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Newfoundland and Labrador Region
Canadian Science Advisory Secretariat
Science Response 2018/051

GUIDANCE ON THE REVIEW OF BIOPHYSICAL AND ECOLOGICAL COMPONENTS TOWARDS A RESEARCH AND MONITORING PROGRAM OF THE LABRADOR SEA

Context

The Government of Canada has committed to protecting 10% of Canada's marine and coastal areas by 2020 as part of its commitment to achieve international (the Convention on Biological Diversity 2011-20 Strategic Plan for Biodiversity's Aichi Targets) and domestic (2020 Biodiversity Goals and Targets for Canada) biodiversity conservation goals and targets. Accordingly, a Five Point Action Plan (Fisheries and Oceans Canada [DFO] 2016) has been implemented that includes *Oceans Act* Marine Protected Areas (MPAs) in large offshore ocean areas as options towards meeting Canada's marine conservation targets.

An offshore portion of the Labrador Sea is being investigated as a potential candidate large offshore ocean area. This Study Area extends from water depths of 2,000 m (beyond the continental shelf and slope) to the Canadian Exclusive Economic Zone (EEZ) and sits within Northwest Atlantic Fisheries Organization (NAFO) Divisions 2G and 2H. With nominal resource development, it is considered a Frontier Area (DFO 2009). The scientific knowledge regarding this area's ecosystem is limited, particularly for biological components, as the depths extend well beyond the range typically monitored by Fisheries and Oceans Canada (DFO) and NAFO during stock assessment surveys. Consequently, targeted research is required to support the biophysical and ecological characterization of this Study Area.

Objectives

This Science Response provides the basis for discussion and advice on the specific objectives outlined below:

1. Identify and map, where possible, the available physical and ecological information for the Labrador Sea Study Area.
2. Identify key uncertainties and knowledge gaps as it pertains to the current understanding of the existing environment and species of interest within the Study Area.
3. Define the appropriate techniques to characterize and evaluate the key biophysical and ecological features of the Study Area, including:
    - predominant and/or unique physical and biological oceanographic characteristics;
    - predominant, unique, and/or sensitive habitat features; and
    - key species of interest, such as commercial and non-commercial species, marine mammals and endangered or threatened marine species; including life history relevance of the area to the species, species distribution and abundance (and status and trends where available), and the abiotic and biotic factors influencing these.
4. Where possible, identify known sensitivities/vulnerabilities of habitats and species of interest within the Study Area.

5. Provide an outline of a draft research plan to inform the MPA designation process.

Objective 5 is addressed exclusively in this document. Objectives 1-4 are summarized from an accompanying research document (Cote et al. 2018) for primary ecosystem elements that include:

- Underwater Features,
- Oceanography (including plankton),
- Benthic Communities,
- Corals and Sponges,
- Fish,
- Seabirds, and
- Marine Mammals.

Additionally, information related to Indigenous Traditional Knowledge (ITK) has been provided by the Nunatsiavut Government and the NunatuKavut Community Council.

This Science Response Report results from the Science Response Process of January 9-10, 2018 “Guidance on the Review of Biophysical and Ecological Components towards a Research and Monitoring Program of the Labrador Sea”. The overview and advice arising from this Canadian Science Advisory Secretariat Regional Science Response Process will be used to inform the characterization, design and establishment of MPAs in the Newfoundland and Labrador (NL) Region.

Background

Oceans management decisions, including the designation of MPAs and MPA Areas of Interest (AOIs), are complex and iterative processes that require significant public and stakeholder consultation as well as ecological and socio-economic analyses. Each stream of information is considered before formally initiating the MPA process and establishing AOI boundaries. The characterization of the Labrador Sea Study Area as a large, offshore Frontier Area is challenged by the scarcity of existing ecological data due to the limited research and history of anthropogenic activity in this region. Targeted and strategic efforts are necessary to support oceans management decisions, and consequently an interim Study Area has been defined to focus data collection and ecosystem characterization efforts. The Labrador Sea Study Area encompasses waters >2,000 m in NAFO Divisions 2G and 2H out to the Canadian EEZ (Figure 1). The area sits within the Polar biome as defined by Longhurst (1998) and includes bathyal and abyssal benthic habitats as well as overlying pelagic habitats. The expense, technological challenges and lack of commercial interest has limited the scientific understanding of deep-sea environments relative to shallower shelf and coastal habitats. Nevertheless, it is understood that deep-sea habitats contain a variety of species with specialized adaptations to live in deep, dark and food scarce environments (Priede 2017). Many deep-sea species also have characteristics that make them sensitive to anthropogenic disturbance.

The Labrador Sea Study Area does not contain any formally defined Ecologically and Biologically Significant Areas (EBSAs), but this is likely a result of lack of information on which to base these designations. Adjacent areas along the slope and in international waters contain EBSAs and closures including the Outer Shelf Saglek Bank, Outer Shelf Nain Bank, Hopedale Saddle, Labrador Slope, Southern Labrador Sea Seabird Foraging Zone and the Labrador Sea Deep Convection Area EBSAs as well as the Hatton Basin fisheries closure (Figure 1).

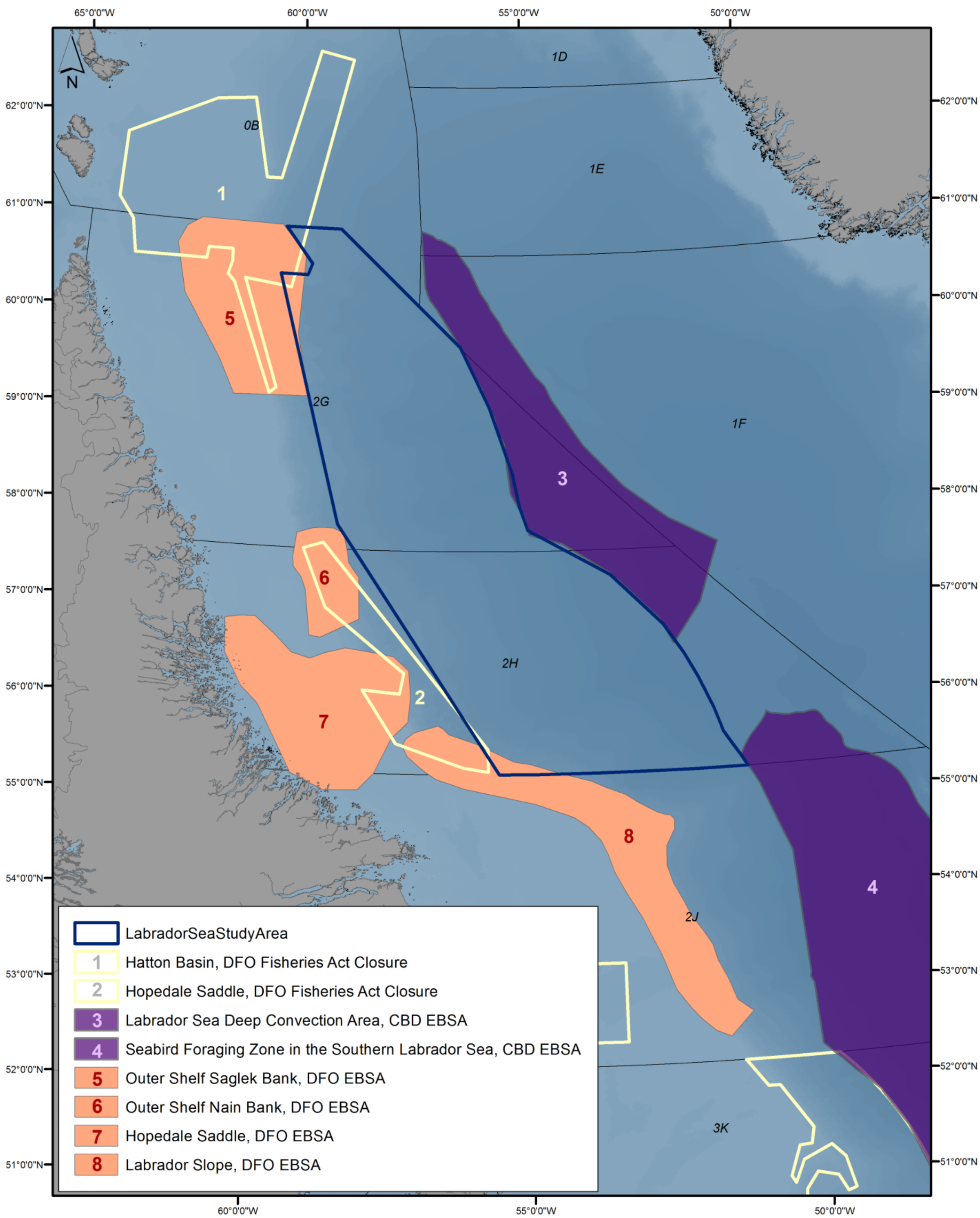

Figure 1: Labrador Sea Study Area with adjacent EBSAs, fisheries closure zones and NAFO zones.

Analysis and Response

Underwater Features

Little has been done to characterize the underwater features of the Study Area relative to coastal areas. While coarse level bathymetry is available from remote sensing (e.g., General Bathymetric Chart of the Oceans dataset [GEBCO]), higher resolution products that are derived from hydrographic and habitat characterization surveys are lacking for the vast majority of the Study Area. While such data would be valuable for guiding future research and management within the Study Area, comprehensive maps are unlikely to be available in the near future due to the size of the area and the requirement for specialized, large, deep-sea-capable echosounding units. These surveys are further complicated by the challenges of ground-truthing acoustically-derived habitat maps with *in-situ* sampling at great depths.

Large research vessels (RVs; e.g., CCGS Amundsen) are usually equipped with multi-beam units capable of surveying the depths of the Study Area and thus any cruises on such vessels should include multi-beam data collection. With appropriate planning, smaller multi-beam units can be mounted temporarily on vessels of opportunity and would also be capable of mapping the shallower portions of the Study Area (2,000-2,800 m). Not only will these data start the habitat inventory process but the habitat data will be useful for interpreting the biological samples collected. In the meantime, existing bathymetry data will be useful for optimizing study design and for predicting important ecological processes. For example, canyons leading into the Study Area have been mapped along the continental slope, and these structures are known to serve as conduits of nutrients and sediments from the shelf habitats to bathyal and abyssal habitats. Similarly, additional processing of coarse bathymetry data (e.g., Relative Position Index and Terrain Ruggedness Index; Riley et al. 1999) can provide an indication of habitat heterogeneity across the Study Area, which would be useful when designing collections aimed at characterizing biological diversity.

Oceanography

A considerable volume of physical, biological and chemical oceanographic data has been collected from the Labrador Sea Study Area and adjacent regions. These data originate from a variety of sources including:

- Historical data,
- The Atlantic Zone Monitoring Program (AZMP),
- The Atlantic Zone Offshore Monitoring Program (AZOMP),
- Remote sensing and international programs such as the Argo float program, Overturning in the Subpolar North Atlantic Program (OSNAP) and Ventilation Interaction and Transports Across the Labrador Sea (VITALS).

Much of the interest in studying the Labrador Sea arises from the fact that its oceanography is of global significance. First, the Labrador Sea is one of only a few regions of the world that undergoes deep water convection (i.e., it delivers oxygenated surface waters to deep ocean depths). This process is driven in part by the presence of sea ice and will be influenced by climate-related changes to surface sea temperature. Second, the North Atlantic, including the Labrador Sea, has the highest marine concentrations of anthropogenic CO_2 on the globe (Sabine et al. 2004) and these levels continue to rise (Yashayaev et al. 2016). For these reasons, the Labrador Sea is particularly important in the study of the effects of climate change on marine ecosystems.

Collectively, the data sources outlined above reveal several important features of the Study Area. Physical conditions of the Labrador Sea differ considerably between the shelf and off-shelf areas. The surface waters of the Study Area, relative to adjacent shelf areas, are warmer, less saline and have little exposure to sea ice. This transition occurs sharply at the shelf edge. Physical conditions within the Study Area are also stratified vertically, with the most distinct transition typically occurring at about 2,000 m. Waters deeper than this originate from the Denmark Strait Overflow Water (DSOW) and are slightly colder and more saline than the Labrador Sea water above (Yashayaev and Loder 2017), where winter surface temperatures in the Study Area are approximately 2°C and warm to approximately 8°C in August. The currents of the Study Area are driven by the counter-clockwise movement of the Northwest Atlantic sub-polar gyre. This system is formed by the West Greenland Current and the Labrador Current. For the Study Area, this results in strong south easterly flows along the continental slope, a westerly flow in the northern off-slope areas and low current velocities in the deeper parts of the Study Area near the centre of the gyre. The strong flows along the continental slope help separate the Study Area's water masses from the adjacent shelf areas.

One particular strength of the oceanography data is the ability to capture the temporal variability of the Study Area. For example, Yashayaev and Loder (2017) document highly variable deep-water mixing from year to year as well as multi-year shifts of salinity and temperature characteristics of the Labrador Sea. Other metrics like upper-layer water temperature have shown long-term trends; decreasing from the 1960s until the early-1990s and then increasing since.

Oceanography studies in the Labrador Sea have also provided important insights into the lower trophic levels (i.e., phyto and zooplankton) in the Study Area. Remote sensing of ocean color indicates that the spring surface bloom in the Labrador Sea is normally initiated from early-May to mid-June and peaks from early-May to mid-July. In recent years, these blooms have been intense and field sampling indicates that recent large-scale surface blooms have been dominated by algae of the genus *Phaeocystis* (mucus-forming colonies). The zooplankton community in the Labrador Sea is dominated by grazing copepods such as *Pseudocalanus* spp. and *Calanus finmarchicus*, but also includes gelatinous and carnivorous zooplankton. The prominence of specific taxa within this zooplankton community appears to cycle over scales of multiple years, with different size classes of taxa showing reciprocal changes over time. Overall, there has been a reduction in zooplankton biomass since peak values were observed in 2007. While phytoplankton abundance has been linked to biophysical drivers, variation in zooplankton abundance has been less clear.

Relative to some higher trophic levels (e.g. benthos and fish), the understanding of the oceanography of the Study Area is relatively strong, particularly for physical oceanographic conditions. However, knowledge of biological elements (plankton) is derived mostly from the shelf to the south and/or west of the Study Area. Within the Study Area, at-sea sampling is primarily restricted to the occasionally sampled offshore stations of the Beachy Island and Makkovik AZMP lines in the southwest. Given the strong differences in water masses of the shelf and the Study Area, there is some uncertainty as to whether shelf observations of plankton communities apply to the Study Area. Furthermore, while the understanding of productivity of surface layers is relatively strong, there is much less information related to the amount of energy reaching benthic habitats. In many parts of the deep ocean, only a fraction of surface productivity reaches bathyal depths, but the deep-water convection could potentially enhance productivity of benthic habitats in the Labrador Sea.

Additional oceanographic monitoring in future years should consider extension of current AZMP sections that would permit analyses of biophysical connectivity between the shelf and the

Labrador Sea Basin and evaluate seasonal changes in biota and physical conditions. Given the importance of the Labrador Sea in air-sea dynamics and exchange of carbon dioxide within the deep basin, additional sampling efforts should be considered to address ocean acidification. Additional analyses on existing data can further the understanding of biological connectivity. For example, knowledge of currents can be applied to questions of larval transport and identification of recruitment sources for species inhabiting the Study Area, as well as determining which regions benefit from Study Area exports. Of course, to make such models reliable, improved biological inputs are needed for most taxa.

The limited opportunities to conduct ship based oceanographic monitoring means that additional data collection will likely require investment in autonomous vehicles and profiling systems fitted with scientific instruments (e.g., ocean gliders, Sea Cycler), long-term deployments of automated collection devices deployed on moorings (e.g., sediment traps for demersal productivity), and/or working collaboratively with other interested research teams. Collaborations hold considerable potential given the international interest in studying oceanographic conditions in the Labrador Sea (e.g., Bedford Institute of Oceanography [BIO], VITALS, OSNAP and the recently formed DFO NOAA Ocean Acidification Working Group).

Benthic Communities

Information on benthic organisms occupying the Labrador Sea Study Area is almost completely lacking as most benthic studies in Atlantic Canadian waters have been conducted on shallower shelf and slope habitats.

Studies in other areas, however, demonstrate that benthic organisms play an important role in the deep sea community and, like fish, benthic communities are stratified by depth (Haedrich et al. 1980, Rex 1981, Howell et al. 2002 in Gale et al. 2015). For example, trawls across a gradient of depths in waters off New England indicate that megafaunal community components such as echinoderms and decapods are common in deep water systems (Haedrich et al. 1980). When characterizing the communities (including fish) at depth zones comparable to the Labrador Sea Study Area, Haedrich et al. 1980 observed that echinoderms comprised five to seven of the top ten taxa in terms of abundance and four of the top ten taxa in terms of biomass. Aside from being an important structural component of deep sea ecosystems, megafaunal species such as asteroid echinoderms serve an important ecosystem function in deep-sea food webs and disturbance regimes (Gale et al. 2013). Macrofaunal (e.g., polychaetes, gastropods, cumaceans and bivalves) and meiofaunal elements are also known to be important elements of other western Atlantic deep sea communities (Rex 1981).

While time series data from the deep sea are extremely rare, a study from the northeast Pacific (Ruhl and Smith Jr. 2004) indicates that deep-sea benthic communities are responsive to climate events such as El Niño and La Niña. Even though environmental conditions such as temperature and salinity are considered much more stable in the deep sea than in shallower shelf waters (Rex 1981), most deep-sea inhabitants still rely on the production of surface waters as a source of energy (exceptions being some organisms that occupy chemosynthetic sites). Epi-pelagic production and resulting particulate organic carbon are more directly affected by climatic cycles and provide a mechanism to introduce temporal variability to deep sea benthic communities (Ruhl and Smith Jr. 2004).

Species and/or Habitats of Interest

The paucity of information on deep sea benthic invertebrates in the Labrador Sea Study Area limits the ability to define species and habitats of particular interest. Echinoderms are likely to form a key structural component of the deep sea ecosystems where these taxa may also initiate key ecological processes (e.g. disturbance regimes; Ruhl and Smith Jr. 2004). The association of some species of benthic invertebrates with fragile deep-sea coral habitats (Baillon et al. 2014, Gale et al. 2015) along the slope of Newfoundland and Labrador suggests that coral/sponge habitats may be important should they occur in abundance in the Study Area (see later section).

Key Uncertainties and Approaches to Address Data Gaps

The absence of benthic collections in the Study Area is a principal data gap. Even though deep sea benthic communities group by bathymetry into a few general ubiquitous assemblages, the exact depths at which they occur and the specific structural components differ according to region (Haedrich et al. 1980, Gale et al. 2015). Furthermore, several other factors beyond depth (e.g., temperature, substrate, presence of other fauna, bathymetry, and climate cycle) influence the distribution of benthic invertebrates (Haedrich et al. 1980, Ruhl and Smith Jr. 2004, Gale et al. 2015). Therefore, while studies from other areas provide useful starting points, region-specific information is important to defining the community composition within the Study Area, particularly given its unique oceanographic conditions (i.e., globally significant downwelling and high levels of anthropogenic carbon).

Perhaps more glaring is the general lack of information regarding the life history and ecological roles of many deep sea benthic species (Gale et al. 2015). If the Study Area's ecology mirrors that of adjacent slope habitats (e.g., Baillon et al. 2011, Gale et al. 2013), a functional understanding the Study Area's ecology will require a better understanding of the role and influence of the benthic species, particularly the echinoderms.

Improving our understanding of benthic communities in the Study Area will be challenging however. During the 2017 survey, drop cameras recorded some benthic megafaunal invertebrates but the areal coverage of this technique is poor (Haedrich et al. 1980). Baited cameras, commonly used for fish, may draw in some species from a larger area but methodological modifications may be required to account for the more limited mobility of benthic invertebrate taxa relative to fish.

Most widespread inventories conducted in deep sea environments used deep water trawls, dredges or remotely operated vehicles (ROVs). Relative to fixed and ROV mounted cameras, the sampled area of mobile collection gear is increased by many orders of magnitude (Haedrich et al. 1980) and it also allows collections of individuals for more detailed scientific examination (e.g., taxonomy, laboratory studies). While mobile collection gear would provide important data, trawling in the depths that characterize the Study Area is beyond the currently configured capability of existing Coast Guard vessels and would require procurement of these specialized services. ROVs provide the opportunity to visually explore behaviour of benthic organisms while allowing for limited sample collection. Unfortunately only specialized ROVs (e.g. ROPOS) can access the depths of the Study Area and the vessels on which to launch these units are not currently available through the Canadian Coast Guard.

Other methodological alternatives include collections from box cores, eDNA samples, and larval settlement plates. Box cores, like cameras, will provide limited spatial coverage but enable additional study of live specimens. eDNA samples are relatively easy to collect and provide the opportunity to characterize a variety of taxa simultaneously. Currently, eDNA remains largely experimental and will be limited by the availability of taxa-specific markers but the DNA in samples can be fixed and archived as baseline information until methods improve. Finally, larval settlement plates provide a relatively simple means of collecting early life stages of benthic animals and gaining an understanding of settlement and disturbance dynamics in the deep sea. Furthermore, using standardized deployment methods allows samples to be compared to other deep-sea collections worldwide. The principal limitation is that they need to be deployed long enough for meaningful settlement to occur.

Given the above considerations, it is recommended that the feasibility of mobile collection gear (e.g., benthic dredges and/or sledges) be explored and opportunistic sampling be conducted by combining multiple collection methods during gear deployment. For example, settlement plates can be deployed on fixed moorings used to monitor cetacean vocalizations and benthic invertebrate observations can be recorded during baited camera and ROV surveys. Where feasible, key representatives of benthic invertebrate ecosystems should be further studied to understand their basic ecology (life cycle and reproductive and feeding ecology).

Corals and Sponges

Corals and sponges are sessile organisms that produce complex three-dimensional structures. They are considered to be important ecosystem engineers because they create, modify and maintain habitat for other benthic species at macro-habitat (i.e. between colonies), micro-habitat (i.e., between branches), and nano-habitat (i.e., within tissue) spatial scales.

The functional roles that corals and sponges play in benthic ecosystems has been well documented (Bell 2008, Buhl-Mortensen et al. 2010, Baillon et al. 2014) and can include protection from predators (Wulff 2006), rest areas from currents (Zedel and Fowler 2009), forage areas for food (Buhl-Mortensen and Mortensen 2004) and nurseries for young (Aldrich and Lu 1967, Mercer 1968, Baillon et al. 2012). Accordingly, coral and sponge habitats are associated with elevated biodiversity (Cerrano et al. 2010).

The bulk of knowledge regarding the distribution of corals and sponges in Canadian waters is derived from random stratified research trawl surveys (Treble et al. 2000, Treble 2002 and 2009), complimented by opportunistic collections by Fisheries Observers on board commercial fishing vessels (Wareham and Edinger 2007, Wareham 2009). In the Eastern Arctic Region, DFO and the Northern Shrimp Research Foundation (NSRF) conduct trawl surveys for Greenland halibut and shrimp in NAFO Divisions 2G and 0AB between 400-1,500 m depth (see Treble et al. 2000, Treble 2002, Treble 2009). However data collection from DFO and NSRF surveys have been restricted to ‘trawlable’ bottoms due to gear limitations of the trawl, and as a result, very little is known about hard substrate environments as well as waters deeper than 1,500 m.

Predictive modeling approaches have been used to infer distributions on hard substrates into bathyal (200-3,000 m) and abyssal (3,000-6,000 m) zones. Using coral species and functional groups, maximum entropy (Maxent) models were generated by Gullage et al. (2017) and showed suitable habitat along the continental shelf break and within canyons. Kenchington et al. (2016) also identified significant concentration of corals and sponges with random forest machine-learning techniques. At depths <1,500 m results were verified with Fisheries Observer data, and overall this model performed well. However, model results beyond 1,500 m have not been validated.

In the shallower waters (<1,500 m) of the Northwest Atlantic, distributions of corals and sponges have been documented from the Grand Banks of Newfoundland to Baffin Bay in the Canadian Arctic (Wareham and Edinger 2007, Wareham 2009). For the most part, they are found along the continental shelf edge and slope with the exception of soft corals and occasionally large gorgonians, which extend on top of the shelf (see Kenchington et al. 2016). As in other areas of the world (Hall-Spencer et al. 2002, Clark and O’Driscol 2003), benthic surveys and fishing activities are altering coral and sponge habitats. Taxa such as large gorgonians (e.g., *Paragorgia arborea* and *P. resedaeformis)* are highly sensitive to anthropogenic disturbances due to their brittle nature, extremely slow growth and long life span (Sherwood et al. 2006, Sherwood and Edinger 2009). Based on growth alone, recovery from fisheries impacts will take decades to centuries and resilience to physical (e.g., clipped, injured or disoriented) or chemical (e.g., sponges) damages are still unknown but may increase predation, parasite loads, and/or disease (see review Clark et al. 2016). Interestingly, the only known location of old growth coral at shelf and shelf break depths occurs adjacent to the Study Area on Saglek Bank-Hatton Basin, Labrador Sea (Wareham and Edinger 2007, Gilkinson and Edinger 2009).

Species and/or Habitats of Interest

The ecological importance of coral and sponge habitat to other benthic and demersal species, along with their sensitivity to anthropogenic impacts, makes coral and sponge taxa of interest for this Study Area. While the Study Area remains largely unstudied for these taxa, both corals and sponges were documented by drop cameras and through long-line catches in waters >2,000 m in 2017. Furthermore, the Labrador Sea (principally the adjacent Hatton Basin and Saglek Bank) has been recognized as a key area for corals and sponges (MPA News 2007, Wareham et al. 2010, Kenchington et al. 2016).

Key Uncertainties and Approaches to Address Data Gaps

Knowledge of coral and sponge distributions in the Northwest Atlantic is particularly limited at depths beyond the continental slope, due to the logistics of accessing deep remote areas and the associated costs of deep-sea research. In more well-studied depths, much of the distributional knowledge is derived from surveys of trawlable habitat, which may not reflect the ideal substrates for important coral taxa (e.g., large gorgonians) (Mortensen and Buhl-Mortensen 2004, 2005). In addition to important distribution information, knowledge of basic life-history traits of coral species (e.g., reproduction, fecundity, mode, age at reproduction, sex, and larval dispersal; Sun et al. 2010, Mercier and Hamel 2011, Mercier et al. 2011a,b, Baillon et al. 2014) is sparse and even less is known for sponges.

In the Study Area, coral and sponge knowledge is particularly scarce. The only known information on corals and sponges is derived from a small sample of baited drop cameras and long-line sets from the 2017 mission. Photos generated from this mission captured bamboo corals (family Isididae) and sponges but spatial coverage and sample sizes were very limited. Understanding how coral and sponge communities are connected in the Study Area to high priority habitats in Hatton Basin is also a significant data gap.

The large scale of the Study Area and the scarcity of information related to corals and sponges at those depths (>2,000 m) pose a significant challenge to addressing the existing data gaps. However, habitat-based models, supported with targeted *in-situ* ground-truthing, will likely provide the best investment for understanding of coral and sponge communities in the Study Area. Multi-beam habitat classification should be conducted and the resulting backscatter maps can form the basis for identifying available habitat types, applying existing habitat-based models and maximizing at-sea efforts to validate model results.

Inventories of corals and sponges can be done opportunistically (e.g., during baited camera surveys, long-line efforts and/or box cores) but ideally these will supplement targeted collections (e.g., with benthic dredges and/or sledges) using sampling designs that are informed by multi-beam derived habitat maps. Other non-invasive techniques, such as eDNA, may be useful for characterizing coral and sponge communities as well as their associations with other taxa.

Finally, where feasible, study of preserved and live specimens should be conducted to document the life-history traits of key coral and sponge taxa in the Study Area. In particular, the study of early life stages will greatly enhance the realism of larval transport models that have been applied elsewhere (Mercier et al. 2013, Young et al. 2018).

Fish

Available Information

The bulk of fisheries knowledge in Canadian waters is derived from RV surveys and harvester logbooks. Within the Study Area's NAFO divisions, these activities are restricted to depths shallower than 1,500 m. Consequently, very little information exists regarding the fish community structure and distribution within the Study Area boundaries. Due to the strong effects of depth on demersal fish community structure (Priede 2017), RV survey catches are not likely to reflect the communities that occur in the depths of the adjacent Study Area.

In August of 2017, a long-line survey based on the methods of Murua and de Cardenas (2005) and a co-located baited camera survey were conducted in the Study Area and the adjacent slope (500–3,000 m). Preliminary results of these surveys reflected strong depth-related differences in fish community structure with long-line catches beyond 2,000 m dominated by Blue Hake, Armed Grenadiers, skates and Cutthroat Eels. Baited camera stations at depths greater than 2,000 m were visited by these same species.

While no other demersal fish data from waters exceeding 2,000 m depth exist from Canadian surveys, the findings of Murua and de Cardenas (2005) from deep waters off NAFO Divisions 3LMN qualitatively mirror the results of the 2017 Labrador Sea survey. Specifically, depth gradients in the catch composition of their long-line sets were apparent, with a pronounced shift in the fish community at depths greater than 2,000 m. The fish community at these depths was qualitatively similar to the preliminary observations in the Study Area in that it was comprised principally of Armed Grenadier, skates and Blue Hake. At a more distant deepwater site at the mid-Atlantic ridge (Fossen et al. 2008), East Greenland (Haedrich and Krefft 1978) and off New England (Haedrich et al. 1980), Armed Grenadier and Blue Hake also dominated catches at depths greater than 2,000 m. Two of these distant deepwater studies (Fossen et al. 2008 and Murua and de Cardenas 2005) also reported declining catches as depths increased beyond 1,500 m, whereas declines did not occur until depths exceeded 2,500 m in another (Haedrich et al. 1980). Despite declining catches at greater depths, fish taxa can dominate the available biomass at depths associated with the Study Area (Haedrich et al. 1980) and fish diversity has been shown to peak at depths between 1900 and 2,300 m (Rex 1981). These results collectively suggest that fish are likely to be an important ecological component in the Study Area. Furthermore, the dominant components of deep-sea communities may be fairly homogeneous across large spatial scales and therefore more distant study locations may be of use in predicting communities in the Study Area. However, less dominant components can differ and reinforce the need for site-specific surveys (Haedrich et al. 1980).

In deep-water environments, small meso-pelagic species (e.g., lanternfish, myctophids; bristlemouths, gonatostomatids; hatchet fishes, sternoptychids; barbelled dragonfishes, stomiids) are thought to dominate the water column (Priede 2017). While few data collections have been conducted within the Study Area, sampling further to the south in the western Labrador Sea indicate widely distributed myctophids such as glacier lanternfish (*Benthosema glaciale*), play an important role in transferring energy from secondary producers such as copepods, to higher levels of the food chain (e.g., seabirds and marine mammals). Myctophids also are the primary mesopelagic taxa captured by RV surveys in adjacent slope habitats. While some taxa of meso-pelagic fish maintain species-specific depth ranges (Priede 2017), others such as lanternfish conduct nocturnal feeding migrations to epi-pelagic waters (Pepin 2013, Priede 2017).

The importance of lanternfish in the pelagic waters of the northern Labrador Sea was confirmed by Sheehan et al. (2012), who found myctophids along with lumpfish (*Cyclopterus lumpus*), redfish (Sebastidae), and squid in abundance in midwater trawls. Other species of note were sand lance, Arctic Rockling, and Greenland Halibut. Among this pelagic fish community in the Labrador Sea were Atlantic Salmon post-smolt and adults, migrating from distant natal rivers ranging from Maine to Labrador (Reddin and Short 1991) to feed on a diversity of prey species including amphipods, squid and fish in the Labrador Sea (Sheehan et al. 2012). Myctophids were also observed in the Labrador Sea camera survey but only at depths along the adjacent slope.

Species and/or Habitats of Interest

The pelagic habitat of the Study Area is an important feeding ground for Atlantic Salmon that likely include members of several populations listed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2010). Individuals of these populations likely inhabit the Study Area throughout the year. Myctophids (lanternfish) also likely play a critical ecological role in the Study Area as they are the principal means of transferring energy from secondary producers to higher levels of the food web as well as moving nutrients through the water column during their vertical migrations.

In demersal habitats, the dominant fish species (Armed Grenadier and Blue Hake) of the Study Area are not currently harvested or known to be at risk. Captured skates remain to be identified but it is unlikely that the species found within the Study Area are used commercially at shallower depths or have *Species at Risk Act* (SARA) or COSEWIC status. In adjacent slope habitats, commercial species such as Greenland Halibut, Roughhead Grenadier and Deepwater Redfish occur. Of these Roughead Grenadier (Special Concern) and Deepwater Redfish (Threatened) are listed as COSEWIC species. Wolffish also occur on the slope and were captured in the 2017 survey, and these fish have SARA and COSEWIC status. With the possible exception of Greenland Halibut, none of these commercial species or species of conservation concern are thought to commonly occur in the depths of the Study Area. In general, deepwater species are slow growing, long-lived, late to mature and have low fecundity (Devine et al. 2006, Priede 2017). These life-history traits make them less resilient to anthropogenic disturbance such as fishing (Devine et al. 2006). While little disturbance exists in the Study Area, deep-water fish species have been negatively affected elsewhere; sometimes catastrophically (Priede 2017).

The near absence of demersal habitat information in the Study Area provides little opportunity to identify sensitive or ecologically important habitats. Baited camera surveys and bycatch from longlines set in the Study Area do indicate the presence of corals and sponges at depths >2,000 m. Such structure forming species are important to fish in other areas (Gilkinson and Edinger 2009, Baillon et al. 2012) and are anticipated to be an important habitat feature in the Study Area.

Key Uncertainties and Approaches to Address Data Gaps

The general absence of field activities within the Study Area leaves significant uncertainty and data gaps. Beyond depth, little in the way of habitat data exists for the Study Area. Similarly, aside from the 2017 mission and the pelagic trawls conducted by Sheehan et al. (2012), virtually no data on fish communities are available. While some inference can be made from other deep sea locations in the Atlantic (Haedrich and Krefft 1978, Haedrich et al. 1980, Murua and de Cardenas 2005, Fossen et al. 2008, Pepin 2013, Parzanini et al. 2017), details of fish community structure varies by region (Haedrich et al. 1980) and more Study Area-specific information is required for a robust characterization. The collections of 2017 did provide important information, however interpretation of these data should be done with the caveats that samples were few, the gear used was focused on demersal species and was biased to species that are predisposed to taking bait (e.g., studies from other areas show 20-30% of deep sea fish respond to bait; Priede et al. 2017). Other important aspects of the ecology of the Study Area's inhabitants (e.g., movement, trophic and reproductive ecology, connectivity) remain undocumented, but samples collected in 2017 may provide some important information. For example, existing research on Blue Hake (Wenner and Musick 1977, Kulka et al. 2003), including collections from the Labrador slope, highlight the notable absence of mature individuals. Preliminary dissections of Blue Hake captured in the Study Area show a high prevalence of mature individuals and could suggest that the importance of the Study Area to Blue Hake reproductive ecology extends across broader spatial scales.

Addressing knowledge gaps is impeded by the remote location and the difficulty (time, technology and cost) of sampling extremely deep habitats. Longline and baited camera deployments have proven relatively cost-effective, provided useful information in this Study Area and in other deep-sea locations (e.g., Henriques et al. 2002, Fossen et al. 2008), and should be continued to improve sample sizes. However, complimentary techniques could be used to address biases related to habitat and the reliance on bait. For example, meso-pelagic sampling via IGYPT (e.g., Pepin 2013) or IKMT trawls or by setting hooks on the vertical lines of longline sets (e.g., Fossen et al. 2008) could provide important information for fish that utilize the water column. Hydroacoustic techniques can be used to survey broader areas for meso-pelagic fish and plankton, particularly when coupled with other capture methods. Though still in developmental stages, eDNA techniques could provide information on species that are not attracted to bait and could be collected in any zone of the water column (epi-pelagic, meso-pelagic and demersal environments). Finally mobile video platforms (benthic sledges, drift cameras or ROVs), used in benthic surveys, could also provide useful information on the fish community and would be less biased to predatory/scavenging species. Concurrent research is needed on collected fish samples to identify predator-prey relationships of Study Area species (i.e., stomach content analyses of fish, birds and marine mammal predators) as well as basic life history parameters (e.g., growth, age at maturity, fecundity). Since cost and time will constrain sampling activity, efforts should be made to link collections from this Study Area to other studies, where appropriate, in order to leverage understanding of deep sea fish communities as well as identifying unique elements of the Study Area.

Finally, fish-habitat associations and sensitive habitats are reliant upon improved habitat information. Multi-beam sonar surveys should be conducted during field operations to begin the process of identifying bottom habitats.

Seabirds

Available Information

There are two main data sources that inform the understanding of the distribution and abundance of marine birds using the Labrador Sea Study Area: at-sea marine bird surveys and tracking studies.

Data from at-sea surveys are available dating back to the 1960s, as part of the Programme Intégrée de Recherche sur les Oiseaux Marin (PIROP). This program was renewed in 2006 as the Eastern Canadian Seabirds at Sea (ECSAS) program, which included updates with modern protocols that allow for distance sampling and true density estimation. Due to its remoteness, the Labrador Sea has not received the same sampling as the other eastern Canadian regions; this gap was identified in the context of offshore oil and gas interests in the Labrador Sea. In 2013, the Environmental Studies Research Fund (ESRF) funded a three year study to augment data collection of pelagic seabirds in the Labrador Sea, which filled in a number of gaps (Fifield et al. 2016). Efforts to use predictive species distribution modeling are underway, in an attempt to estimate distributions and abundances of seabirds outside of surveyed regions (Fifield et al. 2017).

With the advent of miniaturized telemetry and data-archiving devices suitable for marine birds, a wealth of annual tracking has emerged on many marine birds, some of which have been shown to use the Study Area. Although the Study Area is known to host birds throughout the year, it was not known that the Labrador Sea, and Davis Strait to the north, host non-breeding birds from colonies as far away as Norway. Even Atlantic Puffins from the United Kingdom are making excursions into the Study Area and adjacent waters in late summer (Jessop et al. 2013). Taken together it is becoming clear that the Study Area, and adjacent deep waters to the north, south and east are internationally important wintering grounds for a range of Arctic breeding marine birds (Table 1).

Table 1: Marine bird species using the Labrador Sea Study Area based on recent tracking and telemetry studies.

Species	Source colonies	Area used	Timing	Source
Thick-billed Murre *Uria lomvia*	Eastern Canadian Arctic	Extensive use of entire Study Area	Mid-winter	McFarlane et al. 2013
Thick-billed Murre *Uria lomvia*	Greenland	Extensive use of entire Study Area	Fall through spring	Frederiksen et al. 2016
Dovekie *Alle alle*	Svalbard	Northwest portion	Winter	Fort et al. 2013
Atlantic Puffin *Fratercula arctica*	Ireland	Mostly southern portion	August/September	Jessop et al. 2013
Atlantic Puffin *Fratercula arctica*	Mainly Iceland	Mostly southeastern portion	Winter	Fayet et al. 2017
Northern Fulmar *Fulmaris glacialis*	Canadian High Arctic	Throughout	Fall and winter	Mallory et al. 2008
Black-legged Kittiwake *Rissa tridactyla*	Canadian High Arctic, Greenland, Arctic Norway, Faroe Islands	Extensive use of Study Area, especially eastern portions	Fall through spring	Frederiksen et al. 2012
Ivory Gull *Pagophlia eburnea*	Canada, Greenland and Norway (Svalbard)	Extensive use of Study Area, especially northern portions	Winter	Gilg et al. 2010 Spencer et al. 2016

Spatial and Temporal Occupancy Patterns

The marine bird community occupying the Labrador Sea, especially within the Study Area, is highly seasonal and varies through the year. Due to the distance from the coast, locally breeding seabirds are not expected to use the Study Area in large numbers; the bulk of the marine bird community using the Labrador Sea, and the Study Area in particular, is more likely non-breeding migrating, staging and wintering individuals.

In terms of pelagic distributions, densities of marine birds recorded in the ECSAS database are generally higher in the Study Area in fall and winter, when compared to spring and summer. This is corroborated by tracking studies, showing many species using the Study Area for fall migration and/or wintering. Predicted densities in fall are notably high, although confidence in those estimates within the Study Area is low due to a lack of survey coverage at that time of year. Seasonal relative species composition is presented in Table 2. Historical data from the PIROP database show similar patterns and are not presented here.

Ivory Gulls, a species listed as Endangered under the *Species at Risk Act* in Canada, and Near Threatened on the IUCN Red List, use the Study Area, and regions to the north, as part of their core wintering area (Spencer et al. 2016).

Tracking studies demonstrate the importance of the Labrador Sea for non-breeding Thick-billed Murres from a range of Northwest Atlantic colonies in fall, winter and spring (McFarlane et al. 2013, Frederiksen et al. 2016). Vast numbers of Dovekies, from the huge colonies in Northwest Greenland, pass through the Study Area on their fall migration (Fort et al. 2013). Other tracking data show that Northern Fulmars, Black-legged Kittiwakes and even Atlantic Puffins are present in the Study Area at various times of year (Tables 1 and 2).

Table 2: Seasonal counts of birds observed in the Labrador Sea by species group (Fifield et al. 2017).

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

Species and/or Habitats of Interest

Due to their conservation status as endangered in Canada, and near threatened globally, Ivory Gulls are an important species using the Study Area. In fact, the marginal ice zone in the Labrador Sea and Davis Strait is potentially critical non-breeding habitat for the species (Environment Canada 2014).

Thick-billed Murres are abundant in the Study Area and are a species of international conservation focus, due to harvests in Iceland, Canada and Greenland, and their susceptibility to fisheries bycatch and oiling (Conservation of Arctic Flora and Fauna 1996). The species uses the entire Study Area extensively which currently provides a refuge where they are not exposed to their usual threats.

The bulk of the global population of Dovekie, which breeds in Northwest Greenland and likely exceeds 100 million individuals, travels through the Labrador Sea and adjacent waters on fall migration to wintering areas off southeastern Canada.

Key Uncertainties and Approaches to Address Data Gaps

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 was collected in fall, and limited data was collected in winter. These are key periods of migration and wintering for marine birds in the Study Area. To address pelagic survey gaps, a berth on a vessel for a trained seabird observer is all that is required.

Marine bird tracking studies and resulting species distribution models are beginning to inform the annual use of the Labrador Sea 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 Puffins. Only limited data is available for Northern Fulmar, a species present in high densities in the Labrador Sea. Given the large numbers of Dovekies 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 CBIRD (the marine bird expert group for Conservation of Flora and Fauna [CAFF]). For some potential source colonies, additional funds for transmitters and data costs are all that would be required. For other sites not regularly visited, but thought to contribute birds to the Labrador Sea Study Area, a more costly full-scale field team deployment would be needed. It is also possible, through data sharing agreements, that data be acquired from foreign institutions that are working on seabirds that occupy the Labrador Sea.

Understanding the ecological basis for the seasonal occupancy of seabirds in the Study Area is also an important knowledge gap. For example, stomach contents of carcasses collected in the Study Area could inform the feeding behaviour of seabird species and their trophic interactions with other ecosystem elements.

Marine Mammals

Available Information

Limited baseline information exists in regards to the abundance and distribution of marine mammals in the Labrador Sea coastal shelf and offshore regions (see references in Lawson et al. 2017). The majority of marine mammal knowledge in Canadian waters is derived from aerial and acoustic surveys performed by Fisheries and Oceans Canada (DFO) and RV opportunistic sightings collected by DFO, the Canadian Wildlife Service (CWS) of Environment and Climate Change Canada (ECCC), and non-governmental organizations (NGOs). When combined, all of these survey methods produced a total of 3,756 cetacean sightings between 2006 and 2016 within or near the Study Area; 25% of which were in waters greater than 2,000 m. The Long-finned Pilot Whale is the most commonly-sighted cetacean in the Study Area (n=2,071) and approximately 30% (n=610) of these sightings were in depths greater than 2,000 m (Table 3).

Large-scale, systematic aerial surveys were conducted by DFO in 2007 and 2016 using a fixed-wing aircraft flown in an equal-angle zig-zag pattern from the shore to the shelf break. These surveys documented several species of cetaceans and 87 individuals in the western edge of the Study Area (J. Lawson, pers. comm.). In many cases, cetaceans were seen at or beyond the shelf break, at or near the offshore ends of planned survey lines. Based on this, questions remain regarding habitat use of cetaceans in the Study Area, particularly in deeper waters beyond the shelf break. Acoustic monitoring data suggest that marine mammal numbers could be even higher in other periods that are not monitored with aerial surveys (Lawson et al. 2017). Even during the winter, when sea ice covers much of the Labrador Shelf, marine mammals such as Humpback, Fin and Pilot Whales have been detected using visual and acoustic surveys.

Many of these cetaceans potentially move into deeper, ice-free waters of the Study Area in the winter.

ECCC documents whale sightings opportunistically during seabird surveys on ships in the North Atlantic. From 2006 to 2016, a total of 146 individuals were sighted within the Study Area. The species most sighted from this method of observation include; Long-finned Pilot Whale, Fin Whale, Harbour Porpoise, Sei Whale, and White-beaked Dolphin (unpubl. data, Oceans Division, DFO). The white-beaked dolphin was the most commonly-sighted cetacean species during ESRF aerial surveys conducted just west of the Study Area in 2013 and 2014.

Table 3: Sighted numbers of most common marine mammal species in the Study Area in waters greater than 500 m in the Labrador Sea. Data from DFO, CWS and NGO studies.

Rank	Species	-	500-2,000 m	>2,000 m	Max. Count
1	Long-finned Pilot Whale	*Globicephala melas*	1,461	610	2,071
2	Northern Bottlenose Whale	*Hyperoodon ampullatus*	442	69	511
3	White-beaked Dolphin	*Lagenorhynchus albirostris*	347	87	434
4	Sperm Whale	*Physeter macrocephalus*	383	8	391
5	Minke Whale	*Balaenoptera acutorostrata*	54	9	63
6	Harbour Porpoise	*Phocoena phocoena*	32	16	48
7	Atlantic White-sided Dolphin	*Lagenorhynchus acutus*	12	31	43
8	Humpback Whale	*Megaptera novaeangliae*	15	27	42
9	Fin Whale	*Balaenoptera physalus*	3	38	41
10	Killer Whale	*Orcinus orca*	8	29	37
11	Common Dolphin	*Delphinus delphis*	30	0	30
12	Risso's Dolphin	*Grampus griseus*	11	10	21
13	Sei Whale	*Balaenoptera borealis*	12	7	19
14	Blue Whale	*Balaenoptera musculus*	3	0	3
15	Unknown *Mesoplodon*	-	-	-	2
-	-	**Total**	2,813	941	3,756

Three species of seals, Harp (*Pagophilus groenlandicus*), Hooded (*Cystophora cristata*), and Ringed (*Pusa hispida*) are known to frequent the shelf area and/or deeper waters of the Labrador Sea. Harp Seals are also highly migratory and generally use the Labrador coast and shelf area as a migration route (DFO 2011, Stenson 2013). Utilization of these areas is highest after the moulting season. Hooded Seals are highly migratory and spend their time at sea in between breeding and moulting seasons on sea ice. The Labrador Shelf acts as an important foraging area in between these seasons while the Labrador Sea acts as a migratory route (Anderson et al. 2009). For each age and sex class, Hooded Seals utilize areas within the Study Area most during the fall. It is thought that Ringed Seals spend most of their time, certainly during winter breeding periods, closer to the coast than the larger seal species.

Species and/or Habitats of Interest

The Labrador Sea represents a portion of the known range for a variety of listed species including Northern Bottlenose Whales (Scotian Shelf population listed as Endangered; Lawson et al. 2017) and Bowhead Whales (Special Concern). Fin Whales, one of the top 10 most sighted cetaceans in the Study Area, are currently listed as Special Concern. The southern Labrador Shelf, a margin along the Study Area, has been identified as containing highly suitable habitat for this species (Lawson et al. 2017), and large feeding aggregations have been documented in the fall off nearby southwest Greenland (to the northeast of the Study Area).

Furthermore, two EBSAs adjacent to the Study Area, Northern Labrador and Hopedale Saddle, were largely implemented because they were important migratory and overwintering areas for the endangered Eastern Hudson Bay population of Beluga Whales (Seiden 2016).

The paucity of information for marine mammals in the Labrador Sea Study Area often limits the precise delineation of important habitats for some species. In some cases, available data has allowed refinement of habitats of interest. For example, aerial survey data, reports from commercial fisheries observers in the northern portion of the Study Area (J. Lawson, pers. comm.), and habitat modelling indicate that the Labrador shelf break provides highly suitable habitat for Northern Bottlenose Whales (Lawson et al. 2017). Similarly, the southern Labrador Shelf, a margin along the Study Area, has been identified as containing highly suitable habitat for Fin Whales (Lawson et al. 2017), and large feeding aggregations have been documented in the fall near southwest Greenland (to the northeast of the Study Area).

Key Uncertainties and Approaches to Address Data Gaps

During aerial surveys for cetaceans in the Labrador Sea region, many individuals were sighted at or beyond the shelf break (Lawson and Gosselin 2009, Lawson and Gosselin, unpubl. data). To capture more information regarding the extent of offshore use by cetaceans and to track implications of anthropogenic noise from activities on the shelf, it is recommended that survey track lines extend out into deeper waters in future surveys (Lawson et al. 2017). Such efforts, if possible, should be focused in the fall when more species and animals appear to occupy the adjacent shelf.

Given the spatial and temporal coverage limitations of visual surveys, it is recommended that acoustic monitoring studies be pursued in the Study Area. Such studies have a good chance of detecting vocalizing marine mammals (at a great distance for species such as Fin and Blue Whales) as well as characterizing anthropogenic noise stressors such as shipping and seismic exploration. Complimentary techniques, such as eDNA, could provide insight on marine mammal presence in the areas as well as for other ecosystem elements (e.g., fish and benthos). Finally, marine mammal habitat modelling efforts should be extended into the Study Area. These would benefit from integration with seabird data for species with similar diets (e.g., Common Murres and Minke Whales), and better prey availability data collected using dedicated vessel surveys, such as in the AZMP and AZOMP studies further south.

Indigenous Traditional Knowledge

The Study Area supports a diverse number of species; many of which are culturally, commercially and of subsistence importance to the indigenous people who have occupied coastal areas of Labrador for generations. The Nunatsiavut Government and the NunatuKavut Community Council actively engage the Federal government for marine management activities (e.g. Ocean Protections Plan) and have expressed their desire to maintain involvement in the activities planned for the Study Area.

Anthropogenic Activity

Available Information

Human activity within the Study Area is limited due to its remote location and deep water. This area was initially highlighted for further study as a Frontier Area as per DFO's Policy for Managing the Impacts of Fishing on Sensitive Benthic Areas (DFO 2009). The Policy defines Frontier Areas as areas in Canadian waters with no history of fishing and include areas >2,000 m in depth with limited information about benthic habitat features. Although this area has had minimal anthropogenic activity, some human interaction has occurred within the Study Area or nearby, including commercial fishing, oil and gas exploration, and marine transportation.

Fishing activities are primarily limited to the shelf/slope area adjacent to the Study Area, but they have the potential to extend into deeper water to meet quotas. The most commonly caught species in adjacent shallower slope or shelf waters are Northern Shrimp (shrimp trawl) and Greenland Halibut (longline and gillnet). Recently, interest has intensified for offshore oil and gas exploration in the Labrador Sea (C-NLOPB 2008), with oil and gas exploration licenses and calls for bids in the southern portion of the Study Area. In 2008, the C-NLOPB completed a Strategic Environmental Assessment (SEA) for an area of offshore Labrador known as the Labrador Shelf SEA Area with an update planned for early 2018. The C-NLOPB website shows that seismic exploration of this area began in 1980 but coverage has only been significant since 2012, with additional surveys taking place within the Labrador Sea Study Area in 2013 and 2014. The website also indicated that no exploration wells have been drilled inside the Study Area to date but some have occurred on the adjacent shelf.

Marine traffic density is currently low in the Study Area. Ferry service, shipping, and commercial fishing take place in coastal areas and on the continental shelf in areas less than 2,000 m. Various northern shipping routes may open to cargo shipping as warming global temperatures reduce Arctic summer sea ice. A long-term trend of reduced ice coverage may create opportunities for increased Arctic cruise ship tourism, commercial shipping and national sovereignty expeditions (BAE-Newplan Group Limited/SNC-Lavalin Inc. 2008). 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).

Key Uncertainties and Approaches to Address Data Gaps

Anthropogenic activity is minimal within the Study Area primarily due to water depth (i.e., fishery) or remote location. Descriptions of activities such as vessel traffic (shipping/transportation) require additional investigation of existing data sources. The historical activities associated with oil and gas exploration is readily available but it is difficult to predict future plans for exploration activity. Indirect influences of anthropogenic activity such as climate effects on oceanographic conditions and contaminants (e.g. hydrocarbons and plastics) are difficult to distinguish for habitats and biota within the Labrador Sea Study Area. Wherever possible, collection of data should build upon existing surveys. For example, contaminants can be measured in specimens collected during fish and invertebrate surveys, whereas acoustic monitoring of industrial noise/ship traffic can be accomplished with the same instruments used for marine mammal monitoring.

Conclusions

The available knowledge indicates that the Labrador Sea is characterized by important physical and ecological components and processes that are of global significance (e.g., oxygenation of deep-water environments and carbon capture). The Study Area's ecosystem is connected to important adjacent ecosystems (e.g., slope and shelf EBSAs, *Fisheries Act* closure areas) by ocean currents and the migration of organisms (ranging from zooplankton to large marine mammals) that use the area. Such migrations also bring Labrador Sea biota to coastal peoples of Labrador, who have depended on these species as a food source for generations.

The Labrador Sea contains a gyre that likely collects and retains passively transported nutrients and organisms, which in turn has the potential to attract species at higher trophic levels. Existing ecological data confirm that the Labrador Sea supports year round use of migratory marine mammals, seabirds, and fish; several species of which migrate from beyond the region (temperate and tropical latitudes, the Northeast Atlantic and Hudson Bay). Nevertheless, many aspects of the Labrador Sea Study Area's ecosystem remain poorly understood and important ecosystem characterization must occur prior to recommending conservation objectives.

Data gaps are most prominent for some ecological processes (productivity, connectivity, temporal variability) and broad taxa groups (benthos and fish), where the most basic information (community composition, life history information and trophic relationships) is unavailable. Such a broad array of data gaps will require a prioritized research plan. It is suggested that in the short-term, Science initiatives focus on better characterization of the following three ecosystem elements:

- Mesopelagic fish,
- Demersal fish, and
- Benthic community (particularly echinoderms, corals and sponges).

Addressing these areas of focus in the challenging Labrador Sea environment with a finite budget will require a combination of conventional tools (e.g., ROVs, benthic dredges and pelagic trawls), developing techniques (e.g., towed video sledges and eDNA) and partnerships.

General areas of research beyond characterizing community composition should focus on processes of connectivity (drift models, genetics), productivity, trophic links (fatty acids, stable isotopes, stomach contents) and habitat-faunal relationships (e.g., currents, sea bottom).

Although it is recommended to focus resources on the above priority ecosystem elements, sampling of other low-cost/high-value data from other research areas should be augmented where feasible (e.g., adding additional sensors to moorings, including marine mammal and seabird observers on all research missions).

Finally, the following principles are recommended when undertaking research in the Labrador Sea:

- Involve the Nunatsiavut Government and the NunatuKavut Community Council in research activities, incorporate ITK, and build collective capacity through these partnerships;
- Seek collaboration opportunities with other research institutions to maximize knowledge transfer and share research costs;
- Design studies according to the scales of relevant ecological processes (do not artificially confine questions to the Study Area);
- Consider the larger context of the Labrador Sea (i.e., connectivity) when characterizing 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;
- Archive as much material as possible to facilitate future study of these rare samples; and
- Where possible, use less intrusive survey methods to limit damage to vulnerable benthic fauna.

Priority research can be initiated across four cruises over 2018 and 2019 (Table 4). In each of 2018 and 2019, a mission will be conducted aboard the CCGS Amundsen. These missions will sample from a study corridor that extends from the shelf break to abyssal depths (3,000 m) and will primarily study meso-pelagic fish (trawls, fisheries acoustics, eDNA) and benthos (box cores, ROVs, drift cameras, eDNA) as well as characterize habitat (multi-beam, cameras). In addition to these activities, these missions will include the deployment and retrieval of moorings that will track spatial and temporal variability of sediment deposition and nutrients (sediment traps), bottom currents (ADCP), larval settlement (settlement plates) and the presence of marine mammals and anthropogenic noise (acoustic recorders).

While the CCGS Amundsen is well equipped to conduct studies in the north, the vessel's schedule and cost limit its availability to work in the Labrador Sea. Consequently, two additional missions will be conducted from commercial longliners. The first will primarily target demersal fish (long lines, baited cameras, benthic sledge, eDNA) and will also spatially augment bottom characterization and benthos (benthic sledge, baited cameras) studies done aboard the CCGS Amundsen. The second will focus on mesopelagic fish (mesopelagic trawl, eDNA) and their linkages with higher trophic levels (collections of seabirds and seals for stomach content analyses).

All missions will include low cost/high return activities such as marine mammal and seabird surveys and water and plankton collections (Table 4). Model-based analyses can also be conducted to build off and compliment field collections. For example, larval drift models can be constructed and refined based on field collections.

Resourced appropriately, the research of the Study Area will result in much improved understanding of the Study Area as well as enhanced collaborations with other deep sea researchers and indigenous communities.

Table 4: Matrix of ecosystem elements and planned sampling activities for the research cruises in the Labrador Sea, 2018 and 2019.

-	-	Habitat	Oceanography	Plankton	Mesopelagic Fish	Benthos	Demersal Fish	Seabirds	Marine Mammals	Anthropogenic influences
Amundsen, 2018	*Multi-beam*	√	.	.	.	.	.	.	.	.
	Acoustic survey	.	.	√	√	.	.	.	.	.
	Seabird and Marine Mammal Observer	.	.	.	.	.	.	√	√	.
	Sound Recorders	.	.	.	.	.	.	.	√	√
	Sediment Traps	√	√	.	.	√	.	.	.	.
	Bottom Current Profiler	√	√	.	.	√	.	.	.	.
	Larval Settlement	.	.	.	.	√	.	.	.	.
	*Coral Growth**	.	√	.	.	√	.	.	.	.
	Sedimentation Model	√	.	.	.	.	.	.	.	.
	Box Core	√	.	.	.	√	.	.	.	.
	CTD	.	√	.	.	.	.	.	.	.
	Water Samples	.	√	√	√	.	√	.	√	.
	IKMT Trawl	.	.	.	√	.	.	.	.	.
	Plankton Net	.	.	√	.	.	.	.	.	√
	*ROV**	√	.	.	.	√	√	.	.	.
	Camera Drift	√	.	.	.	√	√	.	.	.
Amundsen, 2019	*Multi-beam*	√	.	.	.	.	.	.	.	.
	Acoustic survey	.	.	√	√	.	.	.	.	.
	Seabird and Marine Mammal Observer	.	.	.	.	.	.	√	√	.
	Sound Recorders	.	.	.	.	.	.	.	√	√
	Sediment Traps	√	√	.	.	√	.	.	.	.
	Bottom Current Profiler	√	√	.	.	√	.	.	.	.
	Larval Settlement	.	.	.	.	√	.	.	.	.
	*Coral Growth**	.	√	.	.	√	.	.	.	.

-	-	Habitat	Oceanography	Plankton	Mesopelagic Fish	Benthos	Demersal Fish	Seabirds	Marine Mammals	Anthropogenic influences
	Sedimentation Model	√	.	.	.	.	.	.	.	.
	Box Core	?	.	.	.	?	.	.	.	.
	CTD	.	√	.	.	.	.	.	.	.
	Water Samples	.	√	?	?	.	?	.	?	.
	IKMT Trawl	.	.	.	?	.	.	.	.	.
	Plankton Net	.	.	?	.	.	.	.	.	?
	*ROV**	?	.	.	.	?	?	.	.	.
	Camera Drift	?	.	.	.	?	?	.	.	.
Commercial Longliner I, 2019	*Long-lining*	.	.	.	√	.	√	.	.	.
	Baited Cameras	√	.	.	.	√	√	.	.	.
	Seabird and Marine Mammal Observer	.	.	.	.	.	.	√	√	.
	Water Samples	.	√	√	√	√	√	√	√	.
	Multi-beam	√	.	.	.	.	.	.	.	.
	Plankton Collections	.	.	√	.	.	.	.	.	√
	CTD Cast	.	√	.	.	.	.	.	.	.
Commercial Longliner II, 2019	*Mesopelagic Trawl*	.	.	.	√	.	.	.	.	.
	Seabird and Marine Mammal Observer	.	.	.	.	.	.	√	√	.
	Seal Collections	.	.	.	?	?	?	.	√	.
	Seabird Collections	.	.	.	√	.	.	√	.	.
	CTD Cast	.	√	.	.	.	.	.	.	.

*Depth limitations of the ROV will limit sampling to sites adjacent to the Study Area

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