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BIOPHYSICAL AND ECOLOGICAL OVERVIEW OF A STUDY AREA WITHIN THE LABRADOR INUIT SETTLEMENT AREA ZONE

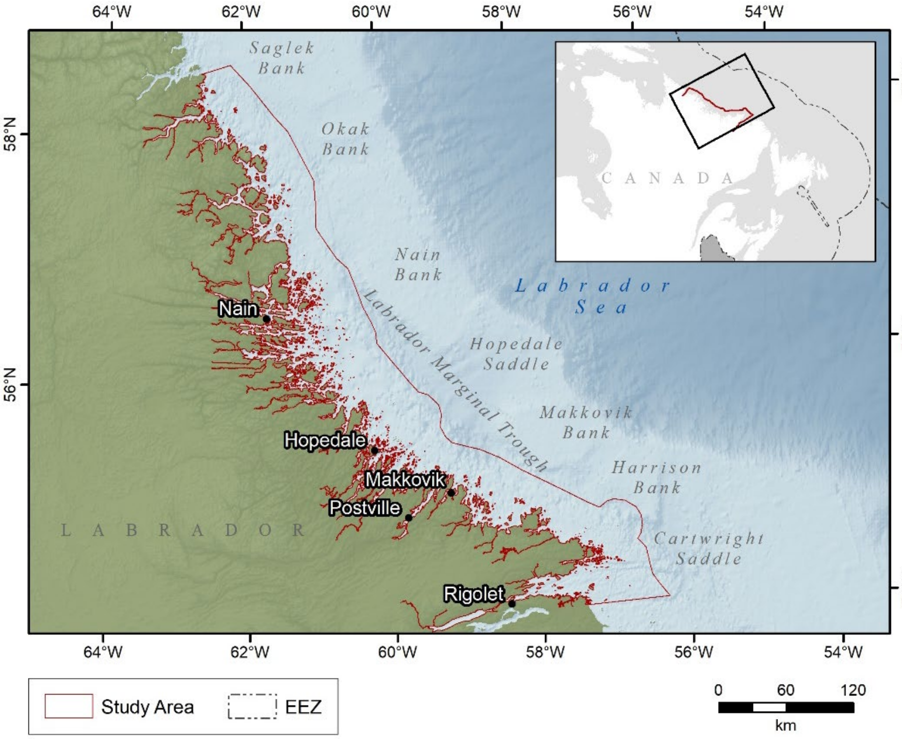

Figure 1: The coastal and marine waters of the study area which fall within the Labrador Inuit Settlement Area (LISA) Zone.

Context:

The Government of Canada has committed to an international and domestic biodiversity conservation target (Aichi Target 11 and Canada's Target 1) which calls for 10% protection of coastal and marine areas by 2020 (Marine Conservation Targets [MCTs]). The designation of new Marine Protected Areas (MPAs) in Canadian waters has been identified as part of the national strategy to meet Canada's target.

The Governments of Canada and Nunatsiavut signed a Statement of Intent in September 2017, which commits to collaborative management of the ocean around northern Labrador (Nunatsiavut Government 2018). The Nunatsiavut Government has expressed interest in exploring potential MPAs off Labrador and has initiated discussions with both Fisheries and Oceans Canada (DFO) and Parks Canada. In response, DFO's Ecosystems Management Branch requested that DFO Science complete a biophysical and ecological overview of a study area within the Labrador Inuit Settlement Area (LISA) Marine Zone.

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Detailed information on the key biophysical, ecological, and cultural attributes of the study area, especially as it pertains to potential conservation objectives and the basic influence of or interaction with other ecosystem components is required. This biophysical, ecological and cultural overview will assist the Ecosystems Management Branch and the Nunatsiavut Government in formulating and/or refining conservation objectives and delineating boundaries of zones (if required) within the study area. The information contained within will also inform subsequent advice on monitoring indicators, protocols and strategies, identification of information gaps requiring further research, and the development of a management and monitoring plan for the area.

This Science Advisory Report is from the November 29-30, 2018 Regional Peer Review on the Biophysical and Ecological Overview of a Study Area within the Labrador Inuit Settlement Area Marine Zone. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- The study area is dynamic, with biophysical conditions and species assemblages changing seasonally and interannually:
    - Local knowledge (LK) and scientific studies have noted multi-year changes in biophysical conditions (e.g. sea ice) and species assemblages.
    - The strong biophysical seasonality of the study area also affects species assemblages.
    - Sea ice is an important ecological, ephemeral feature of the study area. Since many species are associated with specific elements of sea ice, their distribution and abundance are also dynamic.
- Through nutrient and contaminant transport, ocean currents, and migration of species, the study area is connected to adjacent marine, freshwater and terrestrial ecosystems. Similarly, the ecosystem is inseparable from the Labrador Inuit, their way of life, and their future.
- Diverse marine and coastal habitats occur within the study area:
    - Habitat gradients are most pronounced along the lateral axis of the study area (inshore to offshore). This gradient spans habitat zones that include the intertidal, nearshore, continental shelf and continental slope.
    - The latitudinal gradient is large enough that there are important differences in biophysical conditions and species assemblages from the south to north edges of the study area.
- The study area supports a largely intact assemblage of biota, including large marine mammals, apex predators, species of conservation concern, and many species that have sustained Labrador Inuit for generations and/or have been targeted by commercial fisheries.
- Industrial activity (shipping, oil and gas, and commercial fishing) is not as prevalent in the study area region as in other coastal parts of the North Atlantic. However, these activities are more pronounced in areas adjacent to the study area.
- The study area is a challenging area in which to conduct science and therefore there are few scientific studies – particularly in winter and spring when sea ice is present. While the study area does benefit from rich LK of culturally important species in many parts of the coast, there remains 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 DFO Research Vessel [RV] multispecies survey and some parts of the coast less frequently used by Labrador Inuit) are particularly under-represented.

- Some species assemblages are poorly represented in available studies, including coastal fish, invertebrates, and plankton communities. Furthermore, the understanding of the oceanography of the coastal zone remains poorly understood.

INTRODUCTION

Nunatsiavut was established with the signing of the Labrador Inuit Land Claims Agreement (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 Zone. The Zone is used extensively by Labrador Inuit both within the five Nunatsiavut communities and the Upper Lake Melville region. In 2017, the Nunatsiavut Government (NG) signed a Statement of Intent with Environment and Climate Change Canada (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 potential candidate for an *Oceans Act* Area of Interest (AOI). The study area extends 12 nautical miles from the Nunatsiavut coast to the edge of the Zone. 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 particular 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 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 research and LK are synthesized to describe the following features, listed by document Section:

1. Estuaries and Coastal Features
2. Seabed Features
3. Sea Ice
4. Physical Oceanography
5. Biological Oceanography
6. Kelp and Other Marine Vegetation
7. Benthic Communities
8. Corals and Sponges
9. Fish
10. Marine Mammals
11. Marine Birds
12. Ecological and Biologically Significant Areas (EBSAs)
13. Inuit Use and Other Activities
14. Protected Areas and Other Closures

Objectives for this document:

1. Describe, and map where possible, available information on key biophysical, ecological and cultural features, including:
    - predominant and unique physical and biological oceanographic characteristics;
    - predominant, unique, and sensitive habitat features;
    - key species of interest, including general species biology and ecology, distribution and abundance/biomass, status and trends, and the abiotic and biotic factors influencing them; and
    - human use, including culturally important areas/species for the Inuit people of Nunatsiavut.
2. Identify known sensitivities/vulnerabilities of habitats and species of interest.
3. Identify key uncertainties and knowledge gaps as they pertain to the current understanding of the existing environment and species of interest, and where possible outline how gaps can be addressed.
4. Where appropriate, recommend additional ecosystem components/features for potential conservation as indicated in the national guidance for biophysical overview reports (DFO 2005).
5. Utilize data collected and mapped by the Nunatsiavut Government in the LISA Marine Zone to inform objectives 1-4.

Approach and Methods

The Nunatsiavut Government and DFO are full partners in activities and decisions that relate to the study area, which falls entirely within the LISA Zone (Intergovernmental and Indigenous Affairs Secretariat 2005). This partnership is also supported directly by the Final Report of the National Advisory Panel on Marine Protected Area Standards (DFO 2018a), which identifies the need for Indigenous Knowledge to be “meaningfully integrated in all aspects of planning, design, management, and decision-making around marine protected areas” and for government to recognize Indigenous communities as full partners in these processes. The analysis and information presented in this document 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 needs and uses of coastal and marine resources by Labrador Inuit.

This Science Advisory Response summarizes the more detailed analyses presented in an associated research document (McCarney et al. in prep[1]). The data used to inform this process were generated through a variety of research programs and methods and represent a combination of available scientific data and LK collected from Nunatsiavut and Upper Lake Melville communities.

Throughout this document and the associated research document, Local Knowledge (LK) is used 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

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[1] McCarney, P., et al. In prep. Biophysical and Ecological Overview of a Study Area Within the Labrador Inuit Settlement Area Zone. DFO Can. Sci. Advis. Sec. Res. Doc.

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. The Community Coastal Resource Inventory (CCRI) data were collected from the same five communities as those that participated in OFAE, but only a limited amount of data were collected north of Nain (O'Brien et al. 1998; 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 much of the 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 sea, animals travel from one place to another, birds migrate in and out, fish are constantly traveling, and sea ice can join or separate 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 the NG, DFO, and ECCC staff. 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.

ANALYSIS AND RESPONSE

1. Estuaries and Coastal Features

Coastlines provide a network of diverse habitats that are ecologically important to a variety of plants and animals, which in turn provide important economic, cultural and food security benefits to nearby communities. The interface of terrestrial/freshwater and marine environments supports highly productive and diverse ecosystems, but can also be particularly sensitive to anthropogenic impacts (e.g. industrial development, oil spills). A history of glaciation, presence of resistant bedrock, and high coastal relief have made the Labrador coast a highly complex environment, including steep fjords and fjards, rocky shorelines, unconsolidated cliffs, beaches, intertidal boulder flats, deltas, estuaries and marshes. The coastline of the study area, including all 6,924 mapped islands, extends for 17,076 km reaching the Northern limit of the boreal zone (McCarney et al. in prep[1]).

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 included beach profiling and nearshore SCUBA geological/biological sampling, as well as low level aerial photography to map coastal environments. Additional information on coastal features in this area includes research dating from 1956 to 2017 in scientific literature, technical reports, and government documents (e.g. CSAS Research Documents). LK on coastal travel routes and berry picking areas were compiled by the Nunatsiavut Government Imappivut program.

1.2. Sensitive Species and Habitats

Estuaries are among the most productive ecosystems in the world and many animals rely on them for foraging, breeding and migration staging areas (e.g., Spares et al. 2015, NOAA 2014). Coastal estuaries provide 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; 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 other estuaries have yet to be characterized.

Two EBSAs identified along the coast of Labrador fall within or are in close proximity to the study area's coast; Nain Area and Hamilton Inlet (DFO 2013). The Nain Area is composed of Webb Bay, Tikkoatokak Bay, Nain Bay, Anaktalik Bay and Voisey's Bay (Wells et al. 2017). Due to large amounts of nutrient loading from local rivers, this site has a high level of nearshore marine productivity which provides foraging opportunities for a number of marine species including Arctic Char (*Salvelinus alpinus*), Capelin (*Mallotus villosus*), and several species of marine birds. The Hamilton Inlet EBSA (Wells et al. 2017) encompasses Hamilton Inlet, Sandwich Bay and south to Island of Ponds. It includes highly productive Atlantic Salmon (*Salmo salar*) areas and Capelin spawning beaches. Other ecologically important areas include Groswater Bay and the Double Mer River, both of which are found within the 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 Greenland Cod (Environment Canada 1990).

The coastal zone is particularly important to Labrador Inuit. Most of the major settlements are situated on the coast and the coastal zone includes important hunting grounds and travel routes. For example, marine food resources, such as Ringed Seals, are harvested along the coast year-round while other resources (e.g. migratory birds, Harp Seals, Atlantic Salmon and Arctic Char) are harvested seasonally (McCarney et al. in prep[1]). Labrador Inuit also harvest other terrestrial species (e.g. caribou) and forage for berries and other edible plants in coastal environments. Since harvest areas are often located far from established towns, access is often achieved along coastal travel routes during open water and during ice season (McCarney et al. in prep[1]).

1.3. Data Gaps and Recommendations

Despite the importance of the coastal zone to biota in the study area and the Labrador Inuit that reside there, 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 study area intertidal and subtidal plant and animal communities and their associations with the available physical habitats. While shoreline habitats are reasonably well documented in McLaren (1981) and Offshore Labrador Biological Studies (OLABS), there has been scant multibeam mapping conducted in subtidal areas beyond Okak Bay (Allard and Lemay 2012). Such habitat-community associations would provide a means to predict the distribution and prevalence of biotic communities based on the distribution of physical habitat. This is discussed further in the following chapter on Seabed Features.

Estuarine and nearshore zones have unique oceanographic conditions (temperature, water chemistry, currents) that differ markedly from the deeper habitats routinely monitored by programs such as DFO's Atlantic Zone Monitoring Program (AZMP). Unlike areas further offshore, coastal oceanography processes operate at fine scales. It is difficult to infer results much beyond the area being sampled. Nevertheless, sampling at representative index sites would be useful and could contribute data toward more accurate coastal oceanographic models. Considerable research needs exist in the sub-tidal zone.

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. However, for many elements of the coastal zone, quantitative baseline data is lacking and therefore it will be difficult to predict how the area will be affected by large-scale stressors. Climate change has major implications for coastal ecosystems and the social and economic systems that depend upon them. For many aspects of the coastal ecosystem, the LK of residents is providing important perspectives on coastal changes. Coastal ecosystems along the study area are most affected by sea level rise, and increases in storm severity and frequency.

2. Seabed Features

Surveying the marine environment is difficult and often very expensive. As a result, our understanding of marine habitats and species distribution is incomplete for most of the global ocean. 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 species and habitat.

2.1. Available Information

Three sources of information on marine geomorphology were considered here: seabed features mapped by Gordon Fader, the Global Seafloor Features Map published by Harris et al. (2014), and geomorphometric analysis of the Canadian Hydrographic Service Non-Navigational 100 m resolution bathymetry.

2.2. Sensitive Habitats

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). The center of the coastal Labrador study area is characterized by high structural complexity, associated with shelf valleys and glacial troughs, as indicated by the Benthic Position Index (Figure 2), which is a measure of the relative height of a point in comparison to the surrounding area, used to identify peaks and valleys. In general, more complex benthic habitat is associated with high biodiversity and productivity, and provide important holdfast habitat for sensitive corals and sponges (Baker at al. 2012). 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.

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 coastal Labrador study area.

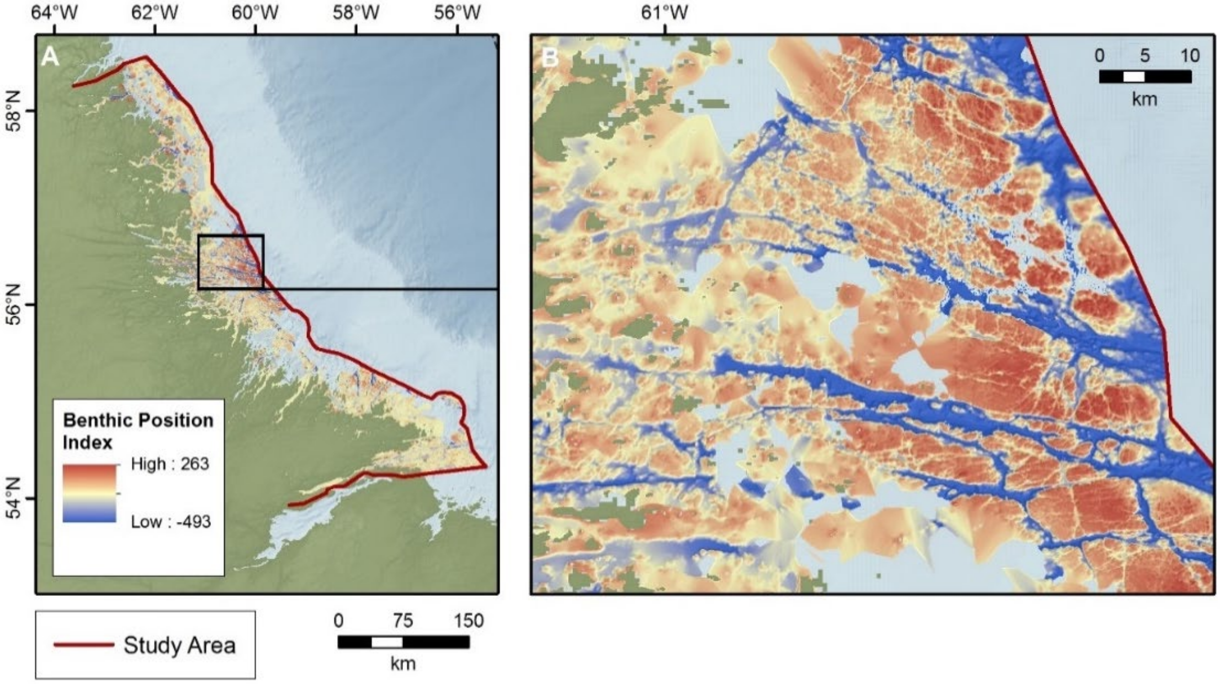

Figure 2: Benthic Position Index (BPI) derived from interpolated Canadian Hydrographic Service (CHS) NONNA-100 bathymetry within the study area (CHS 2018); calculated based on a 25 cell inner window and a 100 cell outer window.

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. Unsurveyed areas should be prioritized for multi-beam echo-sounding. Other sources of data (e.g. bathymetry associated with the DFO RoxAnn dataset, crowd-sourced fisheries single-beam) may also be considered. Substrate and benthic habitat mapping would support research and monitoring of key species and habitats and identification of potential vulnerabilities.

3. Sea Ice

Sea ice is a dynamic ecosystem that provides critical ecological and social-cultural services within the study area. 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, 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 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 NG'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 (2008), the SmartICE monitoring project (Bell et al. 2014; Safer 2016), and ongoing ice monitoring studies by the Canadian Ice Service.

3.2. Sensitive Habitats

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,b). 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 (*Ursus maritimus*) 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). 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 (*Rangifer tarandus*), 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).

Labrador Inuit rely on sea ice for travel routes to cabins, hunting and fishing areas, and as a highway between communities. 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 use sea ice to travel to freshwater Arctic Char (*Salvelinus alpinus*) fishing locations in the winter, to fish for Greenland cod (*Gadus ogac*) (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 (*Rangifer tarandus*). 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 remains 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. Further, while the importance of documenting interannual 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. Imappivut interview participants indicated that the timing of ice formation and breakup, as well as ice thickness and extent, have changed over time (Nunatsiavut Government 2018).

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 shift, areas such as the shear zone (the contact zone between fast ice and pack ice where motion and pressure frequently result in an area of heavily ridged and rubbled ice) 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. 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 NG’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 NG 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.

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. 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, has far reaching downstream influences affecting the marine habitat on the Newfoundland Shelf, the Scotian Shelf and as far south as the Gulf of Maine and 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 inform ecosystem management.

4.1. Available Information

Knowledge of the study area is based on studies and observations collected along the coast of Labrador as early as the 1920s. 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 to 1954 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). 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). An extensive physical and biological oceanographic study was carried out on the Labrador Shelf during 1979-1980 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 and vicinity in support of the Voisey's Bay ecosystem characterization study.

More recently, in 1998 DFO's Atlantic Zone Monitoring Program (AZMP; 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 RV multispecies surveys conducted by DFO (Colbourne et al. 2017, 2018).

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 sub-polar and temperate oceanographic conditions that affects primary and secondary marine production as well as the northern limits of various fish stocks. 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.

4.3. Data Gaps and Recommendations

A significant amount of oceanographic information is available for the study area. However, significant data gaps exist in the *in situ* data coverage particularly during the winter and spring months. 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 sea surface temperature (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

Phytoplankton (microscopic plants) and zooplankton (microscopic animals) 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 informed ecosystem management.

5.1. Available Information

The knowledge of the study area’s biological oceanography draws extensively on information obtained from the AZMP.

Some of the earliest records of plankton taxonomy and distribution on the Labrador Shelf include the 1928 Godthaab expedition (Kramp 1963) and the Blue Dolphin Labrador Expedition that was conducted during 1949-54 (Grainger 1964, McGill and Corwin 1965, Nutt and Coachman 1956). The OLABS program also conducted oceanographic sampling to collect baseline biological information on nutrients, phytoplankton, and zooplankton from coastal bays across the continental shelf during the summer of 1979 (Buchanan and Foy 1980, Buchanan and Browne 1981).

5.2. Sensitive Species and Habitats

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 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. Data Gaps and Recommendations

Research on 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. 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 (devices that measure conductivity, temperature, and depth, or water pressure). 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 a diverse group that are widespread in intertidal and subtidal habitats. They create structural habitat in the nearshore environment that are amongst the most productive habitats in the world (Smith 1981). For example, brown algae dominate subtidal communities in sub polar regions, and are major primary producers and ecosystem engineers (Teagle et al. 2017). Other species such as eelgrass are listed as ecologically significant species (DFO 2009) for their contributions to nearshore habitat, nutrient cycling, and their sensitivity to anthropogenic disturbance.

6.1. Available Information

This section synthesizes information provided by LK compiled by the Community Coastal Resource Inventory, museum records, field surveys (e.g. Wilce 1959, Adey and Hayeck 2011), ecological niche modelling (e.g. Assis et al. 2018), and genetic studies (e.g. Bringloe and Saunders 2018).

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). In contrast, climate change also threatens ancient kelp refugia in the north Atlantic (Assis et al. 2018) and may also affect the genetically unique forms of macroalgae on the coast of Labrador (Bringloe and Saunders 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, 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 (Caines and Gagnon 2012). 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 2011).

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 (Moore and Short 2007). Eutrophication has been a serious problem for eelgrass in temperate estuaries (Moore and Short 2007). 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. Gatuso et al. (2006) used Sea-viewing Wide Field-of-view Sensor (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 ground truthing (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 unutilized 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, ground truthing is also required for this approach. Scientific surveys could be supplemented by LK 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.

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 the benthic species 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. 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 addressed in the following section.

7.1. Available Information

There is limited information on benthic communities in the study area as most studies have focused on regions farther offshore on the continental shelf and slope. The challenges 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. Data on benthic communities come primarily from LK, DFO RV survey data, the Integrated Regional Impact Study (IRIS4) (Allard and Lemay 2012), the Strategic Environmental Assessment Labrador Shelf Offshore Area (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. 2018).

7.2. Sensitive Species and Habitats

Studies in other Arctic regions have noted climate-associated reductions in ice algae 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 (e.g. Drewnik et al. 2017).

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 (*Chionoecetes opilio*) populations over the past four decades (Mullowney et al. 2017). 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.

Rising water temperatures and increased vessel traffic could improve colonization conditions for invasive species such as Green Crab.

7.3. Data Gaps and Recommendations

The lack of recent benthic sampling efforts and targeted research on benthic species in the study area is a principal data gap. Research in the study area is difficult due to logistic challenges and environmental limitations as a result of seasonal ice cover in the study area. Such challenges could be overcome in part by involving coastal communities in scientific activities. 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 structure across depth gradients and substrates 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 structure, focused research in the study area will be critical to understanding habitat characteristics and better defining the community composition.

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. A primary knowledge priority is to collect additional qualitative and spatial data on Inuit use of benthic species to better understand the cultural and food security importance of these species. In addition, accessing and analyzing invertebrate data collected through DFO RV surveys is a priority. The combination of LK and RV survey data will provide an enhanced overview of the spatial distribution of benthic species. 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 by Allard and Lemay (2012). To date, invertebrate data (primarily LK) is concentrated in coastal areas near communities and in the north of the study area (see 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, that 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 (Probert et al. 1979, Krieger and Wing 2002) sessile organisms that live on the sea floor. Their presence is important because of the habitats they create, modify, and maintain at various spatial scales. Attributes of this taxa (i.e. structure and 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 and Edinger 2007).

8.1. Available Information

Corals and sponges have been documented throughout the Northwest Atlantic, including the Labrador Shelf, with the majority of data derived from scientific research surveys. Records are also available from sources like the Fisheries Observer Program (FOP), museum records, and voluntary fisher reports. Annual trawl survey data is available from the DFO-NL RV database (2005-17) and the Northern Shrimp Research Foundation (NSRF). 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.

Examination of museum collections and other on-line databases (e.g. Barcode of Life Data [BOLD] System, Natural Museum of Natural History [NMNH]) yielded records of the soft coral *Gersemia fruticosa* and records of sponges collected within the study area during expeditions dating back to 1949. Locations and example specimens were also provided by a retired gillnet fisherman who fished the Labrador Coast off Makkovik in the 1970s-80s. Examples of bycatch included a 3 m tall *Paragorgia arborea*, and several pieces of *Primnoa cf. resedaeformis* (McCarney et al. in prep[1]).

Predictive modelling of habitat suitability for coral in Labrador waters includes a small portion inside the study area. An area inside Makkovik Bank was shown to be particularly suitable for small and large gorgonians (Gullage et al. 2017). 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 soft Gersemia coral

(McCarney et al. in prep[1]). The area adjacent to the majority of the study area boundary is highly suitable for soft corals in general (Nephtheidae sp.) (Gullage et al. 2017).

8.2. Sensitive Species and Habitats

Corals and sponges have been recognized by Northwest Atlantic Fisheries Organization (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.

8.3. Data Gaps and Recommendations

A large data gap exists for corals, sponges, and bryozoans within the study area. Specifically basic baseline information, including benthic assemblages, bathymetric distributions, and general life history traits. Currently DFO and NSRF research surveys do not cover the coast and this is due to the coarse nature of the substrate 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, LK, etc.). Models can address knowledge gaps but require ground truthing to test 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. Remotely Operated Vehicles (ROVs), eDNA) 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.

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 Labrador Inuit.

9.1. Available Information

Information is available for two general fish assemblages: nearshore/coastal fishes and offshore fishes. Data on nearshore/coastal fishes encompass fish species that are found in marine or estuarine environments for at least part of their lifecycle, while data for offshore fishes includes the dominant and sensitive offshore fish species which are known to occur within or directly adjacent to the deeper extents of the study area. Additional information is provided on fish species that are important for commercial, recreational, and/or subsistence fisheries in coastal Labrador.

9.1.1. Nearshore/coastal fishes

Information on nearshore and coastal fish species was obtained from several studies conducted within the study area as well as data gathered from LK. Important species within the study area include several anadromous species, like Arctic Char (*Salvelinus alpinus*), Atlantic Salmon (*Salmo salar*), Brook Trout (*Salvelinus fontinalis*), and Smelt (*Osmerus mordax*), as well as marine fish like Greenland Cod (*Gadus ogac*, recently characterized as *Gadus microcephalus*, Mecklenburg et al. (2018)) and Capelin (*Mallotus villosus*).

The Blue Dolphin Expeditions (1949-51) documented many coastal species in this region (Backus 1957). Other research undertaken within the study area include environmental baseline studies conducted from 1995 to 1996 to characterize the existing freshwater and marine fish assemblages and habitats in Anaktalak Bay, Kangeklukuluk Bay, Kangeklualuk Bay, Throat Bay, and Voisey's Bay (VBNC 1997), as well as more recent research conducted by Devine (2017) using baited cameras within inshore fjords, including Okak Fjord, which falls within the study area. LK was also used to map distribution of fish species of importance along the coast of the study area. In particular, Arctic Char and Atlantic Salmon are considered two very important fish species for commercial and/or recreational and subsistence fisheries.

9.1.2. Arctic Char (IKaluk, IKalutuinnak)

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, and age at first migration (Black et al. 1986, Dempson and Kristofferson 1987), genetic investigations (Dempson et al. 1988, Bernatchez et al. 1998), and other studies (e.g., hybridization, freezing resistance, and parasite infection) (Dempson et al. 2004). Several other studies have investigated the migratory and overwintering behaviors of Arctic Char (Beddow et al. 1998, Moore et al. 2017, Bernatchez et al. 1998, Dempson and Kristofferson 1987, Spares et al. 2015, Moore et al. 2016).

9.1.3. Atlantic Salmon (Kavisilik)

There are 35 rivers that Atlantic Salmon are known to inhabit in the study area (McCarney et al. in prep[1]). The most recent stock assessment for Atlantic Salmon in Newfoundland and Labrador was completed in 2017 (DFO 2018b). Total returns of small (<63 cm fork length) and large (>63 cm) Salmon to the English River counting facility have been monitored since 1999.

9.1.4. 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 dataset. Because of the study area's water depths and untrawlable substrate types, just 66 trawl sets have been performed within its boundaries since 1971. Additional trawl data within a 10 km buffer adjacent to the study area, as well as sets collected on the continental shelf in NAFO Divs. 2GHJ at a depth ≤160 m (mean depth of the study area plus one standard deviation), were included to increase the amount of information for offshore species.

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. Although Rock Cod (*Gadus ogac*) 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.

9.2. Sensitive Species and Habitats

9.2.1. Nearshore/coastal fishes

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 the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as being of Special Concern, Threatened, or Endangered, or species that are considered vulnerable to impacts due to their particular life history traits.

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 Atlantic 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 2010).

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 harvested in the study area.

Arctic Char occupy the study area during their marine feeding phase, which occurs after ice break up (typically May and early June) and extends to late July through mid-September (Dempson and Green 1985, Dempson and Kristofferson 1987, Beddow et al. 1998). 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 2010, Coad and Reist 2018). Poor environmental conditions during these migrations could have negative impacts for both of these species. The marine environment is of particular concern to Atlantic Salmon, since poor ocean survival is considered the primary cause of the observed widespread decline of the species (COSEWIC 2010). 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, this may result in northward shifting distributions for Arctic Char and Atlantic Salmon and potentially expose them to competition from encroaching southern species (Power et al. 2012, Reist et al. 2006). 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 are poorly represented 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 (*Sebastes* spp.), Atlantic Wolffish (*Anarhichas lupus*), Northern Wolffish (*Anarhichas denticulatus*), Smooth Skate (*Malacoraja senta*), Roundnose Grenadier (*Coryphaenoides rupestris*), Greenland Halibut (*Reinhardtius hippoglossoides*), and Eelpout (Zoarcidae). Alternatively, Arctic Cod, Mailed Sculpin, American Plaice (*Hippoglossoides platessoides*), Daubed Shanny (*Leptoclinus maculatus*), Lumpfish (Cyclopteridae), Rock Cod, and Spotted Wolffish (*Anarhichas minor*), 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 (Ottensen et al. 2011, Wienerroither et al. 2013, DFO 2018c).

Some of the dominant and sensitive species for the area, Atlantic Cod, Greenland Halibut, American Plaice, Capelin, Deepwater Redfish, Northern Wolffish, Spotted Wolffish, Smooth Skate (Funk Island Deep population), and Porbeagle Shark (*Lamna nasus*), 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.

9.3. Data Gaps and Recommendations

9.3.1. Nearshore/coastal fishes

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 environments as well as nearshore marine areas, including estuarine and fjord systems.

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 is an important subsistence fish for Labrador Inuit.

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. 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). Sustainable fisheries management for both Arctic Char and Atlantic Salmon is a priority for Labrador Inuit, however Arctic Char has not had a published stock assessment since 2003. Furthermore, there are few data on subsistence and recreational landings for either Arctic Char or Atlantic Salmon (Dempson et al. 2004). During the marine phase, both species 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 genetic 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).

A greater knowledge of how coastal Labrador is ecologically connected to other regions is another limitation that would be worthwhile to address. Understanding 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). Such initiatives also support the philosophy that Labrador Inuit express about the connectedness of ecosystems.

Finally, the construction of time series data for sensitive and important fish species is of great significance in contributing 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 primary data gap that exists for offshore fish species within the study area originates from the lack of RV trawls within its boundaries. Furthermore, of the trawls that have been performed, only 16 were conducted in the past 10 years. Data are particularly sparse within NAFO Div. 2G, and survey trawls 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 conducted within the shallower strata of NAFO Divs. 2GHJ could be used to bridge this information gap; however, bottom topography make much of the study area unsuitable for trawl surveys. The natural state of the study area has been largely preserved due to limited access by trawls, making it unique to other areas of the NL shelf. As such, future research should be conducted in a way that minimizes impacts. Other methods (e.g. video surveys etc.) better suited to shallow water environments are recommended to characterize and monitor fish species of importance in this predominantly coastal environment. 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), 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 2018c), 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). 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 LK 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

Marine mammals (whales, seals and Polar Bears) are ecologically, culturally, and commercially important in the study area. Collectively, marine mammals are consumers of production at most trophic levels. Because of their large body size and abundance they have a major influence on the structure and function of marine (Bowen 1997, Katona and Whitehead 1988, Roman and McCarthy 2010) and coastal communities (e.g. Galicia et al. 2015).

10.1. Available Information

10.1.1. Cetaceans

In addition to their important ecological role, cetaceans provide 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 important role these species have held in the lives of Labrador Inuit 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, Minke Whales), while the Beluga Whale (*Delphinapterus leucas*) inhabits Arctic and

Subarctic waters only, but migrates south to the study area during the winter months. The most common dolphin species in the area, the White-beaked Dolphin (*Lagenorhynchus albirostris*), is found only in the North Atlantic, in temperate and subarctic waters. The Atlantic White-sided Dolphin (*Lagerhynchus acutus*) is also observed fairly commonly in the study area, particularly in the nearshore waters off the coast of Hopedale. These two species are often collectively identified as “dolphins”, “jumpers” or “squidhounds” locally. The Harbour Porpoise (*Phocoena phocoena*) 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.

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 of Labrador Inuit (Brice-Bennet 1977). Today, seal hunting remains an essential part of life in coastal Labrador, with substantial benefits related to cultural and economic values and regional food security. Five seal species are commonly found in the study area: Ringed Seal (*Phoca hispida;* known locally as jar seal), Harp Seal (*Pagophilus groenlandicus*), Bearded Seal (*Erignathus barbatus*; square flipper or Udjuk), Harbour Seal (*Phoca citulina concolor;* dodders or rangers), and Grey Seal (*Halichoerus grypus*; Appa or horsehead). Hooded Seals (*Cystophora cristata*) and Walrus (*Odobenus rosmarus rosmarus*) are rarely recorded in coastal Labrador and are not considered residents (Boles et al. 1980).

Standardized observations from aircraft have indicated that Harp Seals are found all along the coast (G. Stenson, pers. comm.), where tagged individuals have been observed migrating into, and through, the study area (McCarney et al. in prep[1]). LK records describe frequently used seal hunting areas and seal movement patterns along the coast (McCarney et al. in prep[1]).

10.1.3. Polar Bears

The study area is included within the range of the Baffin Bay/Davis Strait/Northern Labrador (DS) Polar Bear subpopulation (COSEWIC 2008). Polar Bear (*Ursus maritimus;* known locally as Nanuk or Wapusk), is listed as a species of Special Concern under the *Species at Risk Act* and is considered Vulnerable under the *Newfoundland and Labrador Endangered Species Act*. The most recent mark-recapture population survey for the Davis Strait subpopulation took place in 2007 and provided an estimate of 2,158 bears (Peacock et al. 2013). Additional data are derived from a Traditional Ecological Knowledge (TEK) study conducted by the Torngat Wildlife Plants and Fisheries Secretariat (2015) that examined multiple aspects of Polar Bear ecology. 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.

Sightings based on LK indicate that they are typically seen all along the coast. Most sightings are concentrated near Nain, Hopedale and Makkovik, however this may be due to geographic bias of the observations (McCarney et al. in prep[1]).

10.2. Sensitive Species and Habitats

10.2.1. Cetaceans

All of the study area’s cetacean species have been assessed by COSEWIC and the Atlantic population of Fin Whales, assessed as a species of Special Concern by COSEWIC in 2005, is currently listed on Schedule 1 as a species of Special Concern under the *SARA* (DFO 2017). The Eastern Hudson Bay population of Beluga Whale has been assessed as Endangered under COSEWIC. 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. In contrast, 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.

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 (McCarney et al. in prep[1]).

10.2.2. Pinnipeds

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. Nevertheless, these species are sensitive to changes in their ecosystem, and current threats include declining sea ice, reduced prey availability, and environmental contamination.

Sea ice conditions in the Northwest Atlantic are declining due to 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. 2015). Since 1990, there have been significant declines in important seal prey species in Newfoundland and Labrador waters, particularly Capelin. For at least one species (Harp Seals), reduced prey availability has been associated with declines in Harp Seal pregnancy rate (Stenson et al. 2015).

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 Saglek radar station, near the northern edge of the study area, exceed the maximum allowable amount in the *Canadian Environmental Protection Act* and have entered the food chain (Brown et al. 2014). 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 that are present in Ringed Seals of coastal Labrador, including persistent organic pollutants (POPs) and mercury (Brown et al. 2018), cadmium (Brown et al. 2016), and flame retardants and polybrominated diphenyl ethers (PBDEs) (Houde et al. 2017).

It is likely that other seal species are similarly exposed to dangerous contaminants (but see Hellou et al. 1991), 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 Low Density Lipoprotein (LDL) based on analysis of Canada’s Adult Inuit Health Survey (Singh and Chan 2018).

10.2.3. Polar Bears

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 2008). The status of the various Polar Bear subpopulations varies considerably due to differences in habitat and prey availability. Changes in climate have had impacts on 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). The Davis Strait subpopulation has been assessed as stable or potentially increasing (Environment and Climate Change Canada 2018). Scientific studies and Traditional Knowledge from Inuit hunters have provided differing data on body condition among Davis Strait Polar Bears, with scientific studies finding a decline in body condition and Inuit hunters observing stable body condition. The Davis Strait subpopulation has an annual harvest quota of 80 bears. Inuit have interacted and maintained a relationship with Polar Bears for generations and consider them 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).

10.3. Data Gaps and Recommendations

10.3.1. Cetaceans

Given that much of the knowledge and data available for cetaceans is based on non-systematic observations, the ability to identify important or critical habitat for each species is limited. Only two systematic surveys have been completed in the last 11 years (Lawson and Gosselin 2009, 2018), nine years apart, making population trends over time difficult to assess. 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. 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. Furthermore, the opportunistic nature of many cetacean observations make it difficult to identify habitat associations of these species since survey effort is often not systematic or quantified.

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; and
- targeted qualitative and spatial data collection of LK throughout the study area focused on cetacean observations and associated location and habitat information.

10.3.2. Pinnipeds

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.

While population trends and ecology are reasonably well understood for Harp and Grey Seals, they are poorly known for the other species. Coastal wide surveys for Ring and Bearded Seals are needed to determine abundance. 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. While changes in body condition of Harp Seal are well studied, less is known about 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, a better understanding of contaminants in these species is an important data gap.

10.3.3. Polar Bears

Satellite tracking (Taylor et al. 2001) and LK provide information on preferred habitat types for denning (York et al. 2015). However, 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) within the study area 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 the population that is transient at different times of the year (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 prey primarily on 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 primarily use to feed, with Ringed Seals featuring more predominantly in the diets of bears using nearshore and land fast areas and Bearded and Harp Seals consumed more by offshore bears (Bluhm and Gradinger 2008). Polar Bears from the Davis Strait 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 ice may impact the bear’s ability to feed on the whelping patch (G. Stenson, pers. comm.).

11. Marine Birds

Marine birds have inherent biodiversity value, constitute valuable ecological indicators that inform adaptive management, and some species are harvested by Labrador Inuit. The study area includes several areas that are significant to marine birds including those designated as EBSAs and Important Bird Areas (IBAs).

Here, 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).

11.1. Available Information

Six principal data sources were used to describe the distribution and abundance of marine birds within the study area: LK, shorebird surveys, waterfowl surveys, colony surveys, tracking studies, and at-sea marine bird surveys.

With the advent of miniaturized telemetry and data-archiving devices suitable for marine birds, a wealth of annual tracking data has emerged on many species. The Canadian Wildlife Service (CWS) has also provided a large portion of the data for this study area. This survey presents maximum counts by species across survey blocks (initially designed to reflect prominent coastline features that separate coastal segments, inshore bays, and estuaries, and thus delineate functionally distinct habitat units), with coverage along the entire coast of the study area. During Imappivut interviews, participants identified the important food value of marine birds during both spring and fall hunts, highlighting frequently used habitats for several species (Nunatsiavut Government 2018). LK of general distribution, feeding, and nesting habitats for marine birds were also compiled by the CCRI surveys (O'Brien et al. 1998, DFO 2007) and Our Footprints are Everywhere (Brice-Bennett 1977).

Taken together, all of this information indicates that the study area provides habitat for many marine bird species of cultural and ecological importance. In addition to local and national interests, tracking of migratory birds shows that this study area and the adjacent deep waters to the north, south, and east are internationally important wintering grounds for a range of Arctic breeding marine birds (McCarney et al. in prep[1]). Pelagic waters of the southern Labrador Sea, adjacent to Canada's Exclusive Economic Zone (EEZ), have been designated as an EBSA by the Convention on Biological Diversity (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).

11.2. Sensitive Species and Habitats

The Labrador coast provides important habitat to diverse marine birds, including several vulnerable species that are recognized by COSEWIC, *SARA*, and/or the province of Newfoundland and Labrador. Migratory shorebirds use the coastal habitats of the study area as staging and feeding areas, including Red-necked Phalarope (COSEWIC Species of Special Concern), the Endangered Red Knot (*SARA* Schedule 1), and the Endangered Eskimo Curlew (*SARA* Schedule 1). The Eastern populations of Harlequin Duck and Barrow's Goldeneye, listed as species of Special Concern (*SARA* Schedule 1), both rely on important moulting and staging areas within the study area. The core wintering areas of the Ivory Gull, an endangered species within Canada (*SARA* Schedule 1) and Near Threatened globally (IUCN Red List), are found adjacent to the study area (Spencer et al. 2016). Ivory gull have also been observed along the coastline of the study area (Todd 1963).

Several IBAs identified within the study area recognize potential vulnerability of these habitats to disturbance from industrial development (e.g., Voisey's Bay mine) and associated marine traffic. A major oil spill and/or chronic spills associated with shipping or routine maintenance could have major impacts on these colonies (Bird Studies Canada, n.d.). For example, recent analysis indicates that Dovekie are particularly vulnerable to pollution events due to their behaviour (i.e., time spent at the surface and/or diving) and the timing and spatial distribution of their offshore habitat use (Fort et al. 2013).

Sea ice is an important habitat for many species of marine bird, including Ivory Gull, Thick-billed Murre, and Black Guillemot (Ainley et al. 2003). These habitats are sensitive to human activity (e.g., vessel traffic) and to anthropogenic climate change. For example, research conducted in Hudson Bay indicates that early ice break up creates a temporal mismatch between breeding and peak food availability, with impacts for many species, including murres and eiders which are also present in this study area (Mallory et al. 2010). Vulnerability of sea ice habitat is described in detail in Section 3.

11.3. Data Gaps and Recommendations

11.3.1. Local Knowledge

It would be helpful to better understand species ranges and distribution within the study area, including identifying specific and sensitive habitats for marine birds. 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. 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 related to range shifts further north along the coast of Labrador.

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 and many interview participants discussed the importance of the spring hunt for opportunities to gather wild food out on the land. At the same time, participants expressed concerns about the long-term sustainability of the spring goose hunt and said they would like to see 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 birds as an important source of wild foods, so any conservation measures and policies focused on birds need to consider the food security needs and harvesting rights of Inuit.

11.3.2. Shorebirds

There is a clear need for systematic shorebird surveys to determine distribution and abundance, as well as patterns of use over time. The Atlantic Canada Shorebird Survey (ACSS) 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.

11.3.3. 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 the 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 and Bufflehead.

11.3.4. Tracking 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.

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, but rather 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 CBIRD (the marine bird expert group for CAFF [Conservation of Flora and Fauna]).

11.3.5. At-sea studies

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 is conducted as part of ongoing ECCC programs. Though possibly not an option at this time for the offshore portion of the study area, 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).

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. Photography is evolving quickly and is contributing significantly by enabling developing observers to make meaningful contributions to our understanding of bird distribution (e.g., via eBird).

12. Ecological and Biologically Significant Areas

Ecologically and Biologically Significant Areas (EBSAs) are areas identified through science-led processes that call attention to areas of particularly high natural value. Their identification and description is meant to facilitate the provision of a greater-than-usual degree of risk aversion in management of activities in such areas. They are identified based on criteria established by DFO Science (DFO 2004) using available scientific and LK.

12.1. Available Information

Portions of three EBSAs are found within the Study Area (DFO 2013): Nain Area, Hopedale Saddle and Hamilton Inlet (Figure 3). Three EBSAs border on the study area: Northern Labrador, the Labrador Marginal Trough, and Lake Melville. Other EBSAs that are nearby but outside the Study Area are the Outer Shelf Nain Bank and Labrador Slope EBSAs, which occur further offshore on the continental shelf and slope of the Labrador Sea. Finally, a transitory EBSA, Southern Pack Ice, overlaps with the southern portion of the study area seasonally. All EBSAs are described in detail by Wells et al. (2017).

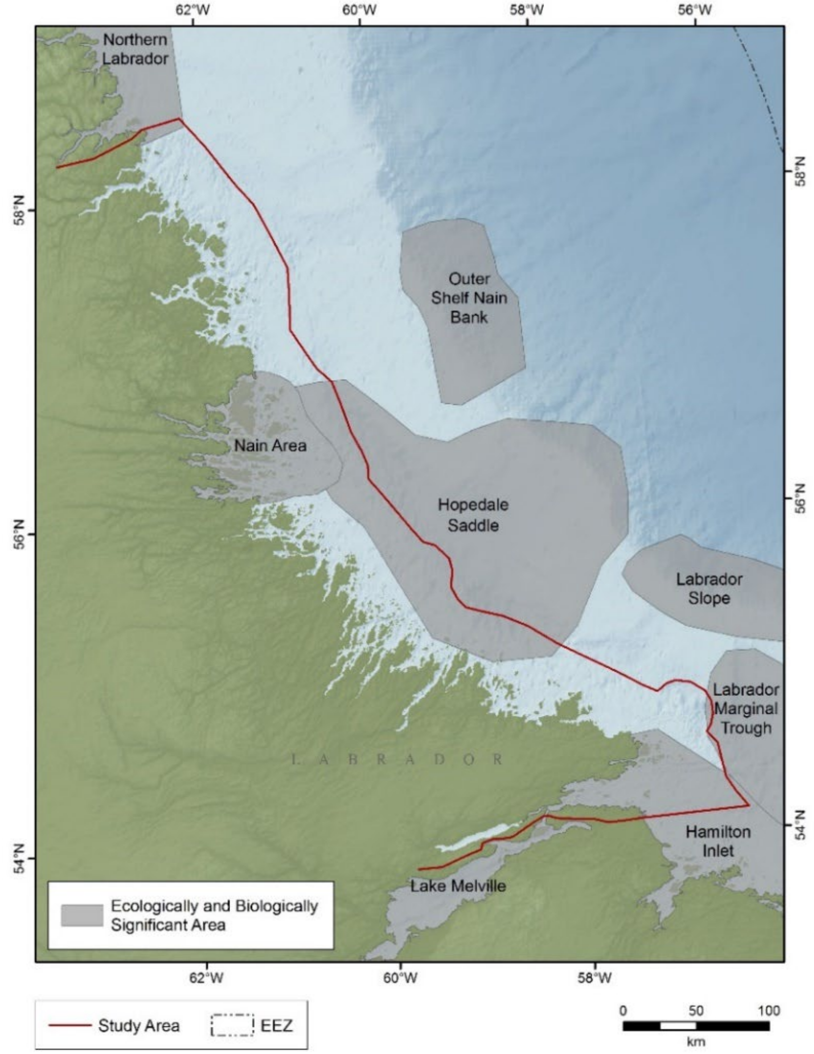

Figure 3: Ecologically and Biologically Significant Areas (EBSAs) that have been identified within and adjacent to the study area.

12.2. Sensitive Species and Habitats

The Nain Area EBSA was identified based on aggregations and colonies of seabirds and waterfowl, Capelin spawning beaches, and because the area is known to be highly productive for Arctic Char (DFO 2013). While the key feature of the Hopedale Saddle EBSA is the unique overwintering area for Eastern Hudson Bay belugas, it also includes high concentrations or aggregations of several coral, fish and seabird species. It is 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 highly productive for Atlantic Salmon (DFO 2013). Other features of these areas are described in detail in Wells et al. (2017). Features of EBSAs adjacent to or just outside the study area are described in McCarney et al. (in prep[1]) and Wells et al (2017).

12.3. Data Gaps and Recommendations

While several EBSAs have been identified within or adjacent to the study area (McCarney et al. in prep[1]), many of the habitat features that underlie significant ecological and biological processes in the coastal zone were poorly resolved during the delineation process (Wells et al. 2017). Because of this, and because of changes in environmental and community structure observed in the ecosystem in recent times, it was recommended that EBSA delineations be revisited periodically as more information becomes available from scientific research, monitoring and LK. The vast amount of information collected during this overview would contribute to further refinement of EBSAs and their features within and adjacent to the study area.

13. Inuit Use and Other Activities

13.1. Available Information

13.1.1. Inuit Use

Nunatsiavut, the homeland of Labrador Inuit, is a self-governing region that was established through the signing of the Labrador Inuit Land Claims Agreement on December 1, 2005. Labrador Inuit use and rely on the ocean. The ocean is Inuit's connection to food, sustainability, economic growth, and culture and therefore is fundamental to Inuit survival, health, and well-being. Labrador Inuit have traveled over, and harvested in, the marine environment in all seasons for many thousands of years.

For Inuit, sea ice is critical infrastructure and is a central part of culture, community, and livelihood. Ice is an extension of the land, imperative to Inuit for travel and access to areas, as well as a platform to access the ocean and its resources (McCarney et al. in prep[1]). Sea ice connects Inuit, allowing for travel between communities within Nunatsiavut and also to other Inuit regions in Canada. The ice also allows Inuit to access harvesting areas (both on land and water) at different times of the year and connects Inuit to historical and culturally important areas, including cabins, seasonal camps, and trap lines. The reliance of Labrador Inuit on ice is reflected by their extensive understanding of ice at each stage – formation, solidity, stability, crystallization, and breakup (Aporta 2017). The knowledge held by Inuit about the sea ice has been taught and handed down for many generations.

Inuit continue to share and use traditional knowledge and culturally important food sources and travel routes while hunting, fishing, trapping, and relying on the land and ocean. They utilize plants, berries, fish, benthic invertebrates, birds and their eggs, and mammals; sustainably benefiting from these resources for thousands of years. Recent anthropogenic factors and changes in climate have had significant impacts on many species of importance for 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. The main commercial species caught on the Labrador Coast are: Northern Shrimp, Snow Crab, Greenland Halibut, Northern Cod and Arctic Char (McCarney et al. in prep[1]). The primary species currently caught in the community fishery are Arctic Char and scallops.

Inuit traditionally share food and this includes foods harvested from the marine environment. On a monthly basis, more than a thousand individuals visit Nunatsiavut community freezers and thousands of pounds of food are distributed.

13.1.2. Other Activities

In addition to the diverse Inuit uses of the marine environment, there are other activities taking place within the vicinity of the study area, including commercial and recreational (nonindigenous) fishing, oil and gas exploration, and marine traffic. The majority of commercial fishing occurs in the deeper waters east of the study area. The most commonly caught species are Greenland Halibut (gillnet and trawl), Northern Shrimp (trawl), and Snow Crab (traps) (McCarney et al. in prep[1]).

Recreational fisheries for Atlantic Salmon and Brook trout (angling) also exist in the area (DFO 2018b). Currently there are nine scheduled salmon rivers draining into the study area. In 2018, however, the recreational fishery for Atlantic Salmon was reduced to a catch and release fishery with a daily limit of three fish.

Interest has intensified for oil and gas exploration in the Labrador Sea. Seismic exploration of this area started in 1980 with significant coverage since 2012. No exploration wells have been drilled within the study area to date but some have occurred just outside. The area adjacent to the study area includes five Significant Discovery Licenses (SDLs) for natural gas, as well as, Call for Bids and Sectors (McCarney et al. in prep[1]). In 2008, the Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB) completed a Strategic Environmental Assessment (SEA) for an area of offshore Labrador known as the Labrador Shelf SEA Area. A SEA Update Report is being developed by C-NLOPB with assistance of a Working Group co-chaired by C-NLOPB and the NG.

Marine traffic density is currently low in the study area (McCarney et al. in prep[1]), with the heaviest activity occurring in and out of Nain and Happy-Valley Goose Bay along the coastal boat route and in fishing areas near the study area boundary. The majority of shipping traffic includes: commercial fishing, cargo supply ships, ferry service, tankers, search and rescue, and research vessels.

Northern shipping routes may experience an increase in shipping traffic as warmer ocean temperatures reduce Arctic summer sea ice (i.e., Northwest Passage) (Struzik 2016). This could result in the Labrador Sea being more actively used for marine shipping activities as the Canadian gateway to the Arctic (Fort et al. 2013).

13.2. Sensitive Areas

Inuit consider all parts of the study area as sensitive and important to their cultural, health and well-being. The connection between environment and health is inherent to Inuit, and therefore, changes in the marine environment directly affect Labrador Inuit.

There is evidence of Inuit nearly everywhere on the central and northern Labrador coast (Brice-Bennett 1977), including traditional homesteads and culturally sensitive sites. LK collections indicate Inuit still travel from their communities during all seasons to visit some of these culturally significant areas, including areas such as Hebron, Okak and Saglek.

13.3. Data Gaps and Recommendations

Although LK collections have gathered large volumes of data about significant areas and human use, much knowledge remains undocumented. Specific parts of the study area (such as the Hebron and Okak areas around Nain, and Double Mer around Rigolet) are inadequately covered by existing interviews. Addressing these data gaps may require targeted visits with individuals with knowledge specific to these areas. Finally, understanding changes in biological communities and commercial fishery species is imperative to ensure long-term economic sustainability, as well as ensuring there are culturally important food sources available for Labrador Inuit. This information can be collected through further LK gathering initiatives as well as targeted science 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, 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. Both Marine Refuges protect corals and sponges and are closed to all bottom contact fishing activity under the *Fisheries Act*. These areas also provide important overwintering habitat to Narwhal and Beluga whales.

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 Canada's 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 and supports the largest and most diverse seabird breeding colony in Labrador.

CONCLUSIONS AND ADVICE

Despite rich LK of culturally important species in many parts of the coast, there remains significant gaps in the understanding of species distributions and ecology in the LISA Zone. Some parts of the study area are particularly under-represented in existing ecological datasets; examples include shelf areas inside the limits of the DFO RV surveys and some parts of the coast less frequently used by Labrador Inuit. Similarly, some seasons (winter and spring), ecological processes (e.g., fine-scale oceanography in the coastal zone), and species assemblages (e.g., coastal fish, marine invertebrates, and plankton communities) are poorly represented in available studies. This lack of scientific information may be partly attributable to challenging environmental conditions (e.g., sea ice, remote nature).

The available information, however, indicates that the study area is very dynamic, with biophysical conditions and species assemblages changing seasonally and across years. Sea ice is a particularly important ecological and ephemeral feature of the study area as many species are associated with or excluded by it. Over longer timescales, multi-year changes in biophysical conditions (e.g., sea ice) and species assemblages related to anthropogenic climate change have been observed.

Diverse coastal and marine habitats of the LISA Zone span depth (intertidal, nearshore, continental shelf and slope) and latitudinal gradients. These habitats support relatively intact species assemblages that include large marine mammals and predators and are home to species of conservation concern. The Labrador Inuit, stewards and rights holders of this ecosystem, rely on many marine species that have sustained them for generations. 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.

Due to a combination of factors (LILCA 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.

RECOMMENDATIONS

- Future research should aim to provide a better understanding of 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 LK 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).

OTHER CONSIDERATIONS

- Data provided by Labrador Inuit LK supports decision-making focused on maintaining sustainable populations of marine species.
- The synthesis of scientific and LK data in this document is supported by previous studies that show both social and ecological indicators are key to successful conservation efforts. Recognition and respect of the interdependence of the Labrador Inuit and ecosystem will be paramount to achieving conservation goals in this study area.
- The following principles are recommended when undertaking research in the study area:
  - Involve the NG in research activities, incorporate LK, 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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SOURCES OF INFORMATION

This Science Advisory Report is from the November 29-30, 2018 Regional Peer Review on the Biophysical and Ecological Overview of a Study Area within the Labrador Inuit Settlement Area Marine Zone. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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