (Wienerroither et al. 2011).	- Observed across the continental shelf of NAFO Divs. 2HJ, with highest density catches restricted to medium and high relief areas on the continental shelves along the Nain and Makkovik Banks. Some high density catches have also been observed in NAFO div. 2G.	- Trends do not exist for the NAFO divisions that the study area overlaps, or for *T. nybelini.* **Commercial/Cultural Importance:** - No known commercial, recreational, or cultural importance.
American Plaice (*Hippoglossoides platessoides*)	**Biology:** - Maximum age of the species ranges depending on geographic location; however, plaice up to 25 years of age have been caught in NL (Pitt 1982). - Age at maturity has declined in recent years from 10–11 years to 6–8 years (COSEWIC 2009). - Fecundity is highly variable, but large females may be capable of producing >1 million eggs (COSEWIC 2009). - Females are batch spawners and can spawn for more than a month at a time (COSEWIC 2009).	**Global:** - *H. platessoides* habitat is widespread throughout the NL region with species often found occupying more than 80% of areas surveyed (DFO 2012). It ranges from Georges Bank and the Bay of Fundy, North to the eastern Coast of Baffin Island, Nunavut. Within the North Atlantic, the species is widespread inhabiting the continental shelf from the Barents Sea to the British Isles in the east and extending from Rhode Island just short of the Arctic Circle in the west (COSEWIC 2009). **Regional:**	**COSEWIC Status:** - Threatened (Newfoundland and Labrador Population). **Abundance and Biomass:** - Fall surveys in SA2+3K estimated abundance to be ~200 million, and biomass to be ~25,000 t in 2012. - Fall surveys in division 2H estimated abundance to be ~42 million, and biomass to be ~41,000 t in 2012 (Morgan et al. 2013). **Population Trends:** - Biomass and abundance declines were observed in the SA 2+3K

Species	Biology/Ecology/Influencing Factors	Distribution	Status, Abundance and Biomass, Trends, Commercial/Cultural Importance
	- Eggs and larvae are pelagic and metamorphose into juveniles at 20–40 mm (COSEWIC 2009). **Ecology:** - Adults are not known to undertake large migrations to spawn, but may move into deep, warmer waters during winter months (COSEWIC 2009). - They are considered opportunistic feeders; juveniles consume copepods and other zooplankton, while adults consume polychaetes, echinoderms, molluscs, crustaceans, and a variety of fish (COSEWIC 2009). **Abiotic/Biotic Factors:** - Juveniles are found at depths <200 m, while adults are primarily concentrated between 100–300 m (COSEWIC 2009). - Juveniles prefer habitats with fine particle sediments; adults can withstand a wider range of sediment size for burrowing (COSEWIC 2009). - Suitable habitat is based largely on access to prey and appropriate temperatures (COSEWIC 2009). - Adult plaice prefer water temperatures between -0.5°C and 4°C (COSEWIC 2009).	- Observed across the continental shelf of NAFO Divs. 2HJ, with highest density catches concentrated on medium and high relief areas of the continental shelves. Smaller catches have also been observed in channels across the shelf, as well as within Div. 2G.	stock from the late-1980s until 2002 (Morgan et al. 2013). - The rate of decline for the adult population was 97% over a 28 year period in SA 2+3K (Morgan et al. 2013). - Since 2002 both indices have been increasing (Morgan et al. 2013). - Current biomass in 2J3K is at 10% of the mid-1980s average (Morgan et al. 2013). - Current abundance in 2J3K is 25% of the mid-1980s average (Morgan et al. 2013). - Estimates in 2H have shown increases since 1996 but remain low (Morgan et al. 2013). **Commercial/Cultural Importance:** - The directed fishery for the species is under moratorium, but they are still subject to removal as by-catch in other fisheries (COSEWIC 2009).
Deepwater Redfish (*Sebastes mentella*)	**Biology:** - Live up to 75 years (COSEWIC 2010b). - Grow up to 60 cm (males 40–45 cm; females 45–60 cm) (COSEWIC 2010b). - Sexual maturity 10–15 years (COSEWIC 2010b).	**Global:** - *S. mentella* are distributed along the eastern and western boundaries of the North Atlantic. In the west, the population runs from southern NL north to Baffin Island, with eastward extensions towards the south coast	**COSEWIC Status:** - Threatened (Northern Population) - Endangered (Gulf of St. Lawrence-Laurentian Population). **Abundance and Biomass:**

Species	Biology/Ecology/Influencing Factors	Distribution	Status, Abundance and Biomass, Trends, Commercial/Cultural Importance
	- Viviparous; internal fertilization (COSEWIC 2010b). - 1,500 to 107,000 larvae (size dependent) (COSEWIC 2010b). - Breed September-December and Larvae are released late spring-early summer (COSEWIC 2010b). **Ecology:** - Semi-pelagic species making large-scale daily vertical migrations (Gauthier and Rose 2002). - Predominantly found on the edge of the continental shelf/slope and in deep channels on the shelf (COSEWIC 2010b). - Diet of larvae includes eggs of fish and invertebrates (COSEWIC 2010b). - Adults feed upon copepods, euphausiids, and other fish (COSEWIC 2010b). **Abiotic/Biotic Factors:** - Preferred temperatures: larvae=4-11°C; adults=5°C (DFO 2014). - Preferred depth: larvae=11–30 m (day); 10 m or less (night); adults=350–500 m (DFO 2014). - The northern population is also subject to predation by Harp and Hooded Seals (COSEWIC 2010b).	of Greenland, surrounding Iceland, and along the northern coast of Europe. In the west the species occurs in the western Barents Sea to the Norway Sea (COSEWIC 2010b). **Regional:** - Distribution largely restricted to the edge of the continental shelf, as well as within channels across the shelf in NAFO Divs. 2GHJ.	- Lowest abundance within NAFO division 2J3K=14 million in 1995 (DFO 2011b). - Highest abundance within NAFO division 2J3K=413 million in 2009 (DFO 2011b). - There are no abundance estimates available for NAFO division 2GH (DFO 2011b). - Mature biomass for the Northern DU in 2010 was about 54,000 t (DFO 2011b). **Population Trends:** - Abundance of mature individuals in 2J3K declined by 98% since 1978 (COSEWIC 2010b). - Declines have stopped since the mid-1990s (COSEWIC 2010b). - Increases have been observed in some areas since (COSEWIC 2010b) 2J3K has been closed to directed fishing since mid-to late-1990s (COSEWIC 2010b). **Commercial/Cultural Importance:** - Species is taken as bycatch in commercial fisheries for Northern Shrimp, Striped Shrimp, and Greenland Halibut (DFO 2014) - An experimental fishery directed towards Redfish also exists in NAFO subareas 3+4 (COSEWIC 2010b).
Thorny Skate (*Raja radiata*)	**Biology:** - Live for 16–20 years (COSEWIC 2012b). - Maximum observed size was in the NL region at 110 cm (COSEWIC 2012b).	**Global:** - *R. radiata* is found throughout the North Atlantic from Hudson Bay to South Carolina in the west; bordering	**COSEWIC Status:** - Special Concern (Atlantic and Arctic Ocean Population). **Abundance and Biomass:**

Species	Biology/Ecology/Influencing Factors	Distribution	Status, Abundance and Biomass, Trends, Commercial/Cultural Importance
	- Compared to the Grand Banks, the species reaches sexual maturity at a smaller size on the northeast Newfoundland Shelf to West Greenland; females at 37 cm, males at 50 cm (COSEWIC 2012b). - Average age at maturity is 11 years (COSEWIC 2012b). - Reproduce year-round, with peak spawning occurring in the fall and winter (Templeman 1987; del Río and Junquera 2001). - Studies on the Scotian Shelf indicate that Females produce 41–56 egg cases per year (McPhie and Campana 2009). **Ecology:** - The species has been found to perform limited cross-shelf movements on the Grand Banks (Kulka et al. 2004a). - Their diet varies by region and size of individual (González et al. 2006). - A study on the Grand Banks showed the species consumed a wide range of prey but identified Sand Lance and Snow Crab as the most important items (González et al. 2006). **Abiotic/Biotic Factors:** - Inhabit a wide range of depths, and bottom types (COSEWIC 2012b). - In NL, 88% of those observed during RV trawl surveys from 1971–2009 were found between 50–350 m; but they have been observed as deep as 1,400 m (COSEWIC 2012b). - In the NL region the species can be found in water temperatures ranging from -	Greenland, Iceland, and Spitzbergen in the north; and running from Norway to the southern North Sea in the east (Chevolot et al. 2007). Surveys performed by DFO in the Newfoundland and Labrador region indicated the species is widely distributed from Baffin Bay to the Laurentian Channel, with the majority of the population concentrated on the southern Grand Banks (Kulka and Miri 2003; Simpson et al. 2011). **Regional:** - Distribution extends across much of the continental shelf in NAFO Divs. 2HJ; however, highest density catches are located within Hopedale Saddle.	- 2015 estimates indicate biomass index of Thorny Skate in 2J3K to be ~16 kt, while abundance indices were ~22 million (DFO 2017c). **Population Trends:** - Abundance of mature individuals in the northern range of the species has been increasing; however, there have been significant declines and contractions in the southern portion of their range (COSEWIC 2012b). - In Divisions 2J3K, biomass and abundance have been generally increasing since 2004; however, the 2015 index decreased relative to 2014 (DFO 2017c). **Commercial/Cultural Importance:** - There is a directed fishery for the species on the Grand Banks but catches in commercial fisheries have not been directly linked to declines (COSEWIC 2012b).

Species	Biology/Ecology/Influencing Factors	Distribution	Status, Abundance and Biomass, Trends, Commercial/Cultural Importance
	1.7°C to 11.4°C, but 81% are found between 0°C and 4°C (Colbourne and Kulka 2004). - Predators include marine mammals and fish, while egg capsules may be eaten by gastropods (COSEWIC 2012b).		
Eelpout (NS) (*Lycodes* sp.)	**Biology:** - Benthic (Scott and Scott 1988). - Size varies from 24 cm (*L. turneri*) to 55 cm (*L. lavalaei*) (Scott and Scott 1988). - Little is known about sexual maturity and/or reproduction for these species, but spawning is thought to occur in summer or early fall (Scott and Scott 1988). **Ecology:** - Diet is not well known but is thought to consist of amphipods (Scott and Scott 1988). **Abiotic/Biotic Factors:** - Species show a preference for soft bottom habitats (Scott and Scott 1988). - Depth ranges vary by species with *L. lavalaei* occupying depths up to 535 m, and *L.turneri* occupying depths to 190 m (Scott and Scott 1988). - Along the coast of Labrador, *L. lavalaei* is found in waters with temperatures from - 1.2°C to 2.52°C, while *L. turneri* are rarely found in water above 0.3°C (Scott and Scott 1988).	**Global:** - Of the Eelpout species, two are most commonly identified in the study area: *Lycodes lavalaei,* and *L. turneri. L. lavalaei* is restricted to the western North Atlantic, ranging from Jan Mayen Islands, south to the Gulf of St. Lawrence. *L. turneri* has a nearly circumpolar distribution from Europe and Asia to the Beaufort Sea and Greenland. In Canada, the species southern limit is the Gulf of St. Lawrence (Scott and Scott 1988). **Regional:** - Distribution extends across much of the continental shelf in NAFO Divs. 2HJ; however, highest density catches are located within Hopedale Saddle and channels along the continental shelf.	**COSEWIC Status:** - No Status. **Abundance and Biomass:** - Not well known. **Population Trends:** - Not well known. **Commercial/Cultural Importance:** - No known commercial, recreational, or cultural importance.
Daubed Shanny (*Lumpenus maculatus*)	**Biology:** - Maximum size is ~20 cm (Meyer Ottesen et al. 2014).	**Global:** - *L. maculatus* has a circumpolar distribution extending from Ellesmere Island in the western North Atlantic along both coasts of Greenland,	**COSEWIC Status:** - No Status. **Abundance and Biomass:** - Not well known. **Population Trends:**

Species	Biology/Ecology/Influencing Factors	Distribution	Status, Abundance and Biomass, Trends, Commercial/Cultural Importance
	- Females reach sexual maturity at 7 years, while males reach it at ~6 years (Meyer Ottesen et al. 2014). - Spawning is thought to occur in shoal areas in the winter (Scott and Scott 1988) - Females have relatively low fecundity (<1,000 eggs) (Scott and Scott 1988). - Post-larvae are pelagic for 2–3 years before becoming benthic (Meyer Ottesen et al. 2014). **Ecology:** - Adult diet consists of polychaetes and crustaceans as well as annelid worms and amphipods (Scott and Scott 1988). - Post-larvae largely consume *Calanus* spp. (Meyer Ottesen et al. 2011). - This species represents a valuable food source for fish, birds, and seals, making it an ecologically significant species (Meyer Ottesen et al. 2011). **Abiotic/Biotic Factors:** - Inhabits shallow waters to depths of 475 m but are usually found at depths less than 170 m (Scott and Scott 1988; Froese and Pauly 2016). - Shows a preference for sandy, muddy, or pebbly bottoms (Scott and Scott 1988; Froese and Pauly 2016).	Baffin Island, Hudson Bay, and Labrador to Cape Cod (Fahay 2007), as well as along the coasts of the North Pacific and Arctic Oceans (Mecklenburg and Sheiko 2004). In the northwest Atlantic the species range extends south to Nova Scotia (Scott and Scott 1988). **Regional:** - Distribution is largely restricted to areas of medium to high relief along the continental shelf within NAFO Divs. 2HJ. Highest density catches appear along Hamilton Bank in the southern region of the study area.	- Not well known. **Commercial/Cultural Importance:** - No known commercial, recreational, or cultural importance.
Lumpfish (NS) (*Eumicrotremus* sp.)	**Biology:** - Benthic species (Scott and Scott 1988). - Size ranges up to 11.5 cm but is usually smaller (Scott and Scott 1988). - Maximum age of *E. spinosus* is 3 years (Berge and Nahrgang 2013).	**Global:** - The two species of lumpfish which are most commonly identified in the study area include: *Eumicrotremus spinosus* and *E. derjugini. E. spinosus* ranges from Prince Patrick Island, extending south along the west coast of Greenland, to the	**COSEWIC Status:** - No Status. **Abundance and Biomass:** - Not well known. **Population Trends:** - Not well known. **Commercial/Cultural Importance:**

Species	Biology/Ecology/Influencing Factors	Distribution	Status, Abundance and Biomass, Trends, Commercial/Cultural Importance
	- Research of *E. spinosus* suggests that the species matures quite early (Berge and Nahrgang 2013). - Reproduction of *E. spinosus* is thought to occur in the winter (Berge and Nahrgang 2013). **Ecology:** - Diets include pelagic and epibenthic invertebrates, oikopleura, as well as fish (Coad and Reist 2004). **Abiotic/Biotic Factors:** - Suitable depths for the species' range from shallow waters to 930 m (Coad and Reist 2004), although observations in Labrador have been concentrated in much shallower waters (Scott and Scott 1988). - The species are found in water temperatures ranging from -2°C to 3°C (Scott and Scott 1988).	Grand Banks, Gulf of St. Lawrence, and off Nova Scotia, and east along the coast of Jan Mayan, the Svalbard-Barents Sea, as well as the Kara Sea (Scott and Scott 1988; Byrkjedal and Høines, 2007 Weinerroither et al., 2013; Berge and Nahrgang, 2013). *E. derjugini* ranges throughout the Canadian Arctic to Spitsbergen and the Kara Sea, and southward along the Labrador Coast (Scott and Scott 1988). **Regional:** - Distribution is largely restricted to areas of medium to high relief along the continental shelf within NAFO Divs. 2HJ. Surrounding the study area, highest density catches appear along Nain, Makkovik, and Hamilton Bank. Other high density catches have also been observed in NAFO div. 2G.	- No known commercial, recreational, or cultural importance.
Rock Cod (Greenland Cod) (*Gadus macrocephalus ogac*)	**Biology:** - Subspecies of Pacific Cod (*Gadus macrocephalus*). - Demersal species (Scott and Scott 1988). - Maximum age is 11 years (Scott and Scott 1988). - Reach sexual maturity at 3–4 years (Scott and Scott 1988). - Spawns in shallow waters in late March-April (Mikhail and Welch 1989). - Females are estimated to produce 1–2 million eggs (Scott and Scott 1988). **Ecology:**	**Global:** - The species exhibits a circumpolar, mid and low arctic distribution. It is found from Alaska to Greenland, and, in the northwest Atlantic, its range extends south to Cape Breton, Nova Scotia (Scott and Scott 1988). **Regional:** - Few observations have been made during RV multispecies trawl surveys. However, of those that do exist, Rock Cod appear to occur in highest densities in shallow areas of	**COSEWIC Status:** - No Status. **Abundance and Biomass:** - Not well known. **Population Trends:** - Not well known. **Commercial/Cultural Importance:** - The species is subject to a subsistence fishery for Labrador Inuit.

Species	Biology/Ecology/Influencing Factors	Distribution	Status, Abundance and Biomass, Trends, Commercial/Cultural Importance
	- Diet consists primarily of fish, but also includes invertebrates, amphipods, shrimps, crabs, molluscs, and polychaetes (Scott and Scott 1988). - Most common in coastal areas in harbours and fjords; less common offshore (Scott and Scott 1988). - Juveniles are restricted to inshore areas and are found in high densities in eelgrass beds (Laurel et al. 2004). - Adults occupy cobble-pebble substrates and eelgrass beds in shallow bays (Laurel et al. 2003). **Abiotic/Biotic Factors:** - Capable of withstanding a wide range of salinities (Scott and Scott 1988).	continental shelf and are most common in NAFO Div. 2J.	
Atlantic Wolffish (*Anarhichas lupus*)	**Biology:** - Maximum age in the Gulf of Maine has been measured at 22 years (Nelson and Ross 1992). - Females reach sexual maturity between 8 and 15 years (COSEWIC 2012a). - Spawning is thought to occur in the fall, during which the species relies on boulders or caves (COSEWIC 2012a). - Fecundity for the species is low and size dependent (2,440-35,320 in NL) (Templeman 1986). **Ecology:** - Adults are largely sedentary (Templeman 1984). - They are a solitary species except during spawning season when they form pairs (COSEWIC 2012a). - Diet consists primarily of invertebrates (crabs and echinoderms), but also	**Global:** - The range of *A. lupus* extends along both sides of the North Atlantic: in the east, from Iceland south to the British Isles and western coast of France; in the west along western Greenland and southern Labrador, in the Strait of Belle Isle, the Gulf of St. Lawrence, along the coasts of NL, on the Grand Banks, and southwards to the Gulf of Maine (O'Dea and Haedrich 2000). **Regional:** - Highest density catches appear along the edge of the continental shelf as well as within and along the edges channels on the shelf throughout NAFO Divs. 2HJ.	**COSEWIC Status:** - Special Concern (Atlantic and Arctic Ocean Population). **Abundance and Biomass:** - 1999 abundance estimates indicated there were 2.95 million Atlantic Wolffish in NAFO division 2G (COSEWIC 2012a). - 2008 abundance estimates indicated there were 6.69 million Atlantic Wolffish in NAFO division 2H (COSEWIC 2012a). - 2009 abundance estimates indicated there were 23.84 million Atlantic Wolffish in NAFO divisions 2J3KL (COSEWIC 2012a). **Population Trends:** - Between 1981 and 1994 Atlantic Wolffish abundance in divisions

Species	Biology/Ecology/Influencing Factors	Distribution	Status, Abundance and Biomass, Trends, Commercial/Cultural Importance
	includes fish (Templeman 1985; Simpson et al. 2011). - Key predators include seals and various fish species (COSEWIC 2012a). **Abiotic/Biotic Factors:** - Temperature is thought to be the primary factor for delineating suitable habitat (COSEWIC 2012a). - Tolerate a wide temperature range (-1.5–13°C) (COSEWIC 2012a). - In NL they are most abundant between 1.5–4.5°C (Kulka et al. 2004b). - Adults are found on various sediment types (Kulka et al. 2004b) at depths up to 918 m (COSEWIC 2012a). - Abundance in NL peaks at 250 m (Kulka et al. 2004b).		2J3KL dropped from 11.76 million to 0.98 million (COSEWIC 2012a). - Between 1995 and 2009 Atlantic Wolffish abundance in divisions 2J3KL rose from 10.37 million to 23.83 million (COSEWIC 2012a). - No conversion factor exists for the Engel time series so direct comparison between Engel and Campelen time series is not possible. **Commercial/Cultural Importance:** - No known commercial, recreational, or cultural importance.
Northern Wolffish (*Anarhichas denticulatus*)	**Biology:** - Live to at least 14 years of age (COSEWIC 2001a). - Females reach sexual maturity at approximately 5.5 years (COSEWIC 2012c). - Spawning is thought to occur late in the year (COSEWIC 2012c) and takes place on rocky bottoms (DFO 2020). - Females have relatively low fecundity (23,000 eggs for females between 112–134 cm in length) (COSEWIC 2012c). **Ecology:** - More pelagic in nature than other wolffish (Templeman 1984; COSEWIC 2012c). - Diet consists of gelatinous zooplankton and fish (Simpson et al. 2012).	**Global:** - *denticulatus* are found in the North Atlantic, ranging from the Barents Sea to southern Greenland, into the Davis Strait and northern Labrador, south to the southern Grand Bank and Flemish Cap, and the Gulf of Maine (Simpson et al. 2012; COSEWIC 2012c). It is most abundant in the deep waters on the Labrador Shelf and off northeastern Newfoundland, and on the shelf edge of the Grand Bank (COSEWIC 2012c). **Regional:** - Highest density catches appear along the edge of the continental shelf as well as within channels on	**COSEWIC Status:** - Threatened (Atlantic and Arctic Ocean Population). **Abundance and Biomass:** - 1999 abundance estimates indicated there were 152,000 Northern Wolffish in NAFO division 2G (Simpson et al. 2012; COSEWIC 2012c). - 2008 abundance estimates indicated there were 42,000 Northern Wolffish in NAFO division 2H (Simpson et al. 2012; COSEWIC 2012c). - 2009 abundance estimates indicated there were 702,000 Northern Wolffish in NAFO

Species	Biology/Ecology/Influencing Factors	Distribution	Status, Abundance and Biomass, Trends, Commercial/Cultural Importance
	- Key predators include seals and various fish species (COSEWIC 2012c). **Abiotic/Biotic Factors:** - In the NL region, the species is found at depth ranges of 38–1,504 m; most abundant between >500 m and 1,000 m (DFO 2020). - The species has been observed elsewhere at depths up to 1,700 m (Coad and Reist 2004). - Most common in water temperatures from 2–5°C in NL (DFO 2020). - Found on a variety of bottom types but in highest concentrations on sand and shell hash, and coarse sand (DFO 2020).	the shelf throughout NAFO Divs. 2HJ. In Div. 2J, high density catches have also been observed across Hamilton Bank.	divisions 2J (Simpson et al. 2012; COSEWIC 2012c). **Population Trends:** - Since the 1980s, especially in the Labrador Sea, there has been a steep decline in abundance (COSEWIC 2012c). - Between 1981 and 1994 Northern Wolffish abundance in divisions 2J3KL dropped from 8.99 million to 210,000 (COSEWIC 2012c). - Between 1996 and 2009 Northern Wolffish abundance in divisions 2J3KL rose from 1 million to 1.86 million (COSEWIC 2012c). **Commercial/Cultural Importance:** - No known commercial, recreational, or cultural importance.
Spotted Wolffish (*Anarhichas minor*)	**Biology:** - Species lives to approximately 21 years (COSEWIC 2001b). - Females reach sexual maturity at approximately 5.5 years (COSEWIC 2012d) - Spawning is thought to occur primarily in summer (Simpson et al. 2012) - Females have relatively low fecundity (5,080–19,760 eggs) (Simpson et al. 2012). **Ecology:** - Largely sedentary (COSEWIC 2012d) - Diet consists primarily of shrimp and echinoderms (Simpson et al. 2013).	**Global:** - *minor* are found in the North Atlantic and Arctic Oceans, from the coast of Norway in the east, to the coast of Greenland and Iceland, to the Davis Straight, and south to the Gulf of Maine; however, it is rare in the Scotian Shelf and in USA waters. They are concentrated in the deeper waters off northeastern Newfoundland and on the Labrador Shelf (COSEWIC 2012d). **Regional:** - Highest density catches appear across medium to high relief areas of the continental shelf in NAFO div.	**COSEWIC Status:** - Threatened (Atlantic and Arctic Ocean Population). **Abundance and Biomass:** - 1999 abundance estimates indicated there were 160,000 Spotted Wolffish in NAFO division 2G (COSEWIC 2012d). - 2008 abundance estimates indicated there were 400,000 Spotted Wolffish in NAFO division 2H (COSEWIC 2012d). - 2009 abundance estimates indicated there were 820,000 Spotted Wolffish in NAFO divisions 2J (COSEWIC 2012d).

Species	Biology/Ecology/Influencing Factors	Distribution	Status, Abundance and Biomass, Trends, Commercial/Cultural Importance
	- Key predators of juveniles include seals and various fish species (COSEWIC 2012d). **Abiotic/Biotic Factors:** - Suitable depths range from 56–1,046 m, but in the NL region they are most abundant between 200–750 m (Albikovskaya 1982; DFO 2020). - In NL they are most common where water temperatures are between 1.5°C and 5 °C (DFO 2020). - Found on a variety of bottom types but in highest concentrations on sand and shell hash, and coarse sand (DFO 2020).	2HJ (Nain, Makkovik, and Hamilton Bank).	**Population Trends:** - Between 1981 and 1994 Spotted Wolffish abundance in divisions 2J3KL dropped from 6.39 million to 190,000 (COSEWIC 2012d) - Between 1995 and 2009 Spotted Wolffish abundance in divisions 2J3KL rose from 150,000 to 590,000 (COSEWIC 2012d). **Commercial/Cultural Importance:** - No known commercial, recreational, or cultural importance.
Smooth Skate (*Malacoraja senta*)	**Biology:** - Slow growing species (COSEWIC 2012e). - Estimates for the Grand Banks indicate maximum age for the species 17 years (Kulka et al. 2006; COSEWIC 2012e). - Maximum length on the Grand Banks is 73 cm (Kulka et al. 2006; COSEWIC 2012e). - On average, females in Canadian waters reach sexual maturity at 11 years of age (COSEWIC 2012e). - Annually fecundity of the species is between 41–100 eggs (COSEWIC 2012e). **Ecology:** - Diet commonly contains invertebrates such as shrimp, arthropods, oregoniids, euphasiids, and crustaceans (Simon et al. 2012).	**Global:** - *M. senta* are endemic to the northwestern Atlantic Ocean. They range from the Hopedale Channel (mid-Labrador coast) to the southern Georges Bank. The distribution of the species is disjunct, and within Canada they form four designatable units (DUs): Hopedale Channel, Funk Island Deep, Nose of the Grand Bank, and Laurentian-Scotian (COSEWIC 2012e). **Regional:** - Distribution in NAFO Divs. 2HJ is largely restricted to Hopedale Saddle and Hawke Channel (Funk Island Deep population). Some other observations have also been made along the edge of the continental shelf. No observations have been made in NAFO Div. 2G.	**COSEWIC Status:** - Data Deficient (Hopedale Channel Population). - Endangered (Funk Island Deep Population). - Data Deficient (Nose of the Grand Banks Population). - Special Concern (Laurentian-Scotian Population). **Abundance and Biomass:** - The most recent minimum abundance estimates for the Hopedale Channel DU was 3.03 million (COSEWIC 2012e). - The most recent minimum abundance estimates for the Funk Island Deep DU was 1.1 million (COSEWIC 2012e). - However, because catchability of skates in trawls is estimated to be low, it is likely that abundance is

Species	Biology/Ecology/Influencing Factors	Distribution	Status, Abundance and Biomass, Trends, Commercial/Cultural Importance
	- Predators include marine mammals (COSEWIC 2012e). **Abiotic/Biotic Factors:** - Species show a preference for soft mud and clay bottoms (COSEWIC 2012e). - In the NL region the species has been observed during RV trawl surveys over a wide depth range (25–1,436 m), but most abundant between 150 m and 550 m. (COSEWIC 2012e). The temperature range which contains the largest concentration of the species is between 3°C and 10°C (COSEWIC 2012e).		greater than estimated above (COSEWIC 2012e). **Population Trends:** - Surveys in the Hopedale Channel DU have been limited and sporadic since 1977 resulting in high uncertainty of trend information (COSEWIC 2012e). - Abundance estimates of mature smooth skate in the Funk Island Deep DU declined by 94% from 1977 to 1995 (COSEWIC 2012e). - More recent numbers suggest increases of 166% between 1995 and 2009; however, the population is still at less than 20% of the peak abundance estimated in the 1970s (COSEWIC 2012e). **Commercial/Cultural Importance:** - There are no directed fisheries for this species, and bycatch has been low in recent years (COSEWIC 2012e).
Roughhead Grenadier (*Macrourus berglax*)	**Biology:** - Benthopelagic species (COSEWIC 2007). - Maximum age of the species is 25 years (COSEWIC 2007). - Females mature at 13–15 years (COSEWIC 2007). - Spawning occurs in the winter and early spring but may extend throughout the year (COSEWIC 2007). - Females have relatively low fecundity, producing an estimated 25,000 eggs (COSEWIC 2007).	**Global:** - *M. berglax* is distributed on both sides of the North Atlantic and in the Arctic Ocean. It has been observed within deep shelf and slope waters from Georges Bank to the Scotian Shelf, off the coast of Newfoundland along the Grand Bank and northeast Newfoundland and Labrador Shelves, into the Davis Strait, and off western Greenland. On the eastern portion of the North Atlantic, abundances exist off southeastern	**COSEWIC Status:** - Special Concern (Atlantic Ocean Population). **Abundance and Biomass:** - 2015 abundance and biomass estimates indicate that there were 2,809,512 (910,823 kg) Roughhead Grenadier in division 2H (Simpson et al. 2017). - 2015 abundance and biomass estimates indicate that there were 20,251,529 (7,612,162 kg) of

Species	Biology/Ecology/Influencing Factors	Distribution	Status, Abundance and Biomass, Trends, Commercial/Cultural Importance
	- Spawning grounds are thought to lie on the southern and southeaster slopes of the Grand Bank (Scott and Scott 1988). **Ecology:** - Generalist predators whose diet consists of benthic and benthopelagic invertebrates (González et al. 2006; Simpson et al. 2017). - Predators include Atlantic Cod, White Hake, Spinytail Skate, Greenland Halibut, and Black Dogfish (Simpson et al. 2017). **Abiotic/Biotic Factors:** - Suitable water temperatures range from -0.5°C to 5.4°C but prefer temperatures from 1–4°C (Simpson et al. 2017). The species has been observed at depths of 100–2,700 m; however, they are most dense between 500 m and 1,500 m in NL (COSEWIC 2007; Simpson et al. 2017).	Greenland, Iceland, the Faroe Islands, Ireland, Norway, Svalbard, and within the Barents Sea (COSEWIC 2007). **Regional:** - Distributed along the edge of the continental shelf throughout NAFO Divs. 2GHJ, as well as within channels along shelf in NAFO Divs. 2HJ.	Roughhead Grenadier in division 2J (Simpson et al. 2017). **Population Trends:** - No conversion factor exists for the Engel time series so direct comparison between Engel and Campelen time series is not possible; however, abundance and biomass in divisions 2J3K exhibited declines from 1977–1994, followed by increases from 1995–2015 (Simpson et al. 2017). - In the 1980s catch rates declined by 90–95%; during this time the species distribution shifted to deeper strata (COSEWIC 2007). - This shift was thought to be a result of cooling shelf waters and/or local depletion by fisheries; however, since environmental conditions of the shelf waters returned to pre-1980 conditions, the species has not moved to reoccupy the area (COSEWIC 2007). **Commercial/Cultural Importance:** - The directed fishery for this species is currently under moratorium, but it is taken as by-catch, primarily from Greenland Halibut gillnet fisheries (COSEWIC 2007; Simpson et al. 2017).
Atlantic Salmon (*Salmo salar*)	**Biology:**	**Regional:** - The Canadian range of Atlantic Salmon is from Maine, U.S.A. to the	**COSEWIC Status:** - Not at Risk (Labrador population) (COSEWIC 2010c).

Species	Biology/Ecology/Influencing Factors	Distribution	Status, Abundance and Biomass, Trends, Commercial/Cultural Importance
	- Can live up to 14 years but typically individuals live from 4 to 8 years (Gibson 1993 *in* COSEWIC 2010c). - Pelagic, schooling fish species. - Matures at sizes ranging from 10 cm to >100 cm. - There are differences in growth and maturity between anadromous and resident salmon populations. - Fecundity varies by body weight and may be between 1,300 and 2,500 eggs per kg (Coad and Reist 2018). **Ecology:** - Freshwater resident (lacustrine/riverine) and oceanic migrant (anadromous) forms. - Salmon exhibit substantial phenotypic plasticity and are able to tolerate a wide range of variability in habitat and environmental variability. - Iteroparous (individuals can engage in multiple spawning events over their lifetime). - Adults return to natal rivers to spawn primarily between May and November but may also start as early as March. - Eggs are deposited in redds within streams primarily in October and November, incubate over the winter and hatch in April. - Hatched salmon feed off their yolk sac for several weeks before emerging from the gravel as parr. - Juveniles spend one to eight years in fresh water, then one to four years in	outer Ungava Bay and eastern Hudson Bay in Quebec. There are an estimated 700 rivers within the Canadian range that historically and/or currently support salmon habitation (COSEWIC 2010c).	- Salmon from other COSEWIC-listed populations from southern DUs are known to migrate through the Study area and/or the Labrador Sea during feeding migrations (COSEWIC 2010c). **Abundance and Biomass:** - Abundance data unavailable for most rivers in Labrador however the estimated number of mature individuals in each population of the overall Labrador population ranges from 151,049 to 307,731 (COSEWIC 2010c). **Population Trends:** - Average age of adult spawning salmon in the Labrador population is 6.3 years (generation time). - 380% increase in the number of mature individuals over 3 generations (from 1993–2008). - Stable trend in number of populations (for Labrador population) (COSEWIC 2010c). - There are 89 rivers in Labrador with known salmon populations (Reddin et al. 2010). - In Labrador (SFAs 1, 2, and 14B), large salmon that have spent multiple years at sea constitute an important component of these populations (DFO 2018c). - Genetic mixture estimates of 817 salmon samples from the coastal

Species	Biology/Ecology/Influencing Factors	Distribution	Status, Abundance and Biomass, Trends, Commercial/Cultural Importance
	salt water before returning back to natal rivers to spawn. - While at-sea, individuals undertake large-scale migrations (sometimes as far as feeding grounds off western Greenland) to feed and develop (COSEWIC 2010c). - Approximately 40% of Canadian salmon travel to feed in the Greenland feeding grounds (Coad and Reist 2018). - Juveniles tend to feed on invertebrates such as amphipods, copepods, euphausids and crustaceans whereas adults prey on a variety of invertebrates and fish species (COSEWIC 2010c). **Abiotic/Biotic Factors:** - A variety of birds and fish are predators of salmon eggs and juvenile salmon; sea-going salmon are also subject to predation by marine mammals. - Preferred temperatures: egg fertilization and incubation=6°C; juveniles and adults= ~7–17°C (COSEWIC 2010c). - Prefer rivers that are clear, cool, and well oxygenated with gravel, cobble, and boulder substrates. - A number of diseases have been identified to occur in salmon and they also may be affected by sea lice.		Labrador fishery in 2015 and 2016 indicate that ~98–99% of the salmon originate from central Labrador (DFO 2018c). **Commercial/Cultural Importance:** - Important fish species in subsistence fisheries for food, social, and ceremonial (FSC) purposes; also targeted in recreational fisheries within the study area.
Arctic Char (*Salvelinus alpinus*)	**Biology:** - The majority of char caught in northern Labrador are less than 15 years old (DFO 2001). - Pelagic, schooling fish species - Slow growth in freshwater.	**Regional:** - Circumpolar distribution; in North America Arctic Char can be found along coastal areas where freshwater drains into the sea from Maine, along Newfoundland and Labrador, and as far west as Alaska.	**COSEWIC Status:** - No status. **Abundance and Biomass:** - No independent estimates of char abundance from stock complexes of the Nain Fishing

Species	Biology/Ecology/Influencing Factors	Distribution	Status, Abundance and Biomass, Trends, Commercial/Cultural Importance
	- Char from northern Labrador tend to mature at younger ages and smaller sizes than char stocks in the Canadian Arctic (DFO 2001). - Age of sexual maturity for char from Newfoundland and Labrador is usually 6–8 years for males and 8–10 years for females (Dempson 1984). - Females spawn every 2–3 years (Scott and Crossman 1973). - Females lay ~290 eggs per 100 g of body mass (DFO 2001). **Ecology:** - Most northern distributed freshwater fish species and the most abundant anadromous fish in sub-Arctic and Arctic waters (Coad and Reist 2018). - Freshwater resident (lacustrine/riverine) and oceanic migrant (anadromous) forms. - Arctic Char exhibit substantial phenotypic plasticity and are able to tolerate a wide range of variability in habitat and environmental variability. - Iteroparous. - Char reproduce and overwinter in freshwater (Dempson et al. 2004). - Char can spend up to seven years in freshwater before undertaking at-sea migrations. - Estimated to spend 8–9 weeks feeding at sea in northern Labrador (Dempson and Kristofferson 1987). - The magnitude and duration of marine migrations can be determined by fish		Region (stock complexes Voisey, Nain, and Okak) - Largely unknown number of char harvested in recreational and subsistence fisheries. **Population Trends:** - Anadromous populations of Arctic Char tend to be predominant in northern areas whereas resident freshwater Arctic Char are predominant in southern areas (DFO 2001). **Commercial/Cultural Importance:** - Important fish species in subsistence fisheries for food, social, and ceremonial (FSC) purposes; also targeted in commercial and recreational fisheries.

Species	Biology/Ecology/Influencing Factors	Distribution	Status, Abundance and Biomass, Trends, Commercial/Cultural Importance
	size, maturity, environmental conditions, and prey availability (Coad and Reist 2018). - While undertaking their marine migrations, char are primarily coastal and remain within local bays and fiords, usually migrating less than 100 km from their natal rivers (Dempson et al. 2004; DFO 2001). - Larger, more mature fish are known to migrate up river first, followed by smaller, non-mature individuals, and juveniles (Dempson and Kristofferson 1987). - Migration of char to the sea coincides with spring run-off and ice breakup in coastal rivers (Dempson et al. 2004). - Migration of adult char to fresh water peaks in late July and early August (Dempson and Green 1985). - Spawning of char in Labrador typically occurs in October and November; eggs incubate over winter and hatch in the spring. - Diet analyses of char in northern Labrador indicate that they feed primarily on Capelin, Sand Lance, Sculpins, mysids, amphipods, and other prey while at-sea (Dempson et al. 2002). **Abiotic/Biotic Factors:** - Spawn over a variety of substrates (DFO 2001). - Preferred temperatures range is 4–16°C (Kearley 2013).		

Species	Biology/Ecology/Influencing Factors	Distribution	Status, Abundance and Biomass, Trends, Commercial/Cultural Importance
Brook Trout (*Salvelinus fontinalis*)	**Biology:** - Freshwater resident (lacustrine/riverine) and oceanic migrant (anadromous) forms. - Pelagic, schooling fish species. - Max lifespan is 20 years (Coad and Reist 2018). - Can grow up to 6.6 kg with average length of 250–300 mm. - Sexual maturity usually reached after 3 years (Scott and Crossman 1973). - Females lay ~295 eggs per kilogram of body mass (Kearley 2013). **Ecology:** - Anadromous Brook Trout complete their migration to spawning areas from June to September (Scott and Crossman 1973). - Spawning occurs on gravel beds along headwater streams or in gravel shoals of ponds (McCubbin et al. 1990). - Overwinter in freshwater from July/August to May. - Generally, do not undertake wide-spread migration while at sea (Scott and Scott 1988; Coad and Reist 2018); usually staying within a few kilometers of their home rivers (Kearley 2013). - Labrador has an estuarine form that inhabit estuaries and the mouths of rivers and a sea-run form that make marine migrations (Coad and Reist 2018). **Abiotic/Biotic Factors:**	**Regional:** - Found in northeastern North America. Ranges from the Mississippi River basin up to the Gulf of St. Lawrence and the Great Lakes, along Newfoundland and Labrador, and extending up to Baffin Island.	**COSEWIC Status:** - No status. **Abundance and Biomass:** - Unavailable. **Population Trends:** - Unavailable. **Commercial/Cultural Importance:** - Important fish species in subsistence fisheries for food, social, and ceremonial (FSC) purposes; also targeted in recreational fisheries.

Species	Biology/Ecology/Influencing Factors	Distribution	Status, Abundance and Biomass, Trends, Commercial/Cultural Importance
	- Diet consists of small invertebrates (including aquatic insect larvae, terrestrial insects, and zooplankton) and fish (such as Threespine Stickleback). - Predators include fish as well as piscivorous birds (Kearley 2013). - Prefer cool, clear, well oxygenated waters (Scott and Crossman 1973).		
Smelt (*Osmerus mordax*)	**Biology:** - Live up to 7 years. - Pelagic, schooling fish species. - Reach sexual maturity from 2–6 years of age. - Mature length is 20 cm. - Females can lay up to 70,000 adhesive eggs that attach to substrates. - Eggs are deposited over gravel, sandy bottoms (Kearley 2013). **Ecology:** - Freshwater resident (lacustrine/riverine) and oceanic migrant (anadromous) forms. - Anadromous and landlocked Smelt migrate upstream to their natal rivers in spring to spawn. - Anadromous adult Smelt return from the sea in fall to overwinter in estuaries (Bradbury et al. 1999). - Diet: Larvae consume zooplankton while adults eat invertebrates such as shrimp, zooplankton, worms, and small fishes (Kearley 2013). **Abiotic/Biotic Factors:** - Predators include large fishes as well as birds and marine mammals.	**Regional:** - Along the east coast of North America Smelt are distributed as far south as the Delaware River and extend north to the Gulf of St. Lawrence, the coast of Labrador and into the Arctic. There are also land-locked populations in Newfoundland and Labrador, New Brunswick, Nova Scotia, Quebec, and Eastern Ontario (Kearley 2013).	**COSEWIC Status:** - No status. **Abundance and Biomass:** - Unavailable. **Population Trends:** - Unavailable. **Commercial/Cultural Importance:** - Recreational fishery for smelt. - Important forage fish species for commercial and non-commercial fish species.

Species	Biology/Ecology/Influencing Factors	Distribution	Status, Abundance and Biomass, Trends, Commercial/Cultural Importance
	- Preferred temperature range: 7.2°C to 15.6°C (Kearley 2013).		
Round Whitefish (*Prosopium cylindraceum*)	**Biology:** - Live up to 14 years of age. - Iteroparous. - Mature at ages 3 to 8. - Fecundity ranges from 1,000–25,000 eggs per female (Stewart et al. 2007). **Ecology:** - Usually found in ponds, rivers, and streams; however, they can also be found in estuarine/brackish waters, though they may not be as common in brackish waters of Labrador (Backus 1957 *in* Bradbury et al. 1999). - Whitefish spawn generally in November and/or December in shallow areas of rivers, river mouths, and inshore areas of lakes when the water temperature is 2–4.5°C (Normandeau 1969; Scott and Crossman 1973; Bruce 1974; Bryan and Kato 1975; Morrow 1980; Haymes and Kolenosky 1984 *in* Bradbury et al. 1999). - Eggs hatch in April where hatchlings remain on the bottom until migrating out of the spawning area after two to three weeks (Normandeau 1969; Morrow 1980 *in* Bradbury et al. 1999). - Whitefish primarily feed on small benthic invertebrates (Bruce 1974, 1975; Parsons 1975; Armstrong et al. 1977; Ryan 1980 *in* Bradbury et al. 1999). **Abiotic/Biotic Factors:**	**Regional:** - Found in southern Labrador except in areas around the southeastern coast; no reports of whitefish north of the Fraser River (Scott and Crossman 1973; Bruce et al. 1979; Dempson, unpublished data *in* Bradbury et al. 1999).	**COSEWIC Status:** - Not assessed. **Abundance and Biomass:** - Unavailable. **Population Trends:** - Unavailable. **Commercial/Cultural Importance:** - No fisheries target this fish species.

Species	Biology/Ecology/Influencing Factors	Distribution	Status, Abundance and Biomass, Trends, Commercial/Cultural Importance
	- Found commonly in water temperatures from 0°C to 18°C and above 37 m depth in freshwater (Stewart et al. 2007). - Preyed upon by other fishes (Steinhart et al. 2007; Weidel et al. 2007 *in* Stewart et al. 2007).		

APPENDIX E – MARINE MAMMALS

Table E-1: Biology, ecology, abiotic and biotic factors, distribution, status, abundance/biomass and population trends for important cetacean species in the Coastal Labrador study area.

Species	Biology, Ecology, Influencing Factors	Distribution	Status, Abundance/Biomass, Trends
Beluga Whale (*Delphinapterus leucas*) AKA "White whales", "White fish", "White walrus"	**Biology:** - Lifespan is 15–30 years, although they may live beyond 40 years (COSEWIC 2004). - Females become sexually mature at 4–7 years of age, while males achieve it between 6–7 years (COSEWIC 2004). - It is estimated that belugas have a 3.25-year cycle between successive pregnancies (COSEWIC 2004). - Calves are gradually weaned between 12 and 24+ months (Matthews and Ferguson 2015). **Ecology:** - Belugas generally prefer sea ice cover of 70% or less, although they also use areas with multi-year ice and ice concentrations of up to 90% (Barber et al. 2001; Asselin et al. 2011). - Diet has not been well described, but it is likely to include both capelin and Arctic cod, which are important components of Arctic marine food webs and form dense aggregations during the open-water season (Welch et al. 1993; Kelley et al. 2010). - Along the Labrador coast, beluga diving activity suggests repeated movement between partially ice-covered sea surface habitats and warmer, deep-sea areas. Such activity may be associated with foraging (Bailleul et al. 2012). - Belugas wintering in the Labrador Sea continued to spend a large proportion (80%) of their time diving. There, individuals either remained close to the surface or dived close to the sea floor, spending little time in between (Bailleul et al. 2012). - The absence of belugas in some areas has been attributed to the presence of killer whales (Brice-Bennett 1978). **Abiotic/Biotic Factors:** - Optimal temperature range is from 0–4°C (Scott and Scott 1988). - In the Labrador Sea, Eastern Hudson Bay (EHB) beluga preferentially selected an area on the continental plateau characterized by a deep trough (353 ± 171 m). In this region, most of the water column had temperatures of ~0°C, with a minimum of -1.8°C. The one exception was a deep zone where	Populations of Beluga Whales are defined by their summer distributions. The Hudson Bay complex is made up of several populations that migrate to other areas during the winter. Some Eastern Hudson Bay (EHB) beluga are known to migrate to the Labrador Shelf, whereas James Bay whales seem not to (Bailleul et al. 2012). However, in a study where genetics samples were collected off the Labrador coast, 4 beluga whales were from a mix of the Eastern Hudson Bay, northern Hudson Bay, and Baffin Island stocks (J. Lawson and L. Postma, pers. comm.). An analysis of telemetry data using the First Passage Time (FPT) approach identified three seasonally dependent residency areas for EHB beluga: Eastern Hudson Bay, Ungava Bay and the Labrador Sea. The belugas remained in the Labrador Sea during winter months, which was defined as 22 December to 20 March by researchers (Bailleul et al. 2012). Individuals left Ungava Bay between 1 and 25 December, after spending on average 40 ± 17 d there (range: 6 to 55 d). The belugas then migrated approximately 570 km along the coast to an area of deep	**COSEWIC Status:** - The EHB beluga population wasis assessed as endangered by COSEWIC in 2004. **Abundance/Biomass:** - Information is not available, as population size of this species is not well researched in the region (J. Lawson, pers. comm.). **Population Trends:** - The EHB beluga population declined from 4,200–3,100 individuals over the period 1985 to 2004 (Doniol-Valcroze et al. 2011).

Species	Biology, Ecology, Influencing Factors	Distribution	Status, Abundance/Biomass, Trends
	EHB beluga systematically dove to depths where temperatures were between 3 and 4°C (Bailleul et al. 2012). - Depth range of 0–400 m (Froese and Pauly 2016); with highest densities at 100–300 m (Scott and Scott 1988). - Warming temperatures resulting from global warming are likely to impact the distribution of this species (Hop and Gjøsæter 2013). - In a study on several populations of Beluga Whales, researchers found that growth, but not mortality, showed a significant positive relationship with latitude (Luque and Fergurson 2010). Age distributions differed among populations, with animals harvested at the highest-latitude population being the oldest and attaining the longest adult body lengths, compared to lower-latitude populations such as those from Eastern Hudson Bay (Luque and Ferguson 2010).	troughs along the Labrador shelf, where they arrived between 31 December and 23 January and remained until tag failure 61 ± 46 d later.	
Fin Whale (*Balaenoptera physalus*)	**Biology:** - Reach maturity at 5–15 years of age (Perry et al. 1999). - Average length at sexual maturity in the northern hemisphere is 17.2 m (Mitchell 1974; Ratnaswamy and Winn 1993). - Mating and calving are thought to occur in the winter, at low latitudes (Mizroch et al. 1984; Reeves et al. 2002). - Females give birth to a single calf after a gestational period of up to 12 months (COSEWIC 2005). - Calves wean after approximately 6–7 months of age (Omura 1950; Gaskin 1976; Ratnaswamy and Winn 1993). - The mean period between calves is 2.71 years (Agler et al. 1993). - Lifespan is estimated to be 80–90 years (NOAA 2013), may be as high as 100 years (COSEWIC 2005). **Ecology:** - Upon weaning, fin whales show no evidence of long-term social bonds, although they have been observed travelling in groups of 2–7 animals. Larger aggregations have also been found to occur in areas of high productivity (Aguilar and Lockyer 1987), such as off the southwest coast of Greenland. - The diet of fin whales varies based on location and is thought to reflect the species preferences as well as the availability of prey. In eastern Canada, Fin Whale diets consist of euphausiids early in the year and capelin later in the summer (Sergeant 1966), with capelin dominating the diet for fin whales off of Newfoundland and southern Labrador (Mitchell 1974; Brodie et al. 1978; Whitehead and Carscadden 1985). In the fall, spawning herring	Fin whales are found in all major oceans but are more abundant in temperate and polar latitudes (Leatherwood et al. 1988; Reeves et al. 2002). Evidence also suggests that the species is absent along ice edges and in equatorial areas, and that the density of the species is higher beyond the continental slope than near shore (Aguilar et al. 2002). In Canada, the species is most common in the Atlantic Ocean where summer aggregations have been observed off Newfoundland and Labrador, in the St. Lawrence, on the Atlantic coast of Nova Scotia, and in the Bay of Fundy (Mitchell 1974; Perkins and Whitehead 1977; Sergeant 1977). Fin whales in Newfoundland and Nova Scotia appear to move southward in the winter, with the Newfoundland stock summering off the coast of Nova Scotia (Allen 1971; Mitchell 1974).	**COSEWIC Status:** - The Atlantic population of fin whales was assessed as a species of Special Concern by COSEWIC in 2005 and is currently listed on Schedule 1 as a species of Special Concern the SARA (DFO 2017b). **Abundance/Biomass:** - Recent estimates from the Northwest Atlantic International Sightings Survey (NAISS; Lawson and Gosselin 2018) are ~4,400 (compared to ~4,100 in the 2007 Trans North Atlantic Sightings Survey [TNASS]; Lawson and Gosselin 2009) **Population Trends:** - Historic population estimates indicate that there were 30,000–50,000 individuals in the North Atlantic; however, this was reduced as a result of commercial whaling during the 20th century. The population

Species	Biology, Ecology, Influencing Factors	Distribution	Status, Abundance/Biomass, Trends
	and mackerel off Southern Labrador are the most likely food source for these whales (Sergeant 1966; J. Lawson, pers. comm.). **Abiotic/Biotic Factors:** - During the summer, most Fin Whales inhabit high latitudes and the cold eastern boundary currents where food production is high. They range mostly offshore and tend to be nomadic (Mizroch et al. 1984). The reproductive strategy of Fin Whales is closely integrated and synchronized with their annual feeding cycle. Their basic reproductive cycle is biennial, consisting of mating during the winter, birth of the large single precocial calf about a year later on the winter grounds, and weaning of the calf before the end of the following summer on the feeding grounds (Mackintosh and Wheeler 1929; Laws 1961).		level of fin whales in the western North Atlantic was thought to range between 3,600 and 6,300 individuals in the early-1980s (Cetacean and Turtle Assessment Program [CeTAP] 1982). A 1985 analysis of inshore whale abundance in relation to capelin year-class strength suggested that fin whale populations off the Newfoundland and southern Labrador coasts were declining (Whitehead and Carscadden 1985). Subsequent population estimates varied, but 1,013 Fin Whales were believed to inhabit the waters near Newfoundland in 2002, with approximately 53,000 Fin Whales in the whole North Atlantic region in 2000 (Reilly et al. 2013). Recently, the population trend seems to be positive (J. Lawson, pers. comm.).
Harbour Porpoise (*Phocoena phocoena*)	**Biology:** - Harbour Porpoises (*Phocoena* phocoena) are among the smallest cetaceans, with few individuals in eastern Canada exceeding 1.7 m. While there is no information specific to the study area, females in Newfoundland waters grow to be up to 156 cm and 62 kg, while males reach just 143 cm and 49 kg (Richardson 1992). - The species exhibits seasonal reproductive cycles, with conception restricted to a small period of time in the late spring or early summer (Börjesson and Read 2003). - Gestational periods last 10–11 months, and most mature females become pregnant every year (Read 1999; COSEWIC 2006a, NOAA 2014b).	Harbour porpoises are distributed over the continental shelves in cold temperate and sub-polar waters of the Northern Hemisphere (Gaskin 1984; IWC 1996). In eastern Canada, the species is found from the Bay of Fundy northwards to Baffin Island (Gaskin 1992). Reported bycatch information indicates that the species occurs around the entire island of Newfoundland as well as	**COSEWIC Status:** - The Northwest Atlantic population of Harbour Porpoise has been assessed as a species of Special Concern by COSEWIC (COSEWIC 2006a). It is also listed on Schedule 2 as Threatened under the SARA. **Abundance/Biomass:** - During the 2007 TNASS, the estimate for this species was ~8,000 for Atlantic Canada;

Species	Biology, Ecology, Influencing Factors	Distribution	Status, Abundance/Biomass, Trends
	- Calves are weaned at around 8 months (COSEWIC 2006a). - Both females and males reach sexual maturity at approximately 3 years of age (Richardson 1992). - Females reach sexual maturity between 3–4 years of age (NOAA 2014b). - The maximum reported age of the species was estimated to be 24 years of age (Lockyer 1995); however, few individuals are thought to live past their teens (Richardson 1992; Read and Hohn 1995), with the average lifespan being 8–10 years (Culik 2010a). **Ecology:** - A stomach content analysis of harbour porpoises from eastern Canadian coastal waters during 1969–72 revealed that Herring, Atlantic cod and Mackerel accounted for more than 78% of the total diet. Smelt, Pollock, Silver Hake, Redfish and Ocean Pout, Squid, Hagfish, and polychaetes were also identified in the diet in lesser numbers (Smith and Gaskin 1974). **Abiotic/Biotic Factors:** - Harbour porpoise distribution is highly related to the distribution of prey (herring) in the northeast Atlantic (Sveegaard et al. 2012).	in southern Labrador (Lien et al. 1994; Lawson et al. 2004). In the NL region this species is not seen as commonly as the Atlantic White-Beaked Dolphin (J. Lawson, pers. comm.). A recent genetics study for the north Atlantic suggests the Greenland and Canadian stocks do not mix much (Olsen et al. 2022).	however, conditions were poor in the Gulf during the survey, so the estimate was thought to be low (J. Lawson, pers. comm.). During the 2016 NAISS, the estimates were much higher for Atlantic Canada at ~257,000. It was estimated that approximately ~49,000 were found in NL waters with a few off Labrador (J. Lawson, pers. comm.). **Population Trends:** - It is believed that this species has a relatively secure status in the region as a result of measures that have been enacted to restore groundfish stocks (i.e., less fishing gear in the water).
Humpback Whale (*Megaptera novaeangliae*)	**Biology:** - The maximum longevity of humpback whales (*Megaptera novaeangliae*) is approximately 50 years (NOAA 2016a), with females in the North Atlantic reaching sexual maturity at five years (Clapham 1992). - Females give birth to a single calf once every 1–3 years after a gestation period of 11-12 months (Chittleborough 1958; COSEWIC 2003, NOAA 2016a). - Calves are typically born between December and April, but rates peak between January and February. - Mating-related activities also occur during this time of the year (COSEWIC 2003). - Most calves are weaned after 1 year, but some after 2 years (COSEWIC 2003). **Ecology:** - The humpback whale has a generalist diet, feeding on euphausiids and various species of small schooling fish. The latter include herring (Clupea spp.), Capelin (Mallotus villosus), sand lance (Ammodytes spp.), and mackerel (Scomber scombrus). Humpbacks appear to be unique among large whales in their use of bubbles to corral or trap schooling fish.	Humpback whales can be found in tropical, temperate, and sub-polar waters around the world. In the Atlantic, the species is found from the West Indies to Greenland and is commonly observed in Eastern Canada along the coast of Labrador, south along Newfoundland, as well as within the Gulf of St. Lawrence during the summer (Reilly et al. 2008b; Baird 2003). Humpback whales from the North Atlantic have been found to migrate from high-latitude summer feeding areas to the West Indies for breeding and calving during the winter (Whitehead 1982; Martin et al. 1984; Stevick et al. 2003).	**COSEWIC Status:** - The Western North Atlantic population of Humpback whales was assessed as not at risk by COSEWIC in 2003; however, it is listed on Schedule 3 as a species of Special Concern under the SARA. **Abundance/Biomass:** - The estimate from the NAISS for Atlantic Canada was ~10,400, which was greater than the TNASS estimate (J. Lawson, pers. comm.). Approximately 8,500 whales are estimated to inhabit NL waters, with fewer being found off Labrador than off the island of Newfoundland (J. Lawson, pers. comm.).

Species	Biology, Ecology, Influencing Factors	Distribution	Status, Abundance/Biomass, Trends
	Abiotic/Biotic Factors: - Sources of natural mortality of the species include predation, parasitism, disease, biotoxins, beaching, or entrapment (COSEWIC 2003). - There is little understanding of how humpbacks navigate across thousands of miles on their annual migrations, though biomagnetic orientation has been suggested (on little direct evidence) as a component of this ability (Clapham 2009).	Although common in NL, the species is not considered to be unique to the region.	**Population Trends:** - Although the species faced declines as large as 90–95% because of commercial whaling practices in the first half of the 20th century (Johnson and Wolman 1984), it seems to have recovered to a substantial proportion of its pre-whaling size (COSEWIC 2003). The current population trend appears to be increasing (COSEWIC 2003) at a rate of about 3% per year (Reilly et al. 2008b). Population estimates from 1992–93 indicate that there are 11,570 individuals in the North Atlantic (Stevick et al. 2001).
Killer Whale (*Orcinus orca*) AKA "Thrashers"	**Biology:** - Male Killer Whales live for about 30-60 years and females live for about 50–80 years (NOAA 2016b; COSEWIC 2008c). Some may live up to 90 years (Culik 2010b). - Killer whales exhibit sexual dimorphism, with males reaching a maximum of 9 m in length, and females just 7.7 m (Dahlheim and Heyning 1999). - Male killer whales are sexually mature at 12 years of age on average (COSEWIC 2008c). - Female killer whales are sexually mature when they are 4.6–5.4 m in length (NOAA 2016b). - On average females give birth to their first calf at 14.1 years (Olesiuk et al. 2005) after a 16–17 month gestational period (Walker et al. 1998; Duffield et al. 1995). - Females produce single calves (NOAA 2016b; COSEWIC 2008c; Culik 2010b). - Calves are born throughout the year, but rates peak from fall through spring. - Calves are typically weaned between 1 and 2 years of age (NOAA 2016b).	Killer whales found throughout all oceans around the globe and the majority of seas, with ranges only limited by ice in high latitudes (COSEWIC 2008c). There are five distinct populations in Canadian waters (COSEWIC 2008c). The species is most commonly found in highly productive areas, with ranges extending along the east coast from the Scotian Shelf north to Baffin Bay, with extensions into Hudson Bay (COSEWIC 2008c). They are most commonly observed in Newfoundland and Labrador between June and September and are concentrated along the eastern portions of the Island (Lawson and Stevens 2014; J. Lawson, pers. comm.).	**COSEWIC Status:** - The Northwest Atlantic/Eastern Arctic population of killer whales was assessed as a species of Special Concern by COSEWIC in 2008. **Abundance/Biomass:** - The size of the Northwest Atlantic and Eastern Arctic population is not precisely known but estimates indicate that there are likely fewer than 250 individuals remaining (COSEWIC 2008c). Based on photographic records, there are at least 67 identified killer whales in the NW Atlantic; this is an underestimate, since a large portion of images collected was not of sufficient quality to be considered in the

Species	Biology, Ecology, Influencing Factors	Distribution	Status, Abundance/Biomass, Trends
	- The average interbirth interval is an estimated 5 years for some populations (COSEWIC 2008c, NOAA 2016b). - Females produce their last calf at approximately 40 years of age but can live well beyond this age. **Ecology:** - The diet of killer whales varies based on location, but in the northwest Atlantic they have been known to consume white-beaked dolphins, common Minke Whales, Belugas, Humpback whales, Harp Seals, Razor-Billed Auks, Bluefin Tuna, and herring (Lien et al. 1988; Lawson et al. 2007). **Abiotic/Biotic Factors:** - Killer Whales are inherently vulnerable as a result of their discrete populations and limited interbreeding amongst populations. However, they can tolerate wide ranges of salinity, temperature and turbidity (COSEWIC 2008c), and their distribution appears to be determined mainly by the distribution and accessibility of their prey. Receding sea ice appears to be making new habitat (and prey resources) available to Killer Whales in the Arctic (Ferguson et al. 2010).		analysis, and many of the whales do not have easily discernible markings. The discovery curve of newly identified whales has not plateaued, suggesting that there are more whales to identify (Lawson and Stevens 2014). **Population Trends:** - There is no reliable information available on trends (Taylor et al. 2013); however, local knowledge indicates there have been increases in the number of sightings in the eastern Canadian Arctic (NAMMCO 2005; Higdon 2007). It is not clear whether this is the result of increasing population size, increasing sighting efforts, or increasing extent of ice-free habitat (COSEWIC 2008c). The IUCN acknowledges that a 30% reduction over three generations is a possibility for some populations (Taylor et al. 2013). The population in Newfoundland and Labrador waters appears to be recovering (J. Lawson, pers. comm.).
Minke Whale (*Balaenoptera acutorostrata*)	**Biology:** - Can live to approximately 50 years (NOAA 2014a). - Females become sexually mature between 6 and 8 years, while males reach maturity between 6 and 7 years (Christensen 1981; Olsen and Sunde 2002). - The gestational period of the species is 10 months (Hauksson et al. 2011), with peak calving occurring in December for the North Atlantic population (Evans 1987).	Minke Whales are distributed throughout all oceans generally between latitudes 65°S and 80°N. Within the North Atlantic the summer range extends from New Jersey north to Baffin Bay (IUCN). Limited records indicate that the species migrate south in the	**COSEWIC Status:** - The North Atlantic population of Common Minke Whale was assessed as not at risk by COSEWIC in 2006. **Abundance/Biomass:** - Population estimates produced by the IWC in 2003 indicated

Species	Biology, Ecology, Influencing Factors	Distribution	Status, Abundance/Biomass, Trends
	- Females give birth to a single calf (NOAA 2014a) which is weaned after 4–6 months (NOAA 2014a). - The interbirth interval is an estimated 14 months (NOAA 2014a). **Ecology:** - Diet for Minke Whales in the North Atlantic region is comprised primarily of small schooling fish, demersal fish, and krill, and has been found to vary over time and space. - In Newfoundland and Labrador, Capelin is the dominant prey item of minke whales. Other less significant prey species include cod, herring, salmon, squid and shrimp (Sergeant 1963; Piatt et al. 1989). - Minke whales in more northern areas consume mostly krill, while herring, Capelin, and gadoids are consumed more commonly in other areas (Lindstrøm and Haug 2002). **Abiotic/Biotic Factors:** - The abundance of minke whales in Newfoundland and Labrador waters is directly dependent on dense schools of capelin (Sergeant 1963). - Minke Whales are found off Labrador shortly after the break-up of ice and until freeze-up in early winter (Sergeant 1963).	winter to Bermuda, the Bahamas, and the Antilles (Mitchell 1991). Some of the population also over-winter within the summer range (IUCN).	that there are over 180,000 Minke Whales in the northeastern, central North Atlantic, and West Greenland populations combined. The total population of minke whales in the North Atlantic is an estimated 15,000 (COSEWIC 2006b). Estimates of abundance from NAISS for the NL region (Lawson and Gosselin 2018) were approximately 13,000 individuals with ~6,200 of them occurring in the Gulf of St. Lawrence and Scotian Shelf (J. Lawson, pers. comm.). **Population Trends:** - The current population trend is stable (Reilly et al. 2008a). Minke whales are the most abundant rorqual in the world (NOAA 2014a).
White-beaked Dolphin (*Lagenorhynchus albirostris*)	**Biology:** - The maximum recorded age was 37 years (Culik 2010c). - Females mature on average at 8.7 years and males at 11.6 years (Galatius and Kinze 2007). - Females give birth to a single calf after a gestation period of 11–12 months (NOAA 2012). - At the genus level, weaning occurs after 12–18 months (Brownell and Donahue 1999). **Ecology:** - The diet of White-Beaked Dolphins varies by location, but primarily consists of cod (Kinze et al. 1997) and cephalopods (Santos et al. 1994). Foraging by the species is conducted in groups, where they will hunt in a front and surround the prey. Mean school size of the species varies by location but ranges from 4–6 individuals; although much larger groups have been observed in offshore areas (Kinze 2009). **Abiotic/Biotic Factors:**	White-beaked dolphins are found within temperate and subarctic waters of the North Atlantic. In the western North Atlantic, the species extends from Cape Cod, north to the southern portion of Greenland (Kinze 2009; Hammond et al. 2012). The Labrador shelf including south western Greenland is considered one of four centers of high diversity for this species; with the other three centers being Icelandic waters, the waters around Scotland including the northern Irish Sea and the North Sea, and the small shelf stretch along the Norwegian coast	**COSEWIC Status:** - The Atlantic Ocean population of White-beaked dolphin was assessed as not at risk by COSEWIC in 1998. **Abundance/Biomass:** - For Atlantic Canada, the population is estimated to be ~600,000 (Lawson and Gosselin 2018); however, analyses are still ongoing, and the estimate is expected to increase (J. Lawson, pers. comm.). - The number of individuals is not well known for each of the populations, but the Labrador coast region has been

Species	Biology, Ecology, Influencing Factors	Distribution	Status, Abundance/Biomass, Trends
	- This species is known to associate with large whale, and other dolphin species during feeding (Reeves et al. 1999).	extending north into the White Sea (Kinze 2009).	described as having several thousand individuals (Alling and Whiteland 1987). **Population Trends:** - Insufficient data exists to determine the population trend for the Atlantic White-Beaked Dolphin (Hammond et al. 2012; NOAA 2012).

Table E-2: Major threats to cetacean species found in the Coastal Labrador study area.

Species	Major Threats
Beluga Whale	This species is not a major commercial species but has been subject to a directed fishery in the USSR, and by Norway, Danish, and German vessels (COSEWIC 2004).
Fin Whale	Since the cessation of whaling in the 1970s, common causes of fin whale mortality have included ship strikes and entanglement. Other potential, but invalidated threats include interactions with fisheries, exposure to human-generated noise, chemical pollution, and climate change (COSEWIC 2005).
Harbour Porpoise	The most significant threat to the species is bycatch in fishing gear. In 2002 it was estimated that 1,500–2,000 harbour porpoises were bycaught in the nearshore cod fishery around Newfoundland (COSEWIC 2006a). In Greenland, the species is also hunted for consumption. It is possible the individuals removed as a result of this could be from the Newfoundland and Labrador sub-population (COSEWIC 2006a). Although a recent genetics study for the north Atlantic suggests the Greenland and Canadian stocks do not mix much (Olsen et al. 2022).
Humpback Whale	Anthropogenic activities resulting in entanglement, collisions with vessels, exposure to pollutants, interference with prey species, increased vessel traffic, and noise pollution may also have potentially negative effects on the species (COSEWIC 2003).
Killer Whale	Anthropogenic factors such as physical and acoustic disturbances through shipping traffic, prey depletion, and exposure to contaminants (e.g., Desforges et al. 2018) put the species at risk. The Northwestern Atlantic/Eastern Arctic population is also impacted by hunting activities in western Greenland (COSEWIC 2008c).
Minke Whale	Major threats to this species in the North Atlantic include entanglement in fishing gear and ship strikes (Perkins and Beamish 1979; Laist et al. 2001). There is currently an Unusual Mortality Event (UME) declared by for Northeast U.S. minke whales based on unusually large numbers of dead minke whales being found in the U.S. and Atlantic Canada in the last two years. Some of these whales had evidence of gear entanglement, but others died of possible red tide toxins or unknown causes.

Species	Major Threats
White Beaked Dolphin	Historically, mortality of the species was largely associated with directed catches. More recently, threats have been linked to entanglement in fishing gear, high organochlorine, and heavy metal loads (Kinze 2009), and exposure to noise pollution which may cause individuals to strand (NOAA 2018).

Table E-3: Biology, ecology, abiotic and biotic factors, distribution, status, abundance/biomass and population trends for important pinniped species in the Coastal Labrador study area.

Species	Biology, Ecology, Influencing Factors	Distribution	Status, Abundance/Biomass, Trends
Ringed Seal Netsik Pupunatshuk Scientific name: *Phoca hispida* Related terms: - Jar seal - Silver jar (young of the year) - Najangalak (outer island Ringed seal) - Tiggak (mature male) - Otuk (Ringed Seal hauled-out for pring moult)	**Biology**: - Ringed seals (males and females) average 1.5 m and 50–70 kg. - Lifespan for this species is listed by DFO as 25–30 years (DFO 2016), however long-lived individuals can reach 45–50 years (Lydersen and Gjerts 1987). - In the Newfoundland and Labrador region, whelping occurs in the spring (March and April) in subnivean caves dug into sea ice to protect pups from predators and harsh weather conditions (Smith and Stirling 1975). **Habitat and Ecology:** - Diet varies throughout the year. Stomach contents of Ringed seals harvested in Makkovik found seals were feeding primarily on Arctic cod and Greenland cod. Samples from the same area during and after ice break up found more capelin, rock cod, sculpins, and benthic invertebrates (Boles et al. 1980). - Ringed seals dive up to 500 m (Born et al. 2004). - Ringed seal primarily occupy the shorefast ice edge (Brice-Bennet 1977). They use sea-ice almost exclusively for breeding, molting, and resting (i.e., haul-out) habitat (Reeves 1998). - Predators include polar bear, killer whale, fox, gulls, and ravens (Reeves 1998).	Ringed seal are a circumpolar species. They are found throughout the northern Atlantic. They are common as far south as the northern peninsula of Newfoundland but can occasionally be found as far south at New Jersey, USA (Rice 1998). Ringed seals are able to create and maintain breathing holes in ice, allowing them to occupy habitat that is not available to other seal species (DFO 2016; Lowry 2016). In coastal Labrador, Ringed seals move inshore to feed in coastal bays briefly after the ice break-up and move northward for the summer (Boles et al. 1980).	**COSEWIC Status:** - Ringed seal were last assessed by COSEWIC in 1989 and designated **Not at Risk**. - The Marine Mammal Subcommittee has recommended a new assessment for this species (DFO 2016). **Abundance/Biomass:** - There are no estimates of abundance in Labrador waters. Arctic Ringed seal population was estimated at 1,450,000 mature individuals in 2016, (Lowry 2016). **Population Trends:** - Unknown.
Harp seal Kaigulik Pitshuatshuk Scientific name: *Pagophilus groenlandicus*	**Biology:** - Lifespan is 30–40 years (DFO 2016). - Adults average 1.6 m and 130–135 kg (DFO 2016). - Whelping occurs on pack ice in the Gulf of St. Lawrence, and off southern coastal Labrador, and northeastern Newfoundland (Stenson 1994).	Harp seals are found throughout the North Atlantic; the Northwest Atlantic population (present off eastern Canada and western Greenland) is divided into three herds (DFO 2016). The largest	**COSEWIC Status:** - This species is considered abundant and has not been assessed by COSEWIC. **Abundance/Biomass:**

Species	Biology, Ecology, Influencing Factors	Distribution	Status, Abundance/Biomass, Trends
Related terms: - Whitecoat - Beater - Bedlamer - Saddleback	- Females bear one pup per year, between late February and mid-March. Stable ice conditions are required for whelping (DFO 2016). **Habitat and Ecology:** - Harp Seals fed primarily on pelagic fish and invertebrates. The diet is varied, including capelin, Arctic Cod, herring, sculpin, Atlantic Cod, Greenland Halibut, redfish, plaice, shrimp, and crustaceans (DFO 2016). - Generally, capelin are considered the main prey of Harp Seal in the Northwest Atlantic, although Arctic Cod were the primary prey of inshore Harp Seal in Newfoundland and Labrador during the early-1990s when they were more abundant than capelin (Lawson and Stenson 1995). - This species is generally a shallow diver (up to 100 m), however tagged individuals have reached maximum depths of 700 m (Folkow et al. 2004; Stenson, pers. comm.). - Predators include polar bears, killer whales, Greenland sharks (Lavigne and Kovacs 1988; Leclerc et al. 2012).	of these herds, the Front component, breed in southern Labrador and are mostly likely to be found within the study area. Harp seals are a migratory species that winter in the Gulf of St. Lawrence and off southern Labrador/northern Newfoundland	- Harp seals are the most abundant pinnipeds in the north Atlantic (Kovacs 2015). - The Northwest Atlantic harp seal population is estimated at 7.4 million (DFO 2016). **Population Trends:** - Population estimate has been stable (7.0–7.5 million) since 2004. This level represents a 6-fold increase since the 1970s (DFO 2016). - It is possible that the population is no longer increasing due to poor ice conditions, which contribute to juvenile mortality (DFO 2016).
Bearded Seal Udjuk Pammiuligak Scientific name: *Erignathus barbatus* Related terms: - Udjuktok (a place with Bearded seals) - Square-flipper - Lassies (juveniles)	**Biology:** - Adults reach 2.1–2.7 m and 200–430 kg (DFO 2016). - Lifespan is ~25 years (DFO 2016). - Whelping occurs in late April to early May in Labrador, with some geographic variation (Boles et al. 1980). **Habitat and Ecology:** - Stomach contents analysis of Bearded seals indicate a diet that consists of a variety of benthic species including fish (cod, sculpin, eelpout, pricklebacks, flatfishes, sandlances, smelt), fish eggs (unspeciated), invertebrates (shrimp, crab, unidentified mollusks), algae, and bryozoans (Boles et al. 1980; Buren, pers. comm.). - The whiskers (beard) act as feelers for finding food in soft sediments (DFO 2016). Due to the benthic feeding style of Bearded seals, sand and stones are often also present in the stomach (Boles et al. 1980). - In this portion of their range, Bearded seals may be preyed upon by polar bears, killer whales, and Greenland sharks (Kovacs 2016).	Bearded seal is a circumpolar species. Their range extends to northern Newfoundland, though individuals are occasionally recorded as far as Massachusetts (Kovacs 2016). Bearded seals have a seasonal movement pattern similar to Ringed seals, shifting from central to northern Labrador for the summer months. There is some separation by age, with more young Bearded seals inshore, while adults are more commonly found on and around the outer islands (Boles et al. 1980). Bearded seals are solitary, and relatively rare in Labrador waters (Stenson 1994).	**COSEWIC Status:** - Bearded seal are listed as **Data Deficient**. **Abundance/Biomass:** - Unknown. **Population Trends:** - Unknown.

Species	Biology, Ecology, Influencing Factors	Distribution	Status, Abundance/Biomass, Trends
Harbour seal Kassigak Innatshuk kasigiak Scientific name: *Phoca vitulina concolor* Related terms - Dodder (female) - Ranger (male)	**Biology:** - Adults reach 1.85 m and 110 kg. - Lifespan is 30–35 for females and 20–25 for males. - Whelping occurs in April and May in southern Labrador, and June in central Labrador (Brice-Bennett 1977). - Harbour seals whelp inland, in caves, river mouths, or on beaches (Boles et al. 1980). **Habitat and Ecology:** - Harbour seals feed mainly on fish (cod, capelin, sculpins, lumpfish, sandlance). Invertebrates (including gastropods, amphipods, bivalves, and decapods), algae, and bryozoans were also found in some.	Harbour seals are present on all three of Canada's coasts and are broadly distributed throughout temperate and Arctic shores of the Northern hemisphere (DFO 2016). This species is very common along the Pacific coast but less common in the Atlantic.	**COSEWIC Status:** - Harbour seal were last assessed by COSEWIC in 2007 and designated **Not at Risk**. **Abundance/Biomass:** - Global Harbour seal population is estimated at 5–6 million, with approximately 20–30,000 individuals in the Atlantic Canada (Hammill and Stenson 2000). **Population Trends:** - Unknown.
Grey seal Appa Scientific name: *Halichoerus grypus* Related terms: - Horsehead	**Biology:** - Males reach up to 2.3 m and 350 kg. Females reach 2 m and 200 kg. - Lifespan is 30–40 years (DFO 2016). - Whelping occurs in late-December to mid-February (DFO 2016), however Grey seals do not whelp in coastal Labrador (Stenson 1994). **Habitat and Ecology:** - Diet is varied, including sandlance, Atlantic Cod, white hake, herring, flatfish, skate, octopus, and lobster (DFO 2016). - Grey Seals are shallow, short divers; most dives are less than 60 m and 8 minutes. Maximum recorded diving depth is 412 m (Beck et al. 2003).	Grey seals form a single population in the North Atlantic and are found throughout the Atlantic Provinces and the Gulf of St. Lawrence. There are three recognized herds: Sable Island, coastal Nova Scotia, and Gulf of St. Lawrence (DFO 2016). Grey seals found in Labrador waters are seasonal migrants from the Sable Island and Gulf herds (Stenson 1994).	**COSEWIC Status:** - Grey seal were last assessed by COSEWIC in 1999 and designated **Not at Risk**. **Abundance/Biomass:** - The Sable Island and Gulf of St Lawrence herds, from which individuals likely travel into the study area, are estimated at 394,000 and 98,000 respectively (DFO 2016). **Population Trends:** - Estimated population has increased steadily since the 1960s (DFO 2016).

Table E-4: Biology, ecology, abiotic and biotic factors, distribution, status, abundance/biomass and population trends for polar bears in the Coastal Labrador study area.

Species	Biology, Ecology, Influencing Factors	Distribution	Status, Abundance/Biomass, Trends
Polar Bear (Ours blanc, Nanuk, Nanuq, Wapusk) (*Ursus maritimus*)	**Biology:** - Maximum lifespan is approximately 25 years (COSEWIC 2008b). - Males can weigh up to 800 kg and reach 2.8 m in length (DeMaster and Stirling 1981).	Distribution is circumpolar in the northern hemisphere (COSEWIC 2008b), where the population is broken up into 19–20	**COSEWIC Status:** - Special Concern. **Abundance/Biomass:** - Current estimates indicate that there are 15,500 Polar Bears

Species	Biology, Ecology, Influencing Factors	Distribution	Status, Abundance/Biomass, Trends
	- Females typically do not exceed 400 kg and 2.5 m (Amstrup 2003). - Females become sexually mature at 4–6 years of age, while males reach maturity between 8–10 years (COSEWIC 2008b). - On average females have a litter of 1-2 cubs every 3 years (COSEWIC 2008b). - Females enter estrus in March (Palmer et al. 1988; Amstrup 2003) and cubs are typically born in dens between November and early January (Derocher et al. 1992). - Cubs remain in the dens during a period of nursing until late February to mid-April (COSEWIC 2008b). **Ecology:** - Diet is largely comprised of ringed seals (Stirling and Archibald 1977; Smith 1980; McDonald et al. 1997); however, Polar Bears are also known to consume Bearded, Harp, Spotted, and Hooded Seals, as well as Walrus, Beluga Whales, and Narwhal (Stirling and Archibald 1977; Kiliaan et al. 1978; Fay 1982; Lowry et al. 1987; Calvert and Stirling 1990; Smith and Sjare 1990; Derocher et al. 2002). - Activity is highest from May into July during which seal pups are born (Pasitschniak-Arts and Messier 1999; Amstrup 2003). - Movement of pregnant females end after they enter maternity dens, while non-pregnant females and males will also fast and enter snow shelters for 0.5–4 months during the winter (Harington 1968; Watts and Hansen 1987). **Abiotic/Biotic Factors:** - Use of sea ice is a key for the species to access prey and, as a result, their distribution will change based on the sea ice coverage (COSEWIC 2008b). - Early break-up of sea ice in Western Hudson Bay has been linked to decreased survival of non-prime adult age classes (Regehr et al. 2007). - 40–50% of the Canadian population are forced onto land during the summer due to lack of sea ice (Amstrup et al. 2007). - During these periods, bears rely largely on fat reserves but have also been observed feeding on berries, waterfowl, caribous, and salmon (Smith and Hill 1996; Derocher et al. 2000; Brook and Richardson 2002; Brazil and Goudie 2006). - The primary factors influencing Polar Bear distribution and abundance are: starvation, human-caused mortality, and intraspecific predation (COSEWIC 2008b).	subpopulations. Thirteen of these range into or are contained within Canada (Taylor et al. 2001). The North American distribution extends from the southern edge of permanent multi-year ice pack in the Arctic Ocean to sea ice and coastal areas of Greenland, the Canadian Arctic Archipelago, east along the Labrador coast, south to James Bay, and west to the Bering Sea. On occasion they are also observed in Newfoundland, although this appears to occur less frequently than it had historically (COSEWIC 2008b). Polar Bears within Newfoundland and Labrador are considered to be part of the Davis Strait sub-population (Brazil and Goudie 2006).	between Canada, Greenland, and the United States (COSEWIC 2008b). The Davis Strait population is thought to have approximately 2,100 individuals (Peacock et al. 2006). **Population Trends:** - It is estimated that 4 of the 13 subpopulations which represent 27.8% of the Canadian population are in decline (COSEWIC 2008b). - 4 other subpopulations are likely stable (COSEWIC 2008b). - 3 other subpopulations are experiencing increases (COSEWIC 2008b). - The remaining 2 subpopulations have no reported trends due to lack of available data/pending analyses (COSEWIC 2008b). **Importance:** - Within Davis Strait sub-population, Polar Bears are harvested by people from Nunavut, Quebec, Greenland, and Labrador (Brazil and Goudie 2006). - The combined harvest by Nunavut, Quebec, and Labrador averaged 58.6 bears/year from 2002–07 (Brazil and Goudie 2006). - Harvesting of the sub-population by Greenland was relatively low at 1–11 bears/year between 2002–07

Species	Biology, Ecology, Influencing Factors	Distribution	Status, Abundance/Biomass, Trends
	- In Western Hudson Bay, evidence exists that ringed seal production has been reduced by climate warming, negatively impacting Polar Bear populations (Ferguson et al. 2005; Stirling and Parkinson 2006).		(Polar Bear Technical Committee [PBTC] 2007). - As of 2006, the quota for the Labrador Inuit was 6 bears (Brazil and Goudie 2006).

APPENDIX F – EBSAS

Table F-1: Key ecological features of EBSAs that overlap the Study Area (adapted from DFO 2013).

EBSA	Physical Features	Key Ecological Features	Other Ecological Features
Nain Area EBSA	Webb Bay, Tikkoatokak Bay, Nain Bay, Anaktalik Bay, Voisey Bay, Fraser River	• Major colony of Thick-billed Murre (*Uria lomvia*) • Aggregations of several waterfowl and seabird species • Common Eider colonies • Seabird colonies • Capelin (*Mallotus* villosus) spawning beach • Highly productive area for Arctic Char	• High overall productivity in part due to unique aspects of the land-fast ice habitat • Spawning salmon population • Large congregations of Glaucous Gull • 13 CCRI species
Hopedale Saddle EBSA	Hopedale Saddle, Labrador Marginal Trough, Nain Bank High Point	• Unique Eastern Hudson Bay beluga overwintering area	• High concentrations of several coral species • Aggregations of several fish functional groups, core species and rare or endangered species • Aggregations of several seabird species, including Ivory Gull (endangered under SARA) • Harp seal (*Pagophilus groenlandicus*) summer feeding area • Juvenile and female hooded seal aggregation area
Hamilton Inlet EBSA	Coastal and inner shelf area outside of Hamilton Inlet, Sandwich Bay area	• Capelin spawning beaches • Highly productive areas for Atlantic Salmon (*Salmo salar*) • Major colonies of Atlantic Puffin (*Fratercula arctica*) and Razorbill (*Alca torda*)	• Main area where harp seal whelping concentration usually forms • Aggregations of several waterfowl species, including Harlequin Ducks (Species of 'Special Concern' under SARA) • Important colonies of several seabird species • High concentrations of many seabird species • 23 CCRI species

Table F-2: Key ecological features of EBSAs that are adjacent to the Study Area (adapted from DFO 2013).

EBSA	Physical Features	Key Ecological Features	Other Ecological Features
Northern Labrador EBSA	Inner, middle shelf, Saglek Bank; Cape Chidley to Saglek Bay	• Unique migratory area for endangered Eastern Hudson Bay Belugas (*Delphinapterus leucas*) • Important areas for Harlequin Duck (*Histrionicus histrionicus*) and Barrow's Goldeneye (*Bucephala islandica*) (species of 'Special Concern' under Species at Risk Act Public Registry [SARA]) • Increasingly important summer/fall nearshore feeding habitat and migration corridor for polar bears (*Ursus maritimus*) • Significant feeding and summer haul out area for ringed seals (*Phoca hispida*) • Important rearing and feeding areas for Arctic Char (*Salvelinus alpinus*)	• High winter concentrations of Common Eider (*Somateria mollissima*) • Black Guillemot (*Cepphus grille*) and Glaucous Gull (*Larus hyperboreus*) colonies • High densities of several seabird species • Medium benthivores and plankpiscivores (Engel period) • Juvenile Greenland Halibut (*Reinhardtius hippoglossoides*) (Campelen period)
Labrador Marginal Trough EBSA	Cartwright Saddle, Labrador Marginal Trough, Hawke Saddle, inside Hamilton Bank	• Aggregations of several core fish species • Potential corridor for several species of fish and marine mammals • Area of highest probability of use for harp seal whelping • Harp seal summer feeding area • Cetacean feeding/migration area	• Aggregations of several rare or endangered fish species (Engel period) • PlankPiscivores (Campelen period) • Aggregations of several fish functional groups (Engel period) • Female and juvenile hooded seal aggregation area • Aggregations of several seabird species, including Ivory Gull (endangered under SARA)
Lake Melville EBSA	Saltwater tidal extension of Hamilton Inlet; large fjord	• Unique habitat (brackish waters) • High productivity and species diversity • Several freshwater, diadromous and marine fish species • Salmonid spawning rivers and juvenile rearing areas • Highest counts of moulting Surf scoter (*Melanitta perspicillata*) in Eastern Canada • High densities of breeding ringed seals	• Numerous seasonal feeding aggregations of marine mammals

Table F-3: Key ecological features of EBSAs that are outside the Study Area (adapted from DFO 2013).

EBSA	Physical Features	Key Ecological Features	Other Ecological Features
Outer Shelf Nain Bank EBSA	Outer shelf of Nain Bank, Labrador Slope	• High diversity of species • High concentrations of several coral species	• High densities of roundnose grenadier (*Coryphaenoides rupestris*)

EBSA	Physical Features	Key Ecological Features	Other Ecological Features
		• Aggregations of several fish functional groups • Juvenile and female hooded seal (*Cystophora cristata*) aggregation area; pilot whale (*Globicephala melas*) feeding area • Aggregations of several seabird species, including the endangered Ivory Gull	
Labrador Slope EBSA	Labrador Slope, outer shelf, Hamilton Spur	• High diversity of species • High concentrations of several coral and sponge species • Aggregations of all fish functional groups, several core species and several rare or endangered species	• Aggregations of several seabird species, including Ivory Gull (endangered under SARA) • Female and juvenile hooded seal aggregation area