Labrador Shelf Offshore Area Strategic Environmental Assessment Update

Chapter 5

Prepared for:
Canada-Newfoundland and Labrador
Offshore Petroleum Board
240 Waterford Bridge Road
The Tower Corporate Campus – West
Campus Hall
Suite 7100
St. John's, NL
A1E 1E2

Prepared by:
Aivek Stantec Limited Partnership
141 Kelsey Drive
St. John's, NL A1B 0L2

File No: 121414574

Final Report

December 13, 2021

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5.0 MARINE FISH AND FISH HABITAT

The following sections present an overview of the existing fish species and associated habitats that are found within the Labrador Shelf SEA Update Area. This ranges from key marine trophic groups such as phytoplankton, to higher level consumers such as benthic invertebrates and fish species. Desktop review of existing literature provides an overview for each category of marine fish and fish habitat in the sections below. More specific information on harvesting and environmental observation follows this overview and comes from IK studies, both from existing studies and studies done specifically for the SEA Update. As noted previously, updated information has been provided where available, and where information has not changed, text from the original SEA Report (SEM 2008) has been carried over into this update. For many parts of the Labrador Shelf SEA Update Area, there is strong IK on the distribution of various species; however, there may be geographic bias of the observations towards more populated areas of the coast related to concentration of hunting and travel by community members. Therefore, a lack of mapped data should not be inferred to mean a lack of species presence. In addition, the IK included within this SEA Update does not represent the total land usage or knowledge held by Indigenous groups with respect to the Labrador Shelf SEA Update Area.

Fishing for food is a common activity for the Indigenous peoples of Labrador. The NunatuKavut Community Council (2019) shared observations on fish habitat and generally on fish health and populations. Species-specific observations are outlined in the applicable sub-sections of this chapter, with general observations discussed here. Fish populations, though down from historical levels, are stable or increasing in protected areas, but seem to have decreased in areas of poor water quality. There was also a report of fish staying around longer in 2019. Quality of fish was observed to have improved from apparently starved fish in 2018 and years previous, to much healthier fish in 2019. The NunatuKavut Community Council indicated liver health, large fish size, and stomach contents as evidence of the improvement. Other reports suggest the fish were smaller but of good quality, observing shrimp, crab and jelly fish in stomach contents, but no capelin. However, the NunatuKavut Community Council also reported the presence of capelin, as well as shrimp, herring, and crab in the stomachs of seals (NunatuKavut Community Council 2019). Overfishing is described as an influential human activity affecting fish populations.

The Nunatsiavut Government (2018) also shared observations on fish habitat, health and abundance. Most observations were species-specific and are outlined in the following sub-sections; however, some general observations and unusual sightings were also made. Nunatsiavut Government reported seeing a lamprey near the mouth of Kenamu River and observed a change in fish size and decrease in overall fish abundance in some locations. Declining fish stocks were attributed to warmer waters, causing bait (food) to move into deeper, cooler water (Nunatsiavut Government 2018). Nunatsiavut Government reported that the commercial fishery in the 1970s and 1980s put a large strain on the fish in Nain Bay and resulted in fish becoming smaller over time; and overfishing in the past in Tikkoatokak Bay is only now taking effect on the fish stock there (Nunatsiavut Government 2018). Voisey's Bay has been reported to have decreased abundances of fish in recent years (Nunatsiavut Government 2018). Additionally, the disappearance of cod and capelin has been reported to have had negative effects on humans, marine mammals, and waterfowl (Williamson and LIA 1997).

5.1 MACROPHYTE COMMUNITIES

The distribution of macroalgae and marine plants is predominantly limited to areas reached by sunlight, as they are reliant on photosynthesis to produce energy; depending on silt and turbidity levels, that is approximately 75 m for NL (Mathieson and Dawe 2017). Some types of marine algae (e.g., coralline algae) occur at greater depths. Much of Labrador's coast is fully exposed, sloping bedrock shores and subject to high wave action and frequent ice scouring and as such, does not support abundant or diverse algal populations. Conversely, the broad intertidal flats in sheltered and moderately exposed areas along the coast support plant life, although lacking in diversity (Canadian Parks and Wilderness Society [CPAWS] 2009). The appearance of the Labrador coast is very different from other regions of northeastern North America. Northern Labrador is described by Wilce (1959) as subarctic, being environmentally distinct with characteristic fauna. The Labrador Shelf SEA Update Area is mainly characterized by highly exposed areas consisting of cliffs with a gentle sloping shelf rock or boulder base. The surface is highly worn by abrasion from ice and smaller rocks carried by waves. The lack of crevices prevents algal spores from staying on the substrate surface and as a result, the surface remains void of most plant life (Wilce 1959).

Macrophytes (both littoral and sublittoral) are an integral part of the Labrador Shelf SEA Update Area ecosystem in that decomposing macrophytes provide food to herbivores at a time when phytoplankton is low (South et al. 1979). In addition, macrophytes provide substrate for a number of benthic invertebrates and are used for grazing by herbivores. The greatest increase in macrophyte production occurs in the summer, with the standing stock reaching its maximum in early October (Wilce 1959). Macrophyte species create structural habitat in the near shore (Teagle et al. 2017), an environment which is one of the most productive in the world. These species are also important as primary producers and ecosystem engineers and are sensitive to disturbance.

5.1.1 Littoral Community

The composition of the intertidal community is dictated by the substrate type, with diverse substrates accommodating a variety of habitat preferences. The frequency of sea ice along the Labrador coast can prevent proliferation and growth of algae in the intertidal zone and result in weak zonation. Biomass of rockweeds, kelp, mussels, and periwinkles are lower here as compared to more southern shorelines.

Fjords along the Labrador coastline shelter some intertidal communities from wind and wave exposure. Although ecosystems within fjords are not fully understood due to a lack of data and little is known regarding marine vegetation in these sensitive ecosystems, the limited information that is available suggests that there is typically substantial heathy vegetation immediately above the high-water level in these protected areas, usually at the innermost parts of bays and fjords. Algal communities in this zone must be tolerant of salinity changes and long periods of submersion (Wilce 1959). Saglek Bay is an example of a moderately exposed area in the Labrador Shelf SEA Update Area. Algal communities are more abundant and diverse in these areas as the substrate is suitable for algal attachment. Common species include Chordarians (*Chordaria flagelliformis*), green algae (e.g., *Prasiola crispa*), and crustose lichens (e.g., *Haematoma ventosum* and *Umbilicaria* sp.) in the supralittoral/splash zone.

In highly exposed areas, there is little or no algal growth. Taxa such as the green alga *Prasiola*, the black alga *Calothrix*, and a brown filamentous species may form belts on the rock faces in areas with minimal shelter or crevices. As exposure increases, these bands become narrower and higher on the shore resulting in areas of large bare rock. *Chordaria* is also associated with these areas (Wilce 1959, CPAWS 2009).

In coastal Labrador, mudflats occur at the heads of bays and fjords near the entrances of freshwater streams. These flats have low species diversity, but certain species may be present in high abundance. The main species in mudflats consists of *Vaucheria* sp. and various blue-green algae species. Together they form a dense turf that appears dark green to black (Wilce 1959).

Intertidal marshes in the Hamilton Inlet and Lake Melville area contain unique flora, including temperate and Arctic species. Saltmarsh cordgrass (*Spartina alterniflora*) is found in Lake Melville and Groswater Bay, and is rare in Labrador, where it is at the northern limit for this species. Saltmarsh cordgrass plays an important role in stabilizing shorelines, particularly the sandy and silts environments that exist in the Hamilton Inlet area (CPAWS 2009).

A generalized algal zonation is provided in Table 5.1, from the intertidal to the subtidal zone, compared to degree of exposure to waves.

Table 5.1 General Algae in Intertidal and Subtidal Areas in Coastal Labrador

Zone	Typical Algal Species by Degree of Wave Exposure		
	Sheltered	**Moderate**	**High**
Littoral	*Ulothrix flacca*	*Umbilicaria sp.*	*Chaetomorpha melagonium*
	Enteromorpha intestinalis	*Prasiola crispa*	*Spongomorpha arcta*
	Monostroma fuscum	*Urococcus foslieanus*	*Pylaiella littoralis*
	Prasiola crispa	*Calothrix scopulorum*	*Sphacelaria arctica*
	Pylaiella littoralis	*Enteromorpha micrococca*	*Ahnfeltia plicata*
	Ralfsia fungiformis	*Ulothrix flacca*	*Phycodrys rubens*
	Eudesme virescens	*Rhodochorton purpureum*	*Polysiphonia arctica*
	Petalonia fascia	*Fucus* spp.	*Polysiphonia ureceolata*
	Dictyosiphon foeniculaceus		*Rhodomela confervoides*
	Chorda tomentosa		
	Chorda filum		
	Ascophyllum nodosum		
	Fucus distichus distichus		
	Fucus distichus evanescens		

Table 5.1 General Algae in Intertidal and Subtidal Areas in Coastal Labrador

Zone	Typical Algal Species by Degree of Wave Exposure		
	Sheltered	**Moderate**	**High**
Sublittoral	*Chordaria flagelliformis*	*Enteromorpha compressa*	*Alaria grandifolia*
	Dictyosiphon foeniculaceus	*Chaetomorpha melagonium*	*Agarum cribrosum*
	Rhodomela confervoides	*Spongomorpha lanosa*	*Laminaria groenlandica*
	Pylaiella littoralis	*Spongomorpha arcta*	*Laminaria nigripes*
	Chorda tomentosa	*Chaetopteris plumosa*	*Laminaria solidungula*
	Monostroma fuscum	*Sphacelaria arctica*	
	Ectocarpus confervoides	*Lithoderma extensum*	
	Elachistea fucicola	*Elachistea fucicola*	
	Hildenbrandia prototypes	*Desmarestia aculeata*	
	Lithothamnion sp.	*Isthmoplea sphaerospora*	
		Stictyosiphon tortilis	
		Delamarea attenuata	
		Monostroma fuscum	
		Ployides caprinus	
		Euthora cristata	
		Rhodophyllis dichotoma	
		Ahnfeltia plicata	
		Antithamnion boreale	
		Ptiolota serrata	
		Phycodrys rubens	
		Odonthalia dentata	
		Polysiphonia arctica	
		Rhodomela confervoides	

Source: Wilce 1959
Note: Not an exhaustive list

5.1.2 Sublittoral Community

Benthic algal and non-algal microphyte communities provide a stable, year-round source of food for invertebrates and fish when phytoplankton productivity is low (VBNC 1997). Most intertidal vegetation dies in the fall and winter and the resulting decomposing matter becomes food for many herbivores (e.g., sea urchins (*Strongylocentrotus droebachiensis*)) and filter feeders (e.g., blue mussels (*Mytilus edulis*)) (VBNC 1997).

In the Labrador Shelf SEA Update Area, algal growth is mainly concentrated in the sublittoral region and dominated by Fucaceae, Laminariaceae and Corallinaceae (Table 5.1), the bulk of which is unevenly distributed throughout the lower portion of the sublittoral zone. Due to sea ice movement and the influx of water from the melting ice, growth is restricted to water depths greater than approximately 9 m (Wilce 1959).

Eelgrass (*Zostera marina*), an ecologically significant species in Canada, is also present in sublittoral communities within the Labrador Shelf SEA Update Area (Nature Conservancy Canada n.d.). It is found in shallow coastal bays, coves, lagoons, tidal creeks and estuaries in waters less than 4 m, where sunlight can penetrate to the seafloor. Its complex root system allows it to anchor itself to the floors (Nature Conservancy Canada n.d.; Joseph n.d.). These plants host high biodiversity as they provide shelter and food to many marine organisms, such as juvenile cod, crab, snails, and marine birds (Joseph n.d.) and serve as an indicator of ecosystem health (Bernier et al. 2018).

Natural processes and anthropogenic activity can harm underwater plants. Boat anchors and propellers can scrape the bottom and destroy these habitats, the use of fertilizers in agriculture activities or runoff containing high amounts of nitrogen can lead to fast-growing algae which shades eelgrass from the sun, and other activities that reduce penetrable sunlight, such as floating structures on the water. The knowledge and consensus regarding the effects of oil and gas activities on eelgrass are lacking and further studies are required (Fonseca et al. 2017). Fonseca et al. (2017) found no relationship between oil exposure and eelgrass rhizome growth, shoot density or electron transport rate and Macinnis-Ng and Ralph (2003) concluded that *in situ* samples showed no photosynthetic impact due to dispersant and oil-dispersant mixtures, while laboratory samples did.

In and around Nain, large populations of *Halosaccion*, *Fucus*, and *Rhodymenia* can be found in sheltered areas with fucoids dominating (CPAWS 2009). Under-vegetation (primarily small algae) can be dwarfed by larger flora, such as Laminariaceae kelp beds, with *Laminaria longicruris* being the dominant kelp species (Wilce 1959). More turbulent areas with rocky substrate consist mainly of coralline algae (*Lithothamnion* sp.) and narrow robust kelp (Wilce 1959). Further to the south in and around Sandwich Bay in sheltered areas where the sea bottom is more heterogenous, consisting of rock, gravel, sand and mud, seaweeds include *Fucus*, coralline algae, *Agarum, Plumaria, Porphyra, Rhodymenia, Laminaria, Chorda*, dulse, *Alaria, Ascophyllum*, filamentous algae, *Ectocarpus* and sea lettuce. Eelgrass is also present in the bay (CPAWS 2009). Kelp beds thrive in colder temperatures and are vulnerable to temperature changes (Bernier et al. 2018). Highly productive kelp beds are found scattered throughout the coastal archipelago where they are sheltered from ice scour and irregular bathymetry. These make a significant contribution to primary production in the coastal areas of the Labrador Shelf. Although the sessile community has been documented qualitatively, it has not been assessed quantitatively.

5.1.3 Data Constraints for Macroalgal Communities

A considerable amount of the macroalgal community distribution data are based on work by Wilce (1959) and South et al. (1979). While these data are substantial and relevant, they are dated, and in light of changes in the marine ecosystem since 1980, cannot be considered current. There is very limited macroalgal mapping for coastal Labrador (DFO 2021a), including important data gaps regarding benthic macroalgal communities in Nunatsiavut waters, as well as off the coast of Labrador in general. While it is recognized that the macroalgal communities occupy a unique and important niche in the Labrador Sea ecosystem, their contributions are qualitative in nature rather than quantitative. As noted in Section 5.1.1, ecosystems within fjords are not fully understood due to a lack of available data, and little is known regarding marine vegetation in these sensitive ecosystems.

Since macroalgae and eelgrass are sensitive to a number of anthropogenic disturbances. Long-term monitoring of coastal eelgrass and macroalgal communities is required to provide information on effects of climate change, including the northward spread of aquatic invasive species (AIS) (DFO 2021a).

While there are data gaps / constraints, their relation to offshore oil and gas is dependent on the nature and timing of the particular activity. Project-specific EAs should confirm that data constraints are still relevant and have not been addressed or if new data constraints have been identified.

5.2 PLANKTON

Plankton refers to free-floating organisms that drift in the water column. These organisms are a primary source of energy for the marine ecosystem (Brierly 2017). Plankton include bacteria, fungi, phytoplankton (marine algae), zooplankton (invertebrates, macroinvertebrate eggs and larvae), and ichthyoplankton (fish eggs and larvae). Phytoplankton are grazed by zooplankton, which, given their larger size, are more suitable as food for predators, such as fish and marine mammals (Brierley 2017). Given this transfer of energy to upper trophic levels, threats to the planktonic community can have cascading effects on the entire marine community. Zooplankton, composing primarily of Calanoid copepods, dominate the plankton biomass in early summer (late June). Plankton abundance and diversity is lower in the winter than summer. By winter, most plankton species have completed their life cycle (VBNC 1997).

For the purposes of this report and when relevant, the Labrador Shelf SEA Update Area has been divided into three zones: the northern Labrador Sea, southern Labrador Sea, and the central Labrador Sea.

5.2.1 Phytoplankton

The Labrador Shelf SEA Update Area is a biologically-productive ecosystem influenced by the same general factors that regulate phytoplankton biomass in other areas, mainly light and nutrients that increase productivity and herbivore grazing that decreases biomass (Harrison and Li 2008). The distribution, productivity, and growth of phytoplankton in high-latitude ecosystems such as the Labrador Shelf SEA Update Area is complex with light and nutrients being the principal factors promoting phytoplankton production. Phytoplankton in this ecosystem is subject to more extreme variations in light regimes than southern climates due to annual solar cycles and the presence of sea ice (Harrison and Li 2008; DFO 2021a). In addition to light regime variations, these ecosystems are subject to strong meteorological influences including cold water temperatures, strong winds, and currents, which influence phytoplankton biomass and exposure to the light environment in the upper water column. The Labrador Shelf SEA Update Area is part of the Northwest Atlantic sub-polar gyre that is delineated by currents associated with shallow continental shelves (specifically East and West Greenland Coastal and Labrador Currents) and a deep central basin that is subject to strong vertical mixing in the late winter (Lazier et al. 2002). Vertical mixing enhances the supply of nutrients in the water column (specifically nitrate, phosphorus, and silicates), promoting phytoplankton growth.

The spring bloom of phytoplankton is the driving force of high-latitude marine ecosystem dynamics, and the timing of this bloom is a critical factor regulating ecological cycles. During the spring, increasing solar radiation promotes photosynthesis and thermal stratification of the water column, and this thermal stratification extends from southern to northern climates resulting in propagation of the spring bloom from low to high latitudes (Wu et al. 2008). The retreat of sea ice also influences the timing and intensity of the phytoplankton bloom, as well as allowing light to enter the water column. Melting ice in the Labrador Shelf SEA Update Area reduces the surface salinity and causes a shallow mixing zone (Wu et al. 2007). An early ice retreat results in an early and prolonged spring phytoplankton bloom, which has been shown to have effects on the overall ecosystem dynamics (Platt et al. 2003; Fuentes-Yaco et al. 2007). For example, a prolonged phytoplankton bloom can provide prolonged availability of food for fish at higher trophic levels, either directly through the consumption of phytoplankton, or indirectly through consumption of zooplankton, which graze on phytoplankton. This, in turn, can result in strong year classes of haddock (Platt et al. 2003) or an increase in shrimp size (Fuentes-Yaco et al. 2007).

Ocean warming is projected to increase overall phytoplankton productivity in the subarctic Atlantic and will be prominent in ice-influenced regions where Arctic outflow and Atlantic inflow influence phytoplankton dynamics (Harrison et al. 2013). Observations and modelling conducted at high-latitude environments between 1988 and 2013 suggest that the spring bloom and peak seasonal productivity were occurring progressively earlier in the year in the eastern subarctic (Harrison et al. 2013).

Due to upwelling along the slopes of the offshore banks and channels and the outflow of nutrient rich water from the Hudson Strait, productivity in the Labrador Shelf SEA Update Area is high, specifically the Saglek Bank in the northern section of the Labrador Shelf SEA Update Area (Drinkwater and Harding 2001; Breeze et al. 2002, CPAWS 2018). The spring broom can vary from year to year with regards to duration and intensity, but usually occurs from May to June as ice leaves the Labrador Shelf area (Drinkwater and Harding 2001).

Most of the eastern third of the Labrador Sea is in full bloom by May with blooms occurring along retreating ice edges in the northern and western regions (Cota et al. 2003). The early bloom in the north and east areas is a regular occurrence and may be linked to the influence of sea ice melts in late winter (Head et al. 2000). In June, the central basin has relatively low chlorophyll concentrations with elevated biomass most pronounced over shelves, particularly in southern Labrador (Cota et al. 2003). Moderate biomass occurs over much of the deep basin from July through September or even early October. There appears to be a fall bloom over the shelf and slope regions in October in the Labrador Shelf SEA Update Area (Cota et al. 2003). The Labrador Shelf SEA Update Area displays elevated chlorophyll biomass over most of the growing season from April through September-October (Cota et al. 2003). In the Labrador Shelf SEA Update Area, the lowest productivity usually occurs in December due to low light intensity.

Seasonal fluctuations in phytoplankton biomass in the NL region are dominated by changes in the abundance of diatoms (DFO 2007). The spring bloom tends to be dominated by diatoms while the dominant species in the fall bloom are flagellates and dinoflagellates (DFO 2007; Buchanan and Foy 1980). Common phytoplankton found in the Labrador Shelf SEA Update Area from July to September 1997 are listed in Table 5.2.

Table 5.2 Common Phytoplankton in the Labrador Shelf SEA Update Area

Common Name	Genus
Centric diatoms	*Thalassiosira*
	Chaetoceros
Pennate diatoms	*Naviluca*
	Fragillaris
Tecate dinoflagellates	*Schripsiela*
	Dinophysis
	Heterocapsa
	Prorocentrum
	Pavillardia
	Protoperidinium
	Alexandrium
Naked dinoflagellates	*Gymnodinium*
	Gyrodinium
Ciliates	*Tibtinopsis*
Sources: Petro Canada 1982; VBNC 1997	

Fragoso et al. (2015) report dominant taxa (biomass) in the coastal and offshore regions of the southwest Labrador Sea. Coastal phytoplankton communities were dominated by Arctic and sea-ice diatoms, such as *Fossula arctic*, *Fragilariopsos spp*. (large and medium), *Porosira glacialis*, and *Thalassiosira spp*., as well as naked dinoflagellates (small), while offshore southwest Labrador Sea sites were dominated by armoured dinoflagellates (small), naked dinoflagellates (small), *Protoperidinium spp*., and the diatom, *Ephemera planamembranacea.* Fragoso et al. (2015) also confirm that the Labrador Sea phytoplankton community structure differs between spring and early summer blooms and is controlled by the physical and biogeochemical characteristics of the dominant water masses. These physical and biogeochemical characteristics (e.g., light availability, nutrient input and grazing pressure) define phytoplankton phenology (seasonal and interannual variation), biomass, primary production and community structure. Therefore, changes in these parameters (as the climate changes in high latitude oceans) will likely result in cascading effects on higher trophic levels (Fragoso et al. 2015).

Chlorophyll irradiance in the North Atlantic was measured from NASA Satellite Imagery for the four seasons in 2017 to show seasonal variation in chlorophyll *a* concentrations (Figures 5-1 to 5-4). Within the Labrador Shelf SEA Update Area, there are relatively low chlorophyll *a* concentrations during the winter (Figure 5-1). Data from the spring season show the highest chlorophyll *a* concentrations in the area occurring over the Saglek Bank to the north and the Hamilton bank to the south (Figure 5-2). This is consistent with the findings documented in 1989 (Drinkwater and Harding 2001). During the summer, concentrations of chlorophyll *a* were observed between 1 and 10 mg/m^3 in the Labrador Sea (Figure 5-3). These chlorophyll *a* concentrations shifted landward in the fall and were observed along the Labrador Shelf (Figure 5-4).

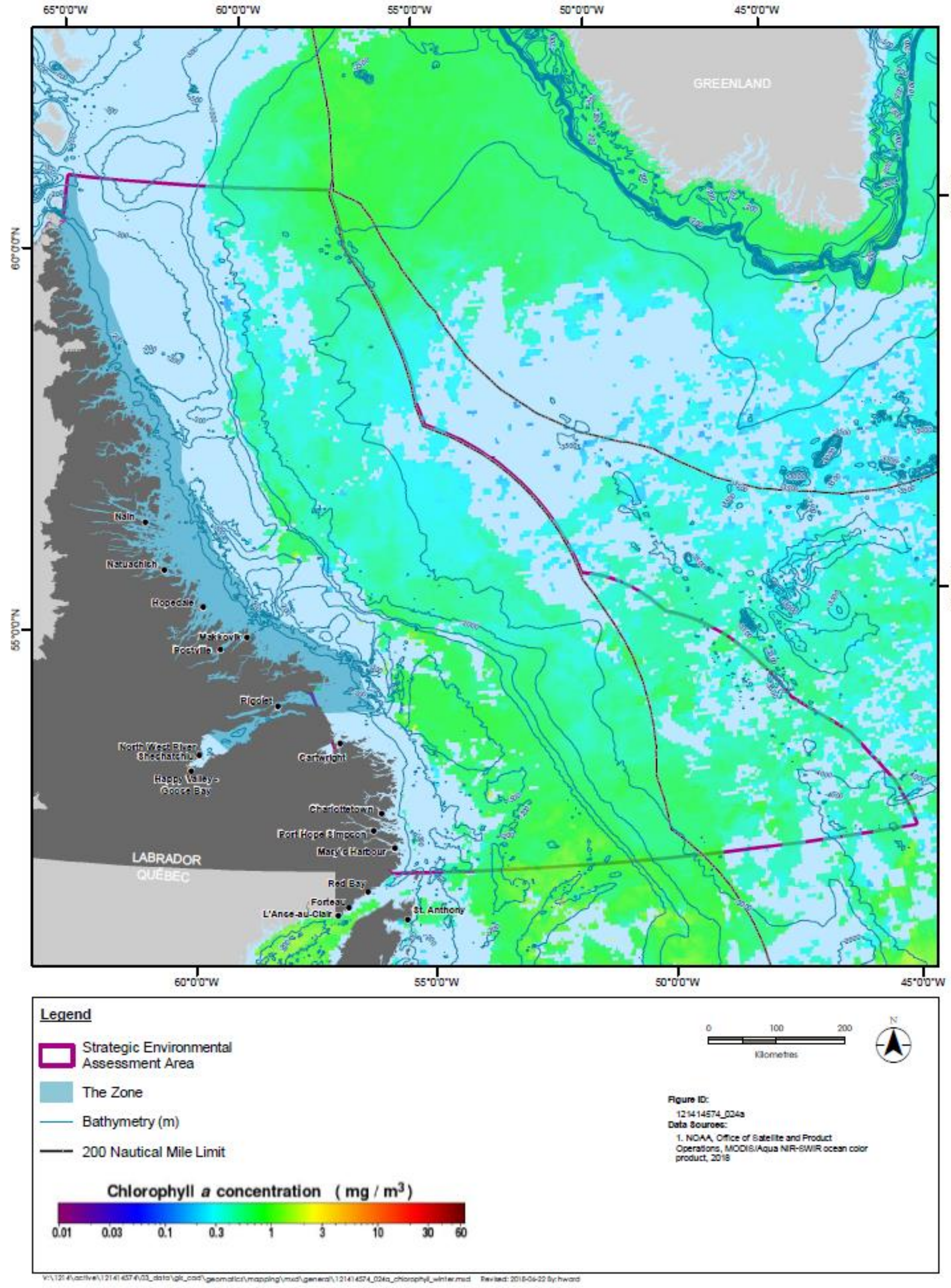

Figure 5-1 **Distribution of Chlorophyll Irradiance Measured from NASA Satellite Imagery of the North Atlantic - Winter (December-February) 2017**

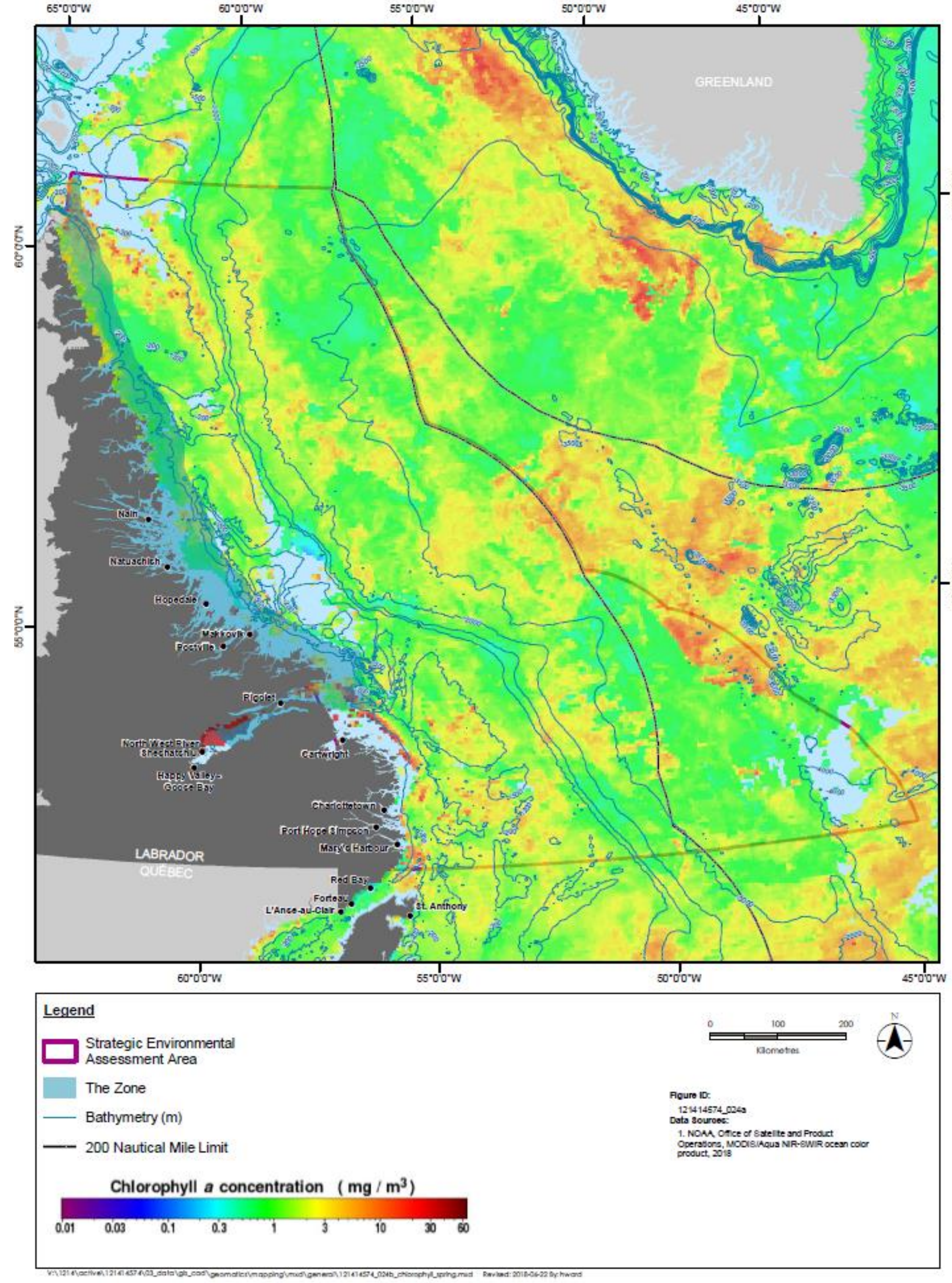

Figure ID:
121414574_024a

Data Sources:
1. NOAA, Office of Satellite and Product Operations, MODIS/Aqua NIR-SWIR ocean color product, 2018

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Figure 5-2 **Distribution of Chlorophyll Irradiance Measured from NASA Satellite Imagery of the North Atlantic - Spring (March-May) 2017**

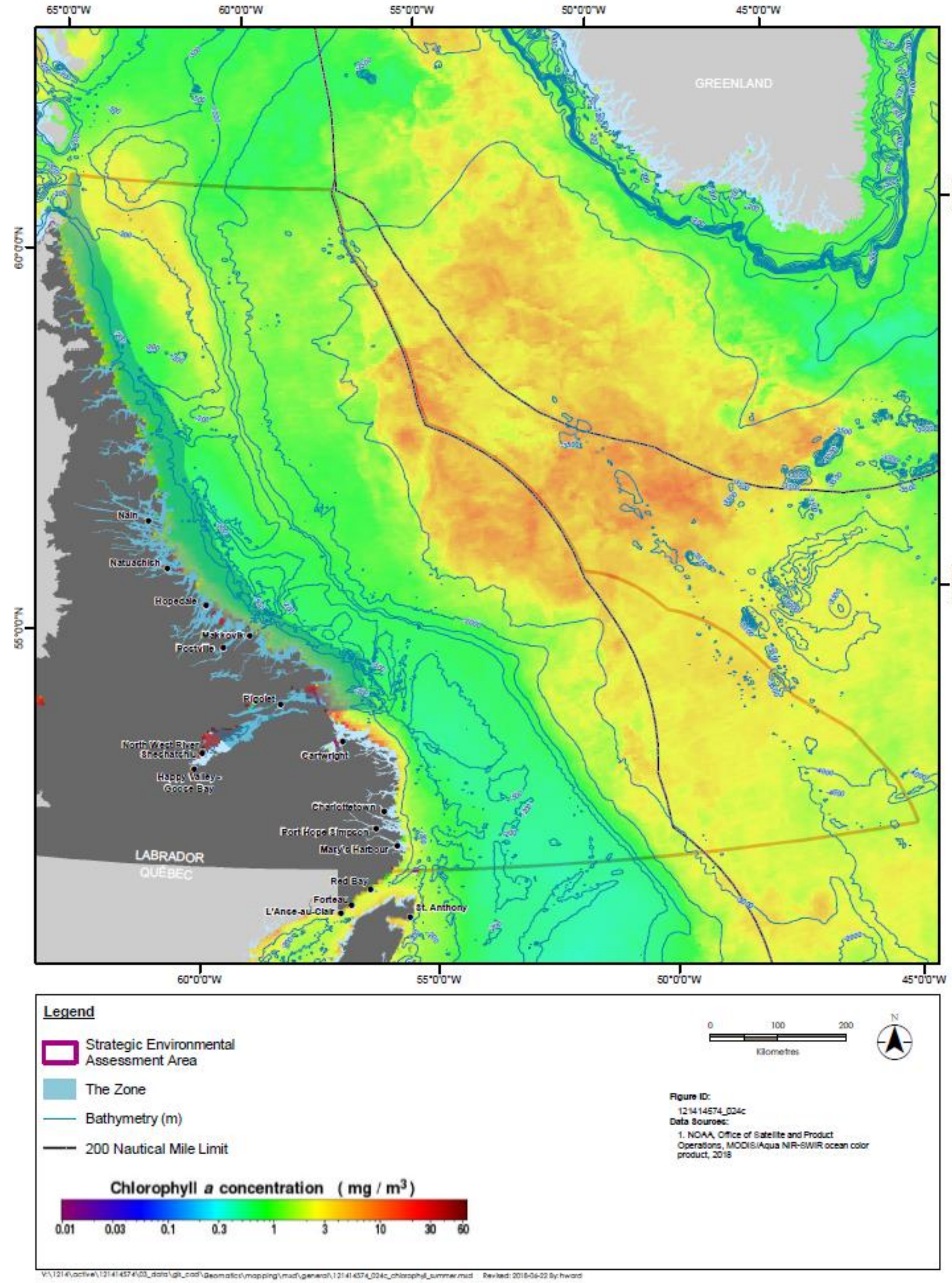

Figure 5-3 **Distribution of Chlorophyll Irradiance Measured from NASA Satellite Imagery of the North Atlantic - Summer (June-August) 2017**

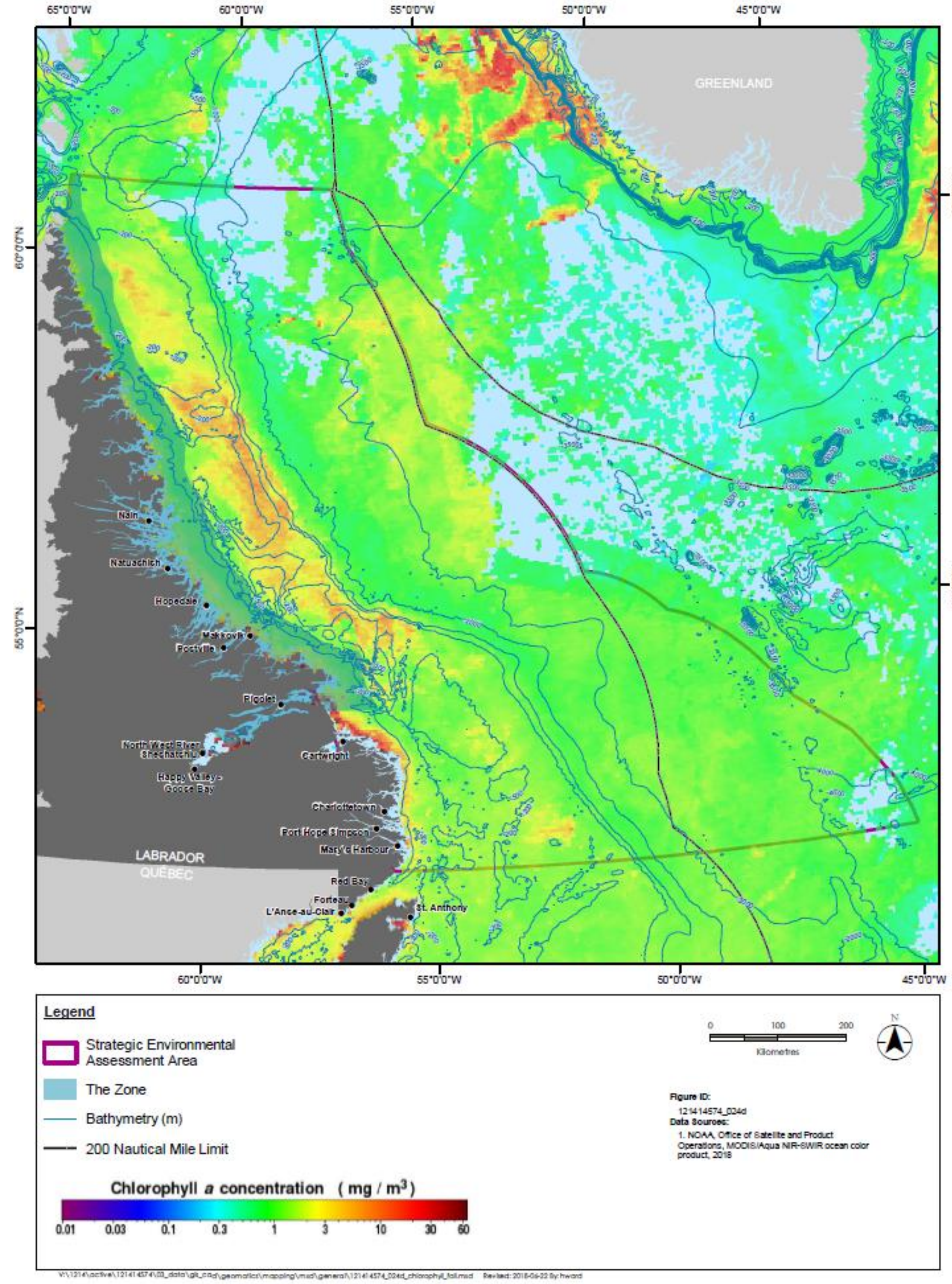

Figure 5-4 Distribution of Chlorophyll Irradiance Measured from NASA Satellite Imagery of the North Atlantic - Fall (September-November) 2017

Harrison and Li (2015) assessed satellite ocean colour data to provide an overview of the seasonal growth dynamics in the Labrador Sea. In addition to a spring bloom, a brief fall phytoplankton bloom occurs off the Labrador Shelf extending from Hudson Strait to southern Labrador. This fall bloom is primarily the result of a shelf-slope mixing (Drinkwater and Harding 2001) and may become more common as climate shifts and results in later freeze up (Ardyna et al. 2014).

5.2.2 Epontic Community

The epontic community is the sea ice biota, both plants and animals, at trophic levels that live in, on, or are associated with sea ice during all or part of their life cycle (Horner et al.1992). Communities are found at the surface, interior, and bottom of the ice, each of which can be further divided, and a sub-ice habitat / community immediately below the ice, but still attached or closely associated with the bottom of the ice. There are different mechanisms for the formation of these communities depending on where the community is located within the ice (Horner et al. 1992) and contribute to phytoplankton growth / production in ice-covered regions (Harrison et al. 2013).

There are three types of ice surface communities. The infiltration community occurs at the snow-ice interface and is formed when the weight of the snow depresses the ice and seawater-containing organisms can then infiltrate the snow. This community is reported as a mixed diatom-flagellate community in layers from 15 to 100 cm thick (Horner et al. 1992). Another mechanism is organisms already present in the ice grow because of a favourable environment after seawater invades the snow-ice interface. This is a result of higher temperatures and nutrient availability. The second type of surface community is called the deformation community, which includes the pressure ridge infiltration community, formed during initial pressure ridge formation and the surface saline pond community, formed when the ice surface is deflected below sea level and flooded. Both autotrophs and heterotrophs can be found in these communities, often with similar groups of organisms (Horner et al. 1992). The third community occurs in melt pools and are formed by thawing of surface ice, flooding, or a combination of both. A variety of organisms are found in melt pools, including freshwater and brackish water species of diatoms, flagellates and ciliates, which can be transported via wind or birds.

Poulin et al. (2011) conducted a first attempt to assess the pan-Arctic diversity of pelagic and sea-ice eukaryotes using data from various sources and review of presence / absence data. The study identified 1,027 sympagic (ice-associated) taxa comprised of 731 diatom taxa and 296 flagellate taxa from studies conducted in Alaska, Canada, Scandinavia including Greenland, and the Russian Federation and represents the most complete set of baseline data for the Arctic region.

Interior habitats depend on air temperatures at or slightly below the freezing point to initiate, but not complete, brine drainage. The uppermost community within the ice is called the freeboard community. This occurs when brine drains from the upper layers due to surface warming, increases in algal growth, heat trapping, and melting ice. This occurs 10 to 30 cm below the upper surface of the ice where the ice is decaying. Krill can also be found in this layer grazing on the algae (Horner et al. 1992). Brine channel communities are the most common interior habitat. They form in spring in response to temperature changes and internal stresses, which create long vertical tubes that allow vertical movement of brine through the ice. As the channels enlarge through growth or melting, they become connected with the underlying community. The amphipod *Gammarus wikitzkii* adapts to a wide range of salinities and is commonly found in the brine channel communities (Horner et al. 1992). Another type of community is the diffuse community. In the Arctic and subarctic areas, diatoms and heterotrophic flagellates are found throughout the ice thickness from the time it forms; however, studies are limited, and little is known about this community (Horner et al. 1992). Band communities are formed either by accretion of new ice under a previously-formed bottom ice layer of organisms, or by incorporation of cells at the time of first freezing of surface waters (Horner et al. 1992). This type of community is more common in the Antarctic but can occur in Arctic region.

The communities found in the bottom layers are the most frequently studied. The interstitial community occurs in the bottom where ice crystals are generally small and is usually only a few centimetres thick consisting of a solid, hard layer of congelation ice. Organisms like pennate diatoms, dinoflagellates, autotrophic and heterotrophic flagellates, ciliates, heliozoans, rotifers, nematodes, harpacticoid and cyclopoid copepods, turbellarians, and polychaete larvae can be found in this layer (Horner et al. 1992). Platelet ice can be found under the congelation ice and is the location of another bottom ice community. Decreased currents and shear near the ice front allows this surface to form. The Labrador Shelf ice population resembles previously described Arctic and Antarctic populations with a mean chlorophyll concentration of 98 mg m^{-3} and a carbon standing crop ranging from 2.8 to 10.8 g/m^3 (Irwin 1990). The average thickness of the ice algae layer was approximately 10 cm, translating into a standing crop of 0.6 g/m^3. Epontic ice flora can account for up to 30% of the annual productivity in the water column (Clark and Finley 1982).

The sub-ice habitat is in the seawater immediately below the ice although organisms may be loosely attached to the underside of the ice. Mats of algal cells floating just under the bottom surface of ice have been observed in the Canadian Arctic along with filaments loosely attached to the bottom surface of the ice (Horner et al. 1992). Organisms such as *Pseudocalanus* sp., harpacticoid copepods, the amphipods *Parathemisto libellula*, *Weyprechtia pinguis*, Onisimus litoralis, juvenile Onisimus spp., and *Gammarus setosus*, and Arctic cod (*Boreogadus saida*) can be found in this habitat (Horner et al. 1992).

It is feasible that the epontic algal communities may act as inoculums for the spring phytoplankton bloom (Anderson 1977). In the Antarctic, Bering Sea, and Chukchi Sea, it has been found that epontic communities contribute a substantial portion of the total annual primary productivity but are also the primary concentration of algae available to grazers during the late winter and early spring (Booth 1984). It has been estimated that approximately 10% of the annual production of coastal embayments may be contributed by epontic algae (Booth 1984). The importance of the epontic community is that it blooms prior to the phytoplankton blooms and increases the food available to grazers during this time (Booth 1984). Climate change may alter the contribution of the epontic community to primary production, as a reduction in ice cover may result in more pelagic and fewer epontic phytoplankton communities (Harrison et al. 2013).

5.2.3 Microflora

Microbiota consisting of bacteria, mould, and yeast are ubiquitous in the marine environment, including the Labrador Shelf SEA Update Area. Microflora occupies a unique niche in marine ecosystems in that they serve as a food source as well as degrade organic matter. Microflora is the link between detritus, dissolved organic matter, and higher trophic levels. Heterotrophic bacteria, through the process of oxidation, decompose complex organic molecules to smaller monomolecular units, thereby grazing the majority of the dissolved organic nutrients formed by phytoplankton (Bunch 1979). Microflora plays a role in the mitigation of climate change by sequestration of carbon in the deep ocean (Li and Dickie 1996).

Typically, microflora is most abundant in the upper layers, and their numbers decrease with depth. In the Labrador Sea, bacteria are present at concentrations of 105 to 106 per millilitre in the top 100 m, and 104 to 105 per millilitre at greater depths (Li and Dickie 1996; Li and Harrison 2001). In general, direct counts of microflora decrease approximately one order of magnitude from 1 to 200 m water depth (Bunch 1979). High values were obtained in surface waters where phytoplankton blooms were ongoing or recent, as evidenced by depleted nutrients (Bunch 1979). Within the water column, the correlation of phytoplankton numbers and direct count of bacteria was high (Bunch 1979). Below 50 m, potential heterotrophic activity is uniformly low, and this condition probably prevails in the four seasons (Bunch 1979), unless strong vertical mixing occurs. Low activity is indicated by a low number of cells. Regardless, microflora is able to persist deep into the aphotic zone where phytoplankton are absent, where they are a dominant metabolic agent mediating the dynamics of organic material (Li and Dickie 1996).

Microflora assemblages are sustained by the flux of dissolved organic matter from phytoplankton and zooplankton. Therefore, a reduction in primary production can determine the vertical distribution of microflora (Li and Dickie 1996). The spring phytoplankton bloom in high-latitude ecosystems is necessary for the development of microflora, which increase by approximately one order of magnitude in response to the bloom (Bunch 1979; Li and Dickie 1996).

5.2.4 Zooplankton

Zooplankton are the link between primary production and high trophic level organisms in the marine environment (Bernier et al. 2018). Zooplankton transfer organic carbon from phytoplankton to fish, marine mammals, and marine birds higher in the food web, and are a food source for a broad spectrum of species and contribute fecal matter and dead zooplankton to benthic communities.

The northern Labrador Sea is comprised of a relatively low number of species as compared to tropical and temperature climates (Huntley et al. 1983). The Labrador Sea is hydrographically complex with water masses from both Arctic and Atlantic water masses interacting. The distribution and ecology of zooplankton are strongly influenced by advection processes, such as those that occur in the Labrador Shelf SEA Update Area (Huntley et al. 1983). Zooplankton have seasonal cycles that often provide insight to the interactions between oceanographic processes and biological responses (Huntley et al. 1983).

Characteristic zooplankton taxa in the offshore Labrador Sea consist of copepods *Oithona* spp., *Microcalanus*, *Scolecithricella minor*, *Calanus finmarchicus*, *C. hyperboreus, Metridia* spp., *Euchaeta* spp., krill (Euphasids) and amphipods (mainly *Themisto libellula*) (Head et al. 2003; Pepin 2013). Arctic water zooplankton biomasses are dominated by calanoid copepods and mainly *C. finnmarchicus* (Huntley et al. 1983; Head et al. 2000). Throughout its biogeographic range, *C. finmarchicus* is a dominant grazer and the main prey for numerous planktivorous fish including herring, mackerel, capelin and young blue whiting and Atlantic salmon, with the larvae of many fish species feeding almost exclusively on the eggs and nauplii of *C. finmarchicus* (Mellea et al. 2014). The ecological importance of the *Calanus* species is based on the fact that they store large amount of lipids, making them a high-energy food source for a variety of marine species, including adult, juvenile, and larval stages of fish, which preferentially select them over other available food items (Falk-Petersen et al. 2009). While small *Pseudocalanus* spp. and *Oithona* spp. copepods generally dominate zooplankton abundance, they only account for a fraction of the total biomass; the large calanoid copepods (e.g., *C. finmarchicus*) often account for >50% of total zooplankton biomass despite its comparatively lower abundance.

Zooplankton community composition in the Northwest Atlantic has shifted over recent years (2014–2018), characterized by an increase in the abundance of small copepods such as *Oithona* spp. and *Pseudocalanus* spp., along with a decline in the abundance of the large, energy-rich calanoid copepods (Bernier et al. 2018; DFO 2020a). Total copepod abundance and non-copepod abundance found on the Labrador Shelf has also increased to higher than average levels in this same time period (Bernier et al. 2018).

Zooplankton reproduction is tied to the spring phytoplankton bloom, which either coincides or immediately follows the brief but intense blooms in high latitudes (Huntley et al. 1983; Head et al. 2000; Head and Pepin 2008), although there is controversy whether egg production starts before or after the spring bloom has occurred. Regardless of the timing of egg production, it is acknowledged that egg production rates are highest during the spring bloom (Head et al. 2000). Zooplankton reproduction in the northern and southern portions of the Labrador Sea would be expected to occur in or around May, with the central Labrador Sea lagging until sometime in June. The presence of stage I and II copepodites in the central Labrador Sea in October and November suggests that there may be a second breeding period in the late summer or early fall (Huntley et al. 1983) and that this aggregate is substantially smaller. The central Labrador Sea has had the highest egg production rates ever observed for *C. finnmarchicus* for the low ambient temperature (Head et al. 2000).

Preadult *C. finnmarchicus* develop in the surface waters over the summer and early autumn, after which the majority migrate to deeper waters to enter a period of dormancy known as diapause (Head and Pepin 2008). The seasonal descent to deeper waters means that *C. finnmarchicus* are largely absent from the Labrador Shelf region during winter months, and then repopulate the shelf regions in the spring. It has been suggested that the subpolar Northwest Atlantic gyre, slope water gyre, and Northeast Atlantic Norwegian Sea gyre form three distinct retention and distribution areas for the overwintering of *C. finnmarchicus* in the North Atlantic (Head and Pepin 2008). This is evident by the high concentrations of *C. finnmarchicus* in the near surface water of the Labrador Slope and central Labrador Sea in spring (Head et al. 2003). This supports the theory that the subpolar gyre provides a springtime source of *C. finnmarchicus* to the NL Shelf regions.

There is variability in the depth of *C. finnmarchicus* in the Labrador Sea, with more individuals found at greater depths near the continental shelves that in the central basin area (Head and Pepin 2008). The abundance of *C. finnmarchicus* in the Labrador Sea reflects production of the area, although slope waters are the areas of highest production with transport to the central Labrador Sea (Head et al. 2000). The abundance of *C. finnmarchicus* overwintering in the Labrador Sea is similar to those reported for the Irminger Basin and Norwegian Sea. The high concentrations of *C. finnmarchicus* in the central Labrador Sea is consistent with the theory that this is a distribution centre of *C. finnmarchicus* for the Northwest Atlantic (Head and Pepin 2008). The overwintering migration to particular depth may be due to several reasons, but in reality, there may not be one, but many reasons. It has been suggested that the reasons for the migration of *C. finnmarchicus* to different depths include: migration to a depth with fixed daylight intensity; depths at which predator avoidance is possible; and depths that are below depths of convection. Essentially the behaviour of the Labrador Sea *C. finnmarchicus* does not support these hypotheses, and the reason for the broad range of overwintering depths is not known (Head and Pepin 2008).

Copepods were found to be the most abundant species within the Davis Strait and northern Labrador, accounting for 88% of the zooplankton community, with *C. finnmarchicus*, *O. similis*, *C. glacialis*, and *Pseudocalanus minutus* accounting for 72% of the copepod species (Huntley et al. 1983). The copepod abundance for the Labrador Sea are based on data from the Seal Island transect (DFO 2007).

5.2.5 Significance of Variability in Oceanic Conditions

Oceanic conditions in the Labrador Shelf SEA Update Area are described in Section 4.4, including past changes and future predictions (Section 4.7).

The biogeochemical characteristics of the different water masses (Labrador Current, North Atlantic Current) and their interactions will determine, in part, the biogeochemical characteristics of the Northwest Atlantic waters. Changes in the physical and biogeochemical properties and transport of the water masses flowing down the Labrador Shelf will undoubtedly have an impact on the Newfoundland Shelf (Lavoie et al. 2017).

The Arctic outflow pathway is subject to changes. Some regional climate models project a decrease in the flow of cold Arctic water through the Canadian Arctic Archipelago because of an increase in sea surface height in Baffin Bay (Castro de la Guardia et al. 2015). The transport variability of the Labrador Current is significantly correlated with the relative abundance of *C. finnmarchicus* and may have direct impact on the recruitment of calanoid copepods in shelf ecosystems in the Northwest Atlantic (Fromentin and Planque 1996, Maillet and Colbourne 2007). Likewise, Balaguru et al. (2018) state that changes in Arctic sea ice cover, and consequent higher levels of freshwater entering the ocean due to melting ice cover, can have an influence over wintertime deep convection in the Labrador Sea, and could negatively influence the success or abundance of spring-time blooms of phytoplankton. This change in convection can potentially have associated effects on the Labrador Current itself and result in large-scale changes to the marine ecosystem within the Labrador Sea. The importance of the changes in oceanic conditions is not limited to calanoid copepods. Variations in oceanic conditions influences growth, recruitment, and distribution of many marine organisms, in addition to phytoplankton and zooplankton (Maillet and Colbourne 2007). Many of the species residing in NL waters are at their northern distribution limit and with the northward expansion of their habitat range limited by water temperatures (Maillet and Colbourne 2007). The marine ecosystem and the transfer of productivity through the ecosystem is a complex, non-linear system, with a variety of physical and biological influences interacting on a species. Variations and pressure exerted on plankton can have impacts throughout the whole marine ecosystem that may be intermediate or long-term changes as species assemblages are affected by the strong biophysical seasonality of the Labrador Shelf SEA Update Area (DFO 2021a).

5.2.6 Data Constraints for Plankton

Plankton, including phytoplankton, zooplankton, epontic communities and microflora, are the foundation to the marine ecosystem as they transfer energy up to higher trophic levels. While there are data and information available on plankton, it is still sparse. Species assemblages of planktonic communities is poorly understood (DFO 2021a). Current research being conducted by government and research institutions is helping to fill data constraints, recognizing that a majority of the research to date is limited in the time of year it is undertaken, in part due to weather, and the locale itself is a data constraint. Sea ice in winter and spring can inhibit the collection of data, and scientific collection is limited to those areas where RV surveys are conducted (DFO 2021a).

Due to the challenges of conducting season surveys, winter information on species composition and distribution of plankton is limited. The role and importance of sea ice dynamics is a constraint. The effect and importance of nutrients on phytoplankton productivity and growth is lacking for winter months. Knowledge on winter mixing and the recharge of surface nutrients is limited. Amplitude and duration of the phytoplankton growth cycle is limited in that research periods have been limited to certain periods of the year, so there are data constraints to the understanding of the “whole picture”. The importance of silicate and nitrates to phytoplankton growth and the full understanding of the processes that different water masses play in their availability is a data constraint.

Understanding the dynamics and community structure associated with epontic communities is limited with the few studies conducted within the area. The actual contribution of epontic communities to productivity is thought to be as high as 30% for high latitude regions but has not been adequately quantified for the Labrador Sea. The actual assemblages of the epontic communities are based on ice edge communities and they may differ for non-ice edge structures. The contribution of epontic communities to the overall primary productivity of the Labrador Sea is limited.

The role of microflora in high latitude regions as an alternative food source at various times of the year is limited. Detailed descriptions of the microflora and its related assemblages is limited.

Zooplankton community structure and ecology is limited for the full year. While there are substantial amounts of information for the summer, winter processes are poorly understood. Significant emphasis has been placed on *C. finnmarchicus* being the dominant zooplankton species, but data constraints exist in the understanding of the ecology and temporal distribution, especially in winter. Information on other zooplankton species, including their ecology and distribution, is limited.

The integration and knowledge of plankton as a marine ecosystem component is limited. Understanding of the role of climate change and its impacts both temporally and spatially on plankton is also limited. The impacts of climate change on the transfer of energy to higher trophic levels also has data constraints. IK on coastal areas not frequented by Indigenous groups is limited (DFO 2021a).

While there are data gaps / constraints, their relation to offshore oil and gas activities is dependent on the nature and timing of the particular activity, and the need to collect additional data will be determined at the project-specific EA stage.

Project-specific EAs should confirm that data constraints are still relevant and have not been addressed, or if new data constraints have been identified.

5.3 MACRO-INVERTEBRATES

Benthic invertebrates are bottom-dwelling organisms and can include a wide taxonomic variety. Benthic organisms can be classified into three categories; infaunal species, sessile species, and epibenthic species (Barrie et al. 1980). Infaunal organisms that live on or are buried in soft substrates include bivalves, polychaetes, amphipods, sipunculids, ophiuroids, and some gastropods. Sessile organisms can live on soft substrate or attached to hard substrates and include barnacles, tunicates, bryozoans, sea anemones, corals, and sponges (see Section 5.3.1). Epibenthic organisms are mobile and/or active swimmers that remain in close association with the seabed and include holothurians (e.g., sea cucumbers), mysids, amphipods (e.g., shrimp-like), and decapods (e.g., crab and lobster).

Benthic macrofauna are important in the Arctic ecosystem. They are important food sources for both humans and animals in the Labrador Shelf SEA Update Area. Having a source of marine macroinvertebrates provides food security for the Inuit communities of Labrador (DFO 2021a). During the collection of IK as part of the original SEA Report (SEM 2008) it was indicated that mussels, clams, sea urchins, and whelk were harvested within the Labrador Shelf SEA Update Area. Additionally, in an Inuit environmental knowledge report, published in 1997, mussels and clams were observed to be plentiful in the Nain district (Williamson and LIA 1997). However, there is limited current information on benthic communities in coastal areas, as most studies have focused on regions farther offshore on the continental shelf and slope (DFO 2021a). Distributions of non-commercial macro-invertebrates are provided in Sections 5.3.1 and 5.3.6 and geographic distribution of fishing activity of commercially important macro-invertebrates are provided in the Chapter 9.

The spatial variability of benthic communities can be attributed to physical habitat characteristics, such as temperature, salinity, water depth, substrate type, currents, and sedimentation. The primary natural factors affecting the structure and function of benthic communities is water mass differences, sediment characteristics, and ice scour (Carey 1991). Effects of offshore oil and gas activities on benthic communities are provided in Section 5.7. The seasonality of phytoplankton can also influence production in benthic communities, adding temporal variability to a highly heterogenous community. The sensitivity of invertebrate communities to climate change is not fully understood. Climate change can exert great pressure on these ecosystems; this could result in major changes to benthic communities in the coming decades. Ruhl and Smith Jr. (2004) noted that deep-sea communities in the northeast Pacific respond to climate events.

The absence of recent benthic studies in the offshore Labrador Sea is a major data gap (Coté et al. 2019). Preliminary results from Coté et al. (2019) show the presence of polychaetes, *Pennatula* sp. sea pens, brittlestars (Ophiurida) and shrimp (Caridea) at depths exceeding 2,000 m. An older study by Stewart et al. (1985) collected benthic invertebrate samples from 14 stations within the southern Davis Strait and Ungava Bay. One of the samples was collected on the northern Labrador Shelf (at 180 m). The dominant species in the samples collected by Stewart et al. (1985) in the northern Labrador Sea were: the molluscs *Tachyrhynchus erosus* and *Macoma loveni*; the polychaetes *Rhodine gracilior*, *Maldane sarsi*, and *Chaetozone setosa*; and the crustacean *Unciola leucopis*. Sediment type at the station was predominantly sand and was located in a mixing zone between the Labrador Current water and deeper, warmer Atlantic intermediate water. Of the species identified in these samples, polychaetes were the most prevalent, accounting for 16 of the 45 species. The five most abundant species were *Maldane sarsi*, *Rhodine gracilior*, *Chaetozone setosa*, *Onuphis conchylega*, and *Scolpos arminger* (Stewart et al. 1985).

Barrie and Steele (1979) found two species associations on shallow sand substrates in Labrador. On open exposed coasts of fine and medium sand, *Diastylis* sp., *Nephtys longesetosa*, *Turtonia minut*a, *Stegophiura stuwitzi*, and *Ampharete arctica* were present. More protected areas with fine sand sediments, such as Nain and Hopedale, were inhabited by *Macoma* sp., *Serripes groenlandicus*, *Ampelisca eschrichtii*, *Prionospio steenstrupti*, and *Pectinaria granulata*. Other distinct benthic assemblages identified by Barrie et al. (1980) include those in shallow water with rocky substrates that contain *Mytilus edulis* and *Hiatella arctica*. On bottoms with a mixture of cobble and sand, *Hyas araneus* and *Diastylis rathkei* were the dominant species. Sandy bottoms were characterized by several bivalves and the polychaete *Nepthys caeca*. Coarse silt substrates were colonized by the amphipod *Byblis gaimardi* and several polychaete species. Gagnon and Haedrich (1991) found that large scale topographical features of the Labrador Sea contributed substantially to the structure of the benthic polychaete community.

The deepwater (2,000 to 3,800 m water depths) sections of NAFO 2GH are characterized by slope and abyssal habitats (primarily Abyssal Plain), with submarine canyons running from the continental shelf into the deeper water (Harris et al. 2014). As most benthic studies are focused on the continental shelf and slope regions, there is limited information on these communities in deeper water (Coté et al. 2019). Polychaetes, sea pens (*Pennatula* sp.), brittlestars (Ophiurida), shrimp (Caridea), corals, sponges, and six species of fish (including blue hake (*Antimora rostrata*), armed / abyssal grenadier (*Coryphaenoides armatus*) and skate species) were recorded in the deepwater areas of NAFO 2GH at depths exceeding 2,000 m (Coté et al. 2019). Eleven fish species (including Greenland halibut (*Reinhardtius hippoglossoides*), grenadier species and wolffish [*Anarhichus* spp.]) were collected at depths <2,000 m (Coté et al. 2019). Myctophids such as glacier lanternfish (*Benthosema glaciale*) are widely distributed in the deepwater habitat of the western Labrador Sea (Pepin 2013).

The following sections provide descriptions of some benthic invertebrate species that have been noted as occurring within the Labrador Shelf SEA Update Area. The species and groups described in the following sections are of importance to commercial, recreational, Indigenous, and emerging fisheries as well as important to the structure of the benthic ecosystem.

5.3.1 Corals, Sponges, and Bryozoans

Corals, sponges, and bryozoans are sessile, slow-growing organisms that play an important role in the marine environment. They provide structural complexity to the seabed, create areas of refuge and habitat for multiple fish species, increase overall biodiversity in areas they are present, and provide benthic-pelagic coupling through nitrogen and carbon cycling via large filter-feeding capacity (Sherwood and Edinger 2009; DFO 2021a).

Corals, sponges, and bryozoans are slow-growing and fragile organisms and are sensitive to disturbances, such as commercial trawling and oil and gas activity. Black corals and gorgonian corals (large and small) have been highlighted as being vulnerable, due to their inability to re-attach to substrate if they are disturbed (Gilkinson and Edinger 2009). Other corals such as sea pens, as well as sessile benthic organisms such as sponges and bryozoans, are also vulnerable to disturbance including impacts from bottom-contact activities such as fishing gear. They are affected both by direct damage from physical contact and indirect damage from smothering (Koen-Alonso et al. 2018). Koen Alonso et al. (2018) provided evidence that Significant Benthic Areas (SBAs) are in the Newfoundland and Arctic Waters and are likely being impacted by fishing activities to the extent where these impacts may have the potential to affect ecosystem productivity. Coral is often caught as bycatch in fisheries for bottom-dwelling fish species, such as Greenland halibut, Atlantic halibut and northern shrimp. The actual extent and degree of impacts to the corals will be based on the species, the level of fishing pressure and role of these corals in overall ecosystem function. Coral life history characteristics include long lifespan and long recovery rates for both disturbed coral and sponge communities (e.g., decades) compared to other benthic invertebrate communities (Henry and Hart 2005; Sherwood and Edinger 2009; Cordes et al. 2016; Henry et al. 2017; Ragnarsson et al. 2017; Liefmann et al. 2018).

Research conducted by DFO, non-governmental organizations and other institutions has shown that corals are distributed along the edge of the continental shelf and slope off Nova Scotia, Newfoundland, and Labrador, but are also found in coastal and deeper ocean areas, which are understudied (Edinger et al. 2007). Typically, corals are found in canyons along slope and channel edges (Breeze et al. 1997) in areas deeper than 200 m, but can also be found in areas shallower than 200 m. Soft and hard (horny and stony) corals occur in both shallow and deep waters. Different species of cold-water corals provide habitats of varying physical size and life spans (Roberts et al. 2009), and corals in the waters of NL are slow-growing and long-lived (Sherwood and Edinger 2009). For example, gorgonians can grow close together and form dense forest-like habitats, sea pens may occur in aggregations known as sea pen meadows, and other species (e.g., scleractinian cup corals) are solitary species and can also form coral fields. Most corals, such as large gorgonians, grow on hard substrates (Breeze et al. 1997; Gass 2003). Small gorgonians, cup corals, and sea pens prefer sandy or muddy substrates (Edinger et al. 2007). Cold-water corals have been shown to play an important role in benthic ecosystems by providing habitat for other species of invertebrates and fishes among other associations (Buhl-Mortensen and Mortensen 2005; Buhl-Mortensen et al. 2010). Studies which have looked at species associations with cold-water corals and their associated fauna have shown evidence that cold-water corals are as ecologically important as shallow-water coral systems by providing structurally complex habitat for a variety of marine species (Buhl-Mortensen et al. 2010; Krieger and Wing 2002; Roberts et al. 2009; Watling et al. 2011).

Mapping of corals has been undertaken for regions within the Labrador Shelf SEA Update Area. Gilkinson and Edinger (2009) identified areas of high coral diversity and abundance in the Labrador Region, in addition to some parts of the Eastern Arctic. They identified areas from Makkovik Bank to Belle Isle Bank, and from Saglek Bank to the southeast Baffin Shelf (Gilkinson and Edinger 2009). More recently, Kenchington et al. (2016) mapped the Labrador Shelf in order to identify SBAs that are considered ecologically important for marine life and are defined in DFO's Ecological Risk Assessment Framework (ERAF) as areas that hold larger concentrations of cold-water corals and sponges (DFO 2013a). The SBAs were identified using a kernel density estimation, a quantitative analysis technique applied to research vessel (RV) data to identify sponge and coral concentrations (Kenchington et. al. 2016). Gullage et al. (2017) used predictive modelling to generate areas of suitable habitat for cold-water corals along the NL shelves, and modelling results concurred with previous studies that areas of suitable habitat and those with a higher presence of corals and sponges were located along the slope of the continental shelf. In particular, the highest predicted sponge probabilities from the study occurred along the Labrador Slope and Saglek Bank. Bamboo coral (*Acanella arbuscula*) fields have been reported in the northern Labrador Sea (DFO 2021b) and in 2017, both corals (including bamboo coral) and sponges were documented by drop cameras and through long-line catches in waters >2,000 m (Coté et al. 2019).

A combination of the findings from Kenchington et al. (2016) and results from DFO RV surveys from 2014 to 2017 have been combined to provide an overview of coral and sponge locations and concentrations within the Labrador Shelf SEA Update Area (Figure 5-5). As illustrated in Figure 5-5, although there are many areas that have had little exploration, the continental shelf remains the area where the highest concentrations of corals, sponges, and sea pens are located and is consistent with other studies that have been conducted in the area (Gilkinson and Edinger 2009; Kenchington et al. 2010; Edinger et al. 2011; Knudby et al. 2013).

Corals are most dense in the region between Makkovik Bank and Belle Isle Bank (Edinger et al. 2007). An underwater hotspot of biodiversity off the coast of Makkovik was recently announced (CBC 2021), primarily deep-sea corals (e.g., *Primnoa*), mixed with a number of sponges. The mid-Labrador coast has relatively high species richness with up to six species per tow (Gass 2003; Gilkinson et al. 2006; Edinger et al. 2007). A breakdown of coral species that are present in the Labrador Shelf SEA Update Area, based on past surveys and studies, are presented in Table 5.3, with the distribution of coral functional groups along with sponges presented in Figure 5-5.

As noted above, corals provide structural complexity and serve as physical substrates, feeding sites, and provide shelter for fish and invertebrates, including polychaetes, amphipods, sponges, barnacles, bryozoans, ophiuroids and ichthyoplankton (Edinger et al. 2007). Areas with corals generally have high species richness and thus attract fish harvesters targeting redfish, halibut, pollock, and shrimp (Breeze et al. 1997).

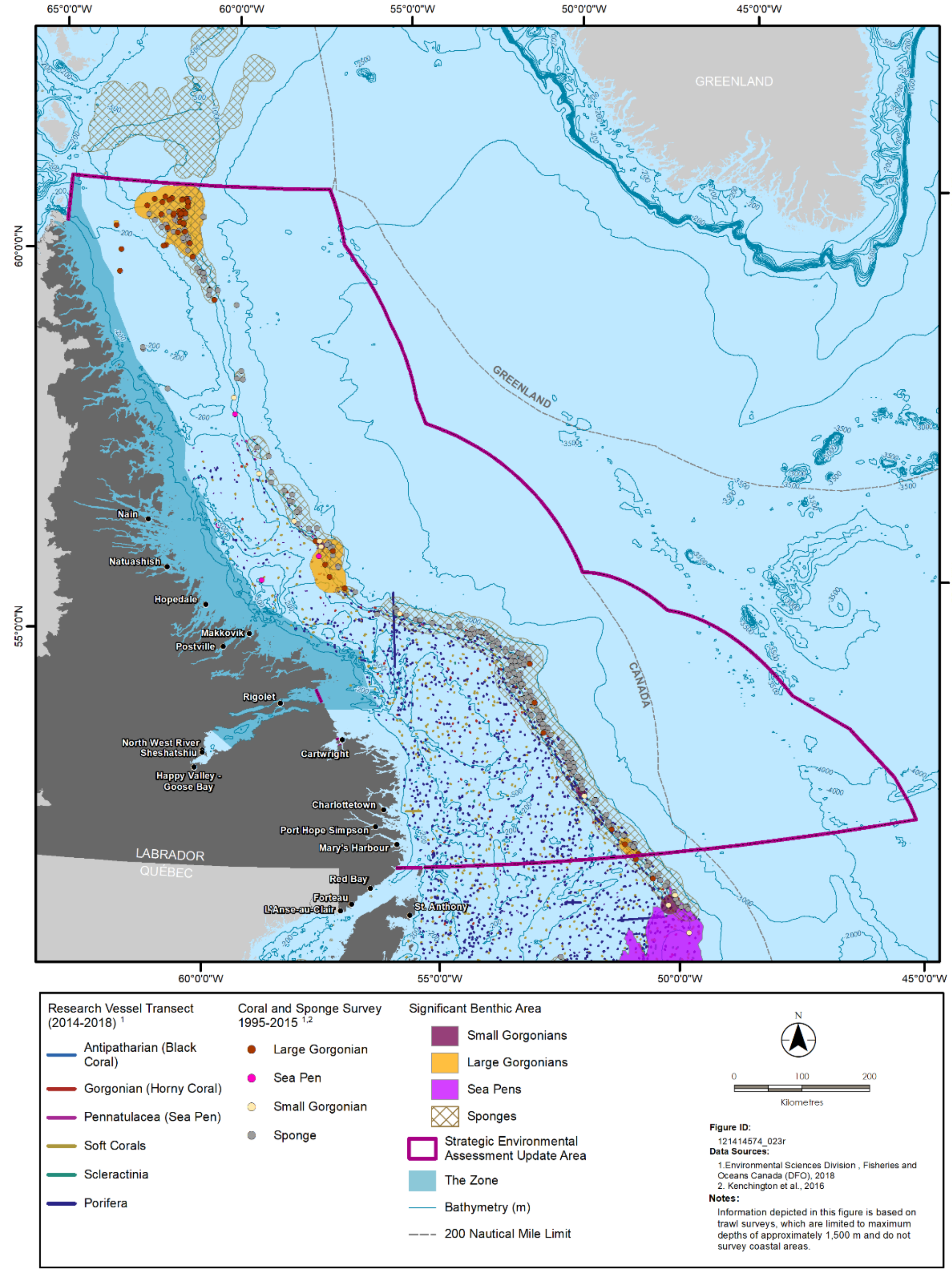

Figure ID:
121414574_023r

Data Sources:
1.Environmental Sciences Division , Fisheries and Oceans Canada (DFO), 2018
2. Kenchington et al., 2016

Notes:
Information depicted in this figure is based on trawl surveys, which are limited to maximum depths of approximately 1,500 m and do not survey coastal areas.

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Figure 5-5 Coral and Sponge Distribution within the Labrador Shelf SEA Update Area

Table 5.3 Coral Species in the Labrador Shelf SEA Update Area

Functional Group	Description	Species Included
Antipatharians	Black corals	*Antipatharia spp*. *Stauropathes arctica*
Alcyonaceans	Small gorgonian horny corals, hard corals typically <1 m in height	*Acanella arbuscula*
		Anthothela grandiflora
		Chrysogorgia cf. agassizii
		Chrysogorgia spp.
		Swiftia spp.
Alcyonaceans	Large gorgonian horny corals, hard corals, typically >1 m in height	*Primnoa resedaeformis*
		Paragorgia arborea (L.)
		Keratoisis grayi
		Acanthogorgia spp.
		Paramuricea spp.
		Parastenella atlantica
		Paramuricea placomus (L.)
		Bathypathes arctica
		Radicipes gracilis
Scleractinians	Cup corals	*Flabellum alabastrum*
		Flabellum (Ulocyathus) alabastrum
		Vaughanella margaritata
		Desmophyllum dianthus
Pennatulaceans	Sea pens	*Anthoptilum* spp.
		Anthoptilum grandiflorum
		Pennatula spp.
		Ptilella grandis
		Pennatula aculeata
		Distichoptilum gracile
		Funiculina quadrangularis
		Balticina finmarchia
Pennatulaceans	Sea pens	*Kophobelemnon stelliferum*
		Umbellula spp.
Alcyonaceans	Soft corals	Nephtheidae Family
		Gersemia spp.
		Gersemia rubiformis
		Duva florida
		Anthomastus grandiflorus
		Gersemia rubiformis
		Duva sp.
Source: Edinger et al. 2007; Kenchington et al. 2016		

Sponges are sessile benthic invertebrates that are characterized by bodies built around a system of canals through which water is pumped to supply food and oxygen and remove waste (Hooper and van Soest 2002; Knudby et al. 2013). Similar to cold-water corals, sponges can form structurally complex habitat for fish and invertebrates, especially when they occur in dense aggregations known as sponge grounds (Amsler et al. 2009; Herrnkind et al. 1997; Knudby et al. 2013), like those that occur off the continental slope in Labrador (Kenchington et al. 2010; Kenchington et al. 2016). Sponges are an important component of benthic ecosystems that enhance both local nutrient and energy exchange in the deep sea (de Goeij and van Duyl 2007; Knudby et al. 2013).

Knowledge of the spatial distribution of sponges in the Labrador Shelf SEA Update Area come from DFO multispecies surveys, observer records, and species distribution modelling (Knudby et al. 2013). The deep-sea sponges of the suborder Astrophorina (*Geodia barretta* and *Geodia phlegraei*) occur off the tip of the Cumberland Peninsula in southwestern Baffin Bay and northwestern Davis Strait, offshore of the eastern limit of NAFO Division 0A (Knudby et al. 2013). They are also known to occur on the Southeast Baffin Shelf and, to a greater extent, on the slope in western Davis Strait and eastern Hudson Strait (Knudby et al. 2013). Research on sponge species distribution north of the Labrador Shelf SEA Update Area in the eastern Canadian Arctic identified sponge species assemblages, some of which have been observed elsewhere, suggesting that they may be common to the North Atlantic (Murillo et al. 2018). This includes two assemblages characterized by large structure-forming astrophorids: one with Arctic species found at mid-water depths in Baffin Bay and the other characterized by boreal species found deeper, south of Davis Strait. Another assemblage characterized by glass and carnivorous sponges was found along the continental slope of western Baffin Bay (Murillo et al. 2018).

Results of species distribution modelling determined that depth and salinity were generally the two most important variables in predicting the distribution of the sponge *Geodia* sp. (Knudby et al. 2013). Sponges have been documented along the Labrador Shelf (Figure 5-5) and there is a high probability that there are additional sponge grounds in the Labrador Shelf SEA Update Area.

Bryozoans are non-aggregating, sessile marine invertebrates commonly associated with sponges. Modelling studies using data from NL-based fisheries surveys have indicated their potential presence along the continental shelf, including the shelf along the southern Labrador Sea (Guijarro et al. 2016). Similar to corals and sponges, bryozoans are habitat-forming organisms and are known to be fragile. Some erect species, which can grow more than 5 cm above the seabed, can have a lifespan in excess of 20 years (Smith et al. 2001; Murillo et al. 2011). The erect bryozoan *Eucratea loricata*, reaching heights up to 25 cm, has been identified in the NL offshore areas in water depths less than 100 m (Ryland and Hayward 1991).

Long-lived erect bryozoans can be susceptible to similar disturbances as corals and sponges such as destruction by bottom-contact activities. Studies on bryozoan beds have shown that bryozoan beds damaged by fisheries trawling gear had not recovered 10 years later, and the loss of the beds was considered permanent (Jones 1992), while less dense aggregations of bryozoans have been less affected by trawling disturbance (Henry et al. 2006).

5.3.1.1 Data Constraints for Corals, Sponges, and Bryozoans

While there has been an increased emphasis on studying deep-sea corals, sponges, and bryozoans off the coast of NL, it is still a relatively new area of focus and research. Data including specific information on benthic assemblages, depth distribution, and life history traits for the Labrador shelf, have not been collected (DFO 2021a). The most vulnerable habitats may be those with a high degree of structural complexity, such as those that contain corals and sponges. Research to date has focused on the mapping of coral distributions and diversity (Gilkinson et al. 2006, Gilkinson and Erdinger 2009, Edinger et al. 2011), with more recent research using habitat modelling to predict the distribution of cold-water corals (Kenchington et al. 2010, Knudby et al. 2013, Gullage et al. 2017), and can be expanded to include bryozoans (DFO 2021a). Additionally, recent research by Coté et al. (2019) has proposed the use of camera and trawl or dredge methods for ground-truthing, as well as multi-beam habitat classification for identifying available habitat types. However, these methods are limited with respect to spatial coverage and sample sizes (Coté et al. 2019). Up to 2005, deep-sea coral research in NL was opportunistic, taking advantage of coral bycatch from multispecies surveys, fisheries observer programs, and local knowledge from commercial fish harvesters. Since 2005, studies on deep-sea corals have expanded to include studies of deep-sea coral trophic relationships, reproductive ecology, and the role of deep-sea corals as fish habitat. Nevertheless, data constraints still exist with identifying the exact locations of corals, and there may be areas where corals exist that have not been surveyed to date. The description of mapping studies in the Labrador Shelf SEA Update Area are based on trawl surveys, which are limited to maximum depths of approximately 1,500 m and do not survey coastal areas.

While there are data gaps / constraints, their relation to offshore oil and gas activities is dependent on the nature and timing of the particular activity, and the need to collect additional data will be determined at the project-specific EA stage. Project-specific EAs should confirm that data constraints are still relevant and have not been addressed, or if new constraints have been identified.

5.3.2 Iceland Scallop

Iceland scallop (*Chlamys islandica*) are widely distributed throughout the subarctic. Iceland scallop are suspension feeders and as such, tend to be most abundant in areas with substantial water movements (Naidu 1997). Iceland scallops are sedentary and live in aggregations (beds) in areas with suitable substrate where currents retain larvae (DFO 2020b). Commercial-sized beds are found at depths of 50 to 80 m on hard substrates consisting of sand, shells and stones (DFO 2020b).

The spawning period for Iceland scallop is short, taking place in June and July, and varies geographically (Crawford 1992). Sexes are separate and are distinguishable by gonad colouration. Fecundity in females is proportional to its size cubed (Pederson 1994). After fertilization, larvae are dispersed throughout the water column, with development taking approximately five weeks. Juveniles then attach to the seabed in proximity to the adults (DFO 2020b).

Nunatsiavut Government reported that Iceland scallops are fished within the Labrador Shelf SEA Update Area from Big Bay to Saglek Bay and Shoal Tickle (SEM 2008). Nunatsiavut Government observed a change in scallop movement in the water, noting that they move with the current more in recent years, and are found in different locations, depending on the tide (Nunatsiavut Government 2018). It was also reported that scallop beds can have up to 200 to 300 scallops (Nunatsiavut Government 2018).

The NunatuKavut Community Council scallop harvest is described in Section 9.2.2.1 and 9.4.3. The NunatuKavut Community Council indicated that harvesting scallops was an historically important commercial and subsistence activity. Scallops are not identified at the species level but are reported at a number of locations in the study area. Scallop harvesting was described as an important commercial activity during the “moratorium times”. The NunatuKavut Community Council observed that commercial netting of other species kills scallops (NunatuKavut Community Council 2019).

The commercial importance of Iceland Scallop is discussed in Section 9.2.5.6.

5.3.3 Crab

The Nunatsiavut Government reported in 2007 that crab (species not specified) are fished within the Cartwright Channel, off Cartwright and Black Tickle, and areas between Makkovik and Hopedale (SEM 2008). An accidental oil release would have serious consequences; the tides and the wind would bring released oil to traditional fishing grounds.

5.3.3.1 Snow Crab

Snow crab (*Chionoecetes opilio*) occurs over a range of water depths in the Northwest Atlantic Ocean, from Greenland to the Gulf of Maine. Snow crab are also widely distributed on the NL shelves (DFO 2005). Commercial-sized snow crab commonly occur on mud or sand substrates (DFO 2005) at depths of 70 to 2,000 m and in temperatures of -0.5°C to 5°C (Fisheries Resources Conservation Council (FRCC) 2005; Dawe et al. 2010). Smaller crabs are also found on harder substrates (DFO 2002a).

Snow crab moult their shells in the spring, where terminal moulting for females occurs upon reaching sexual maturity, between carapace widths of 30-95 mm, while terminal moulting for males occurs between 40-150 mm carapace width (Mullowney et al. 2018; DFO 2005). Additionally, males may reach sexual maturity before their terminal moult.

Mating is known to occur offshore during the late winter or spring; however, the actual area is unknown. Most females reach terminal moult sometime between early winter and early spring (FRCC 2005). Most adolescent males reach terminal moult and maturity in the early spring, but a small percentage does moult during the winter (FRCC 2005). First-time mating generally takes place in late winter, following the terminal moult (FRCC 2005). Mating by repeat spawners occurs later in the spring (FRCC 2005). It is believed that first-time spawners (primiparous) are less productive than the repeat (multiparous) spawners (FRCC 2005). Mullowney et al. (2018) studied the dynamics of snow crab movement and migration along the Newfoundland, Labrador and Eastern Barents Sea continental shelves. It appears that ontogenetic movement is associated with water temperature (i.e., movement towards warmer waters), while seasonal migrations towards colder waters are associated with mating and moulting. The distance associated with seasonal migration appears to differ regionally. This is potentially related to local bathymetry and oceanographic conditions, with the movement being driven by temperature and the scale of the movement being related to the bathymetry between cold and warm water (Mullowney et al. 2018).

Depending on size, females lay between 16,000 to 160,000 eggs deposited on hairy appendages under the abdomen. Fertilized eggs are carried for approximately two years. During this period, the eggs change colour from bright orange to dark purple or black (DFO 2016a). The eggs hatch in the late spring or early summer and larvae may spend two to eight months in the water column, depending on temperature and planktonic food supply, before settling to the seabed (DFO 2016a; FRCC 2005). Once settled on the seafloor, snow crabs go through a series of moults, with growth of approximately 20% between moults. It takes 8 to 10 years for male snow crab to grow to the legal size of 95 mm carapace width in warm areas and slightly older in cold areas (Baker et al. 2021). Females reach sexual maturity and cease moulting at approximately 40 to 75 mm carapace width and are therefore excluded from the fishery. The full natural life cycle for a male snow crab is approximately 14 to 18 years(Baker et al. 2021).

Snow crab feed on fish, clams, benthic worms, brittle stars, shrimps, and crustaceans, including smaller snow crab, and feeding activity is higher at night (DFO 2016a). Predators include various groundfish and seals (DFO 2002a).

5.3.3.2 Toad Crab

Toad crab, or spider crab, is comprised of two species; *Hyas araneus and H. coarctatus*. *H. araneus* prefers soft bottoms while *H. coarctatus* is more common on hard bottoms (Squires 1990). Toad crab have an uneven carapace surface with four pairs of round, tubular walking legs. Their carapace is approximately one and one-third times longer than wide, with a maximum carapace width of approximately 100 mm and a spread of 450 mm. Their maximum weight is approximately 0.7 kg. Like most crustaceans, they are sensitive to disturbance during moulting, which typically occurs between May and September (DFO 1996).

Toad crab is widespread on both sides of the North Atlantic, in water depths up to 1,650 m, in the Gulf of St. Lawrence, Bay of Fundy, Nova Scotia, and NL. Toad crab are very common at intermediate depths, overlapping rock crab and snow crab zones (NL Department of Fisheries and Aquaculture [NLDFA] n.d.).

Crab is harvested commercially and for food both inshore and offshore (NunatuKavut Community Council 2019) (Section 9.4.3). The NunatuKavut Community Council observed a reduction in the population of crab in some areas and noted that crab is an important prey species for seals (NunatuKavut Community Council 2019).

5.3.3.3 Porcupine Crab

Porcupine crab (*Neolithodes grimaldi*) is one of 79 members of the king crab family, but only one of the two species from this family reside in waters off Atlantic Canada. They are a deep-water crab found on the seafloor at water depths between 800 and 2,000 m (Squires 1965). Porcupine crab are often found along the continental slope on both sides of the Atlantic Ocean, ranging from North Carolina to Greenland in the Northwest Atlantic (Squires 1965). The porcupine crab is a large red crab that is covered in large, sharp spines on its legs and carapace. Males can weigh as much as 2.28 kg and have a carapace length of 180 mm; females are generally smaller but carapace lengths of up to 160 mm have been recorded. At first glance, porcupine crab appears to have only three sets of walking legs, as opposed to the usual four sets, and one set of claws; however, hidden under the carapace are the missing set of legs which are much smaller and are used for cleaning gills. The right claw is larger and is used for crushing while the left claw is smaller in size and is used for handling food. It is believed that the porcupine crab is carnivorous, feeding on snails and mussels (Squires 1965).

5.3.4 Whelk

Whelks (*Buccinum undatum*) are gastropod mollusk characterized by a spiral shell and large foot used for locomotion. The species of whelk harvested in NL waters is the waved or rough whelk. This species occurs in the Northwest Atlantic from the Arctic to New Jersey on a wide range of substrates and is very common on mud and sand (NLDFA 2006). Young whelks are common in tide pools and shallow water. Adults can inhabit depths to 200 m and commonly grow to approximately 6.4 cm in length (Gosner 1978). Whelk produce round egg masses that adhere to rocks and wash onshore during storms (Gosner 1978; Harvey-Clarke 1997).

Whelks are carnivorous, and fragments of polychaetes, bivalves and sea urchins are found in whelk stomachs, suggesting they are active predators but also feed as opportunistic scavengers. The suggestion that whelks are scavengers is based on their infrequent feeding, high mobility, and capacity to detect and locate dead animals on the seabed. Whelks are frequently observed approaching sea stars feeding on bivalves, preying on the remains left by the sea stars (Himmelman and Hamel 1993). Although they are highly mobile, their dispersal potential is quite limited compared to other commercially fished invertebrate species due to internal fertilization and the lack of planktonic larvae (Himmelman and Hamel 1993).

The NunatuKavut Community Council indicated that harvesting whelk is typically done while harvesting for scallops and mussels at a number of locations in the study area. The NunatuKavut Community Council observes that dragging for scallops has caused a decline in the whelk population (NunatuKavut Community Council 2019). The NunatuKavut Community Council whelk harvest is described in Section 9.4.3.

The commercial importance of whelk in general is discussed in Section 9.2.5.5, and the commercial and traditional importance of whelk to Nunatsiavut is discussed in Section 9.4.1.

5.3.5 Northern Shrimp

Northern or pink shrimp (*Pandalus borealis*) distributions in the Northwest Atlantic range from the Davis Strait to the Gulf of Maine. Northern shrimp occupy soft, muddy substrates up to depths of 600 m in temperatures of 1 ºC to 8 ºC. Larger individuals generally occupy deeper waters (DFO 2006a). Shrimp undergo a diel vertical migration, moving off the bottom into the water column at night to feed on small crustaceans and other planktonic organisms and then returns to the bottom during the day. Female shrimp undergo a seasonal migration to shallow water where spawning occurs (DFO 2006a). Northern shrimp are a protandric hermaphrodite, meaning that it first functions sexually as a male, undergoes a brief transitional period, and spends the rest of its life as a female (DFO 2006a). The average female lays 2,400 eggs in the summer and these remain attached to the female until the following spring, when the female migrates to shallow waters to spawn (Nicolajsen 1994 in Ollerhead et al. 2004). The hatched larvae float to the surface and feed on plankton organisms (DFO 2006a). The reproductive cycles of most northern shrimp stocks are synchronous with the local spring phytoplankton bloom (Koeller et al. 2009).

Shrimp distribution is affected by dispersal during the pelagic larval stages which, in turn, is influenced by oceanographic (e.g., currents) and biological (e.g., spawning location) factors. Le Corre et al. (2019) showed that the dominant Labrador Current supplied potential northern shrimp settlers to southern populations and that ocean circulation and current velocities during the NAO positive year resulted in different spatial settlement patterns, suggesting sensitivity to changing environmental conditions. Other major factors influencing larval supply and settlement patterns are spawning location and vertical migration behaviour (Le Corre et al. 2019). The results of this study could potentially apply to other species with similar pelagic larval phases.

Like most crustaceans, northern shrimp grow by moulting their shells. During this moulting period, the new shell is soft, causing them to be highly vulnerable to predators such as Greenland halibut, cod (DFO 2006a), Atlantic halibut, skates, wolffish and harp seals (DFO 2000). Northern shrimp are vulnerable to these predators throughout their life cycle but are particularly vulnerable during moulting.

Nunatsiavut Government reported in 2007 that Northern shrimp are fished within the areas between Makkovik and Hopedale (SEM 2008).

The NunatuKavut Community Council observed that shrimp are an important prey species for fish including cod, and for seals, in their traditional knowledge study (NunatuKavut Community Council 2019).

5.3.6 Non-commercial Invertebrate Species

The RV data (2007 to 2018) included other, non-commercial invertebrate species found in the Labrador Shelf SEA Update Area. The top 20 species by weight (excluding commercially fished species [Section 5.3.2 to 5.3.5] and corals [Section 5.3.1]) are listed in Table 5.4 and illustrated in Figures 5-6 to 5-8. Additionally, as mentioned in Section 5.3, Coté et al. (2019) observed the presence of polychaetes, *Pennatula* sp. sea pens, brittlestars (Ophiurida) and shrimp (Caridea) at depths exceeding 2,000 m.

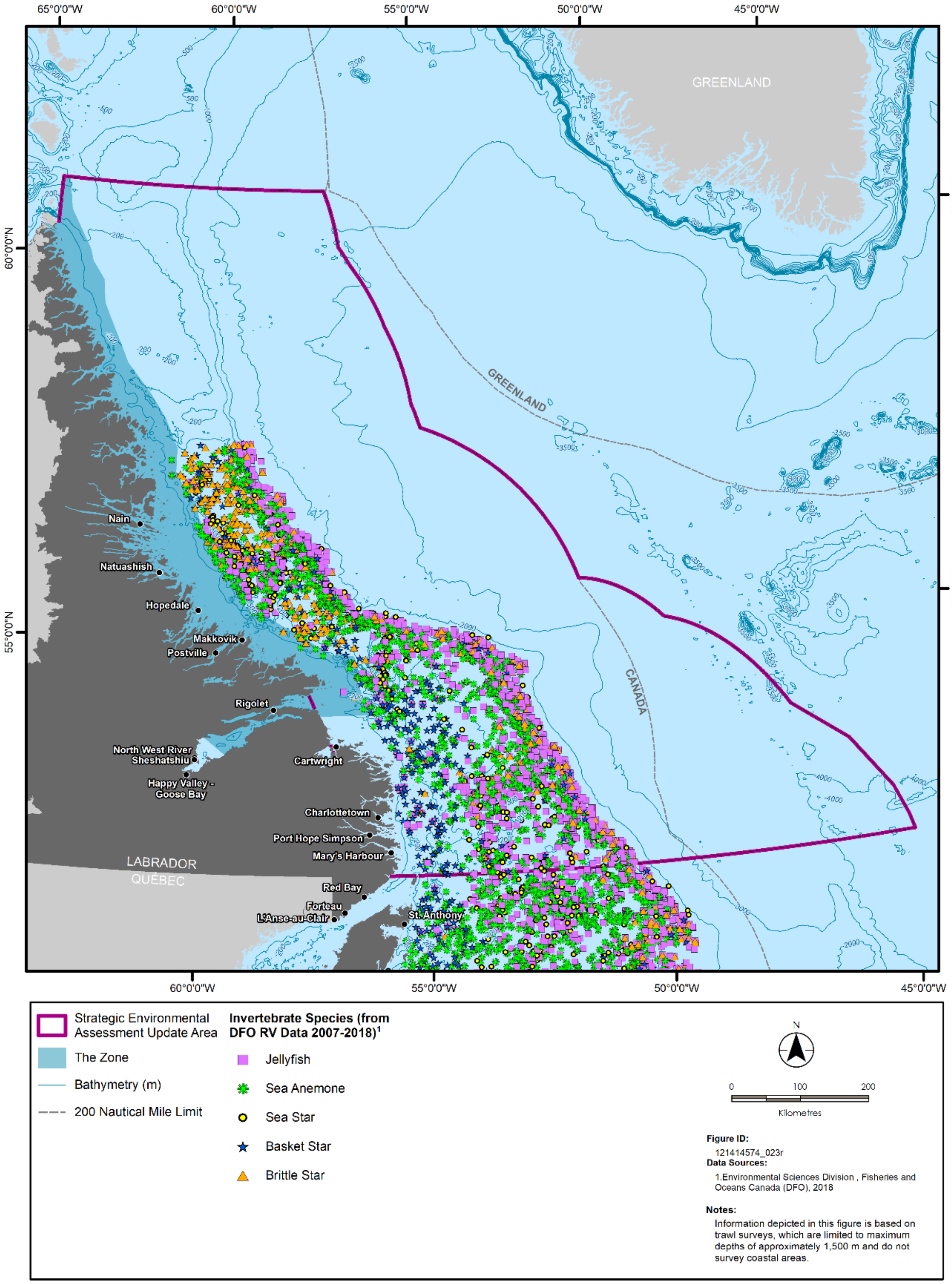

Figure ID:
121414574_023r

Data Sources:
1.Environmental Sciences Division , Fisheries and Oceans Canada (DFO), 2018

Notes:
Information depicted in this figure is based on trawl surveys, which are limited to maximum depths of approximately 1,500 m and do not survey coastal areas.

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Figure 5-6 Top Five Invertebrate Species by Weight from RV data (2007 to 2018)

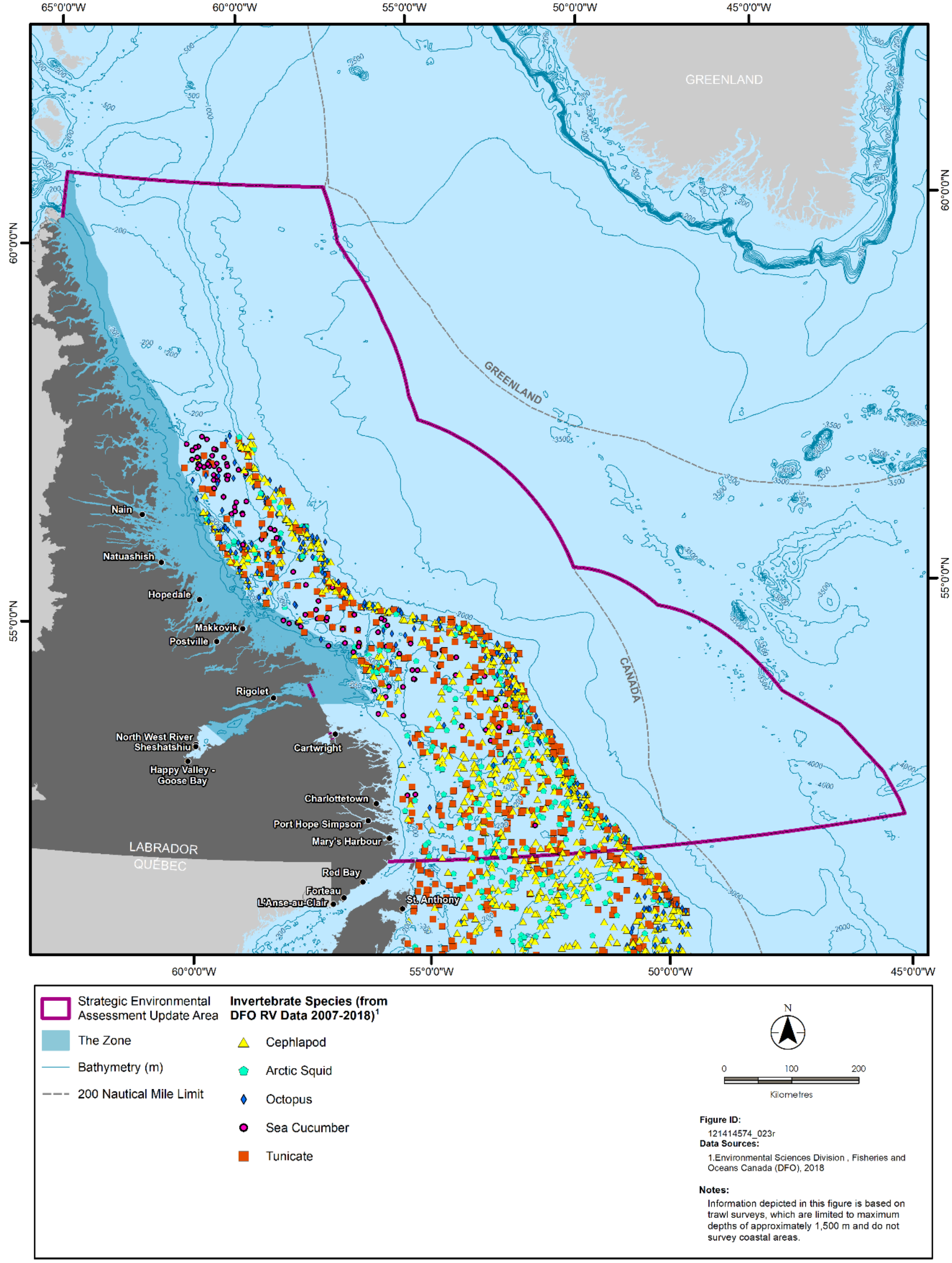

Figure ID:
121414574_023r

Data Sources:
1.Environmental Sciences Division , Fisheries and Oceans Canada (DFO), 2018

Notes:
Information depicted in this figure is based on trawl surveys, which are limited to maximum depths of approximately 1,500 m and do not survey coastal areas.

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Figure 5-7 Other Invertebrate Species from RV data (2007 to 2018) (6th to 10th by Weight as Listed in Table 5.4)

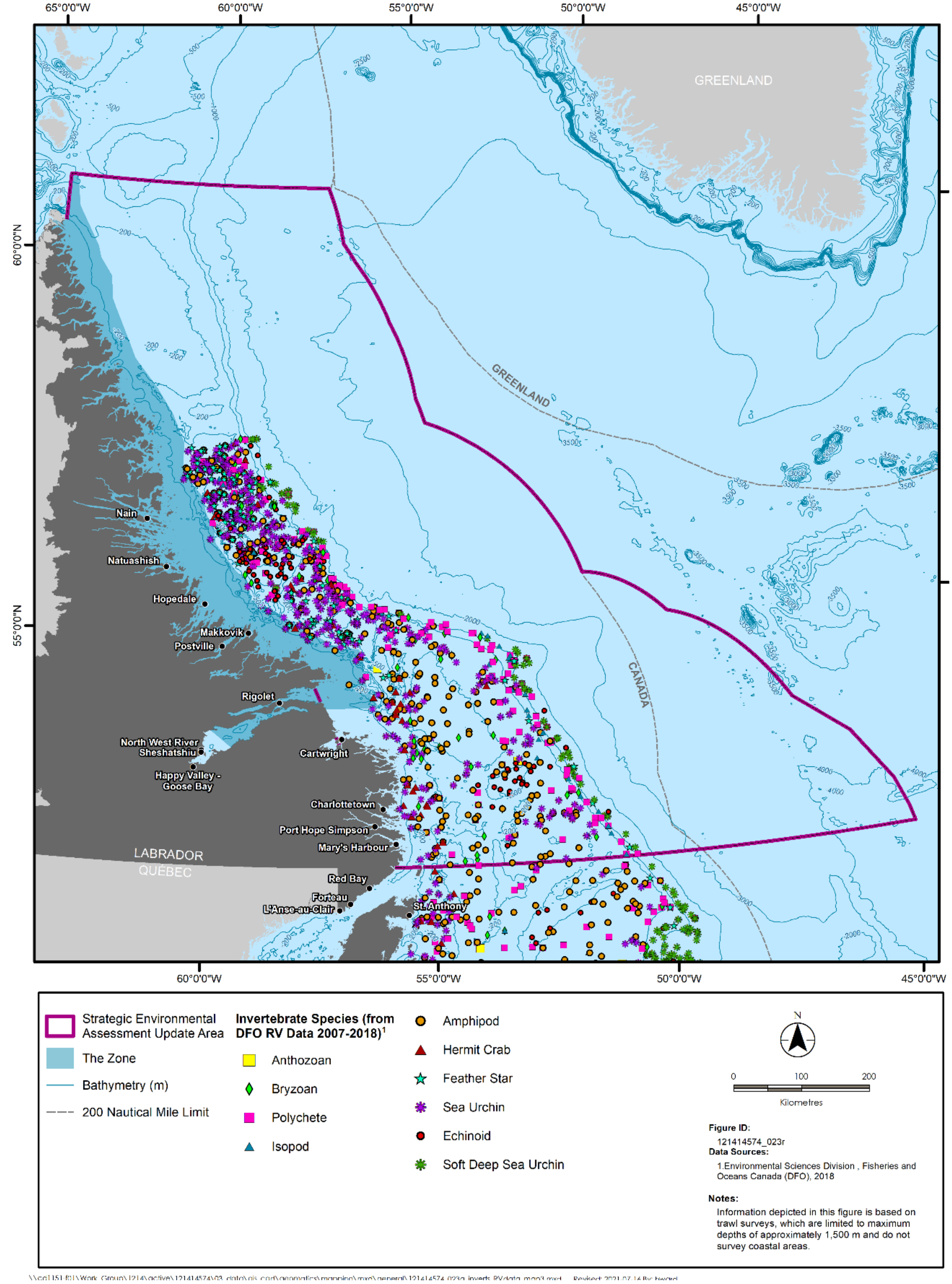

Figure ID:
121414574_023r

Data Sources:
1.Environmental Sciences Division , Fisheries and Oceans Canada (DFO), 2018

Notes:
Information depicted in this figure is based on trawl surveys, which are limited to maximum depths of approximately 1,500 m and do not survey coastal areas.

Figure 5-8 Other Invertebrate Species from RV data (2007 to 2018) (11th to 20th by Weight as Listed in Table 5.4)

Table 5.4 Top 20 Invertebrate Species by Weight from RV data (2007 to 2018)

Common Name	Scientific Name	Common Name	Scientific Name
Jellyfish [A]	Scyphozoan	Brittle star [C]	Ophiuroidea
Basket star [A]	Gorgonocephalidae	Echinoid [C]	*Brisaster Fragilis*
Sea anemone [A]	Actinaria	Arctic squid [C]	*Gonathus Fabricii*
Sea urchin [A]	Echinoidea	Soft deep sea urchin [C]	*Phormosoma Placenta*
Sea star [A]	Asteroidea	Polychaete [C]	Polychaeta
Octopus [B]	Octopoda	Bryozoan [C]	Bryozoa
Feather star [B]	Crinoidea	Isopod [C]	Isopoda
Sea cucumber [B]	Phyllophoridae	Amphipod [C]	Amphipoda
Cephalopod [B]	Cephalopoda	Hermit crab [C]	Paguridae
Tunicate [B]	Ascidiacea	Anthozoan [C]	Anthozoa

Source: DFO 2018
Notes:
A – see Figure 5.6
B – see Figure 5.7
C – see Figure 5.8

5.3.7 Data Constraints Associated with Benthic Invertebrate Communities

There are numerous data constraints associated with benthic invertebrate communities including basic biology and ecology. The ability of species to adapt to a cold and highly seasonal environment is poorly understood, along with the processes controlling species distribution, abundance, and production.

There has been little scientific investigation of the intertidal and subtidal communities along the coastline within the Labrador Shelf SEA Update Area, and there are gaps regarding scientific literature on the biology of the benthic community, as the majority of studies in the area have focused on offshore areas on the continental shelf and slope (DFO 2021a). There are incomplete inventories of benthic invertebrates on the coastlines of NL, and data constraints such as the deep-sea environments of the continental margin. In these areas, information on benthic species distribution, abundance, and diversity is lacking. Within the Labrador Shelf SEA Update Area, there is a lack of information on the potential sensitivities within the benthic community. The lack of published/publicly available data beyond that for commercially-important benthic invertebrates represents a data constraint. Spawning by some invertebrate species occurs in the Labrador Shelf SEA Update Area. However, limited research (including Le Corre et al. 2019 described in Section 5.3.5) has been conducted on the passive movements of planktonic invertebrate eggs and larvae in this area.

While there are data gaps / constraints, their relation to offshore oil and gas activities is dependent on the nature and timing of the particular activity, and the need to collect additional data will be determined at the project-specific EA stage. Project-specific EAs should confirm that data constraints are still relevant and have not been addressed, or if new data constraints have been identified.

5.4 FISH SPECIES

There are a variety of fish species that occur within the Labrador Shelf SEA Update Area. The benthic species which inhabit the Labrador slope and abyssal habitats in the vicinity of the Labrador Shelf SEA Update Area are not yet well studied. These species typically have life history traits of late maturation, long life-spans, low reproductive rates, and slow growth which leave them sensitive to habitat and population disturbances (Devine et al. 2006, Baker et al. 2012). Emerging continental slope fisheries for species such as grenadiers are resulting in additional pressures for other continental slope species found within the Labrador Shelf SEA Update Area, such as hake, roughhead grenadier, roundnose grenadier, skate species and synaphobranchid eels (Devine et al. 2006).

Pelagic species are generally either resident pelagic species or migratory pelagic species. Resident species generally complete their life histories within the cold northern waters and, in many cases, are well-represented in the DFO RV survey data. In contrast, migratory pelagics in the Labrador Shelf SEA Update Area are typically species that seasonally migrate from temperate areas into northern waters to feed. During their northern migrations, these migratory species (with the exception of capelin and salmon) typically remain in the warmer waters of the Gulf Stream (Walli et al. 2009; Vandeperre et al. 2014), and therefore would be expected to be at relatively low abundance in the area, which is predominantly exposed to the cooler Labrador Current.

The species list in Table 5.5 was developed using the results from the DFO RV surveys collected between 2007 and 2018, to give an indication of species that may be present within the surveyed parts of the Labrador Shelf SEA Update Area. Figure 9-54 (Section 9.5) illustrates the research vessel transects / surveyed parts of the Labrador Shelf SEA Update Area from 2007 to 2018. Trawls are limited to maximum depths of approximately 1,500 m and do not survey coastal areas. The RV survey includes sampling of fish and invertebrates using a Campelen 1800 shrimp trawl. These surveys are the primary data source for monitoring trends in demersal species distribution and abundance of finfish in the region.

Table 5.5 Key Fish Species from the Canadian RV Survey Sets Collected within the Labrador Shelf SEA Update Area 2007 to 2018

Common Name	Scientific Name	Potential for Occurrence in the Labrador Shelf SEA Update Area[1]	Timing of Presence
Demersal			
American plaice[2]	*Hippoglossoides platessoides*	High	Year-Round
Atlantic cod[2]	*Gadus morhua*	High	Year-Round
Atlantic halibut	*Hippoglossus hippoglossus*	Low	Year-Round
Arctic cod	*Boreogadus saida*	Low	Year-Round
Arctic eelpout	*Lycodes reticulatus*	Low	Year-Round
Atlantic wolffish[2]	*Anarhichus lupus*	Low	Year-Round
Black dogfish	*Centroscyllium fabricii*	Low	Year-Round
Blue hake	*Antimora rostrata*	Low	Year-Round

Table 5.5 Key Fish Species from the Canadian RV Survey Sets Collected within the Labrador Shelf SEA Update Area 2007 to 2018

Common Name	Scientific Name	Potential for Occurrence in the Labrador Shelf SEA Update Area[1]	Timing of Presence
Deepwater redfish[2]	*Sebastes mentella*	High	Year-Round
Greenland halibut	*Reinhardtius hippoglossoides*	High	Year-Round
Haddock	*Melanogrammus aeglefinus*	Low	Year-Round
Kaup's arrowtooth eel	*Synaphobranchus kaupii*	Low	Year-Round
Longfin hake	*Urophycis chesteri*	Low	Year-Round
Longhorn sculpin	*Myoxocephalus octodecemspinosus*	Low	Year-Round
Marlin spike	*Nezumia bairdi*	Low	Year-Round
Monkfish	*Lophius americanus*	Low	Year-Round
Northern wolffish[2]	*Anarhichas denticulatus*	Moderate	Year-Round
Roughhead grenadier	*Macrourus berglax*	Moderate	Year-Round
Roundnose grenadier[2]	*Coryphaenoides rupestris*	Low	Year-Round
Spinytail skate	*Raja spinicauda*	Low	Year-Round
Spiny dogfish[2]	*Squalus acanthias*	Low	Year-Round
Sand lance	*Ammondytidae*	High	Year-Round
Sea raven	Hemitriperus americanus	Low	Year-Round
Shorthorn sculpin	*Myoxocephalus scorpius*	Low	Year-Round
Smooth Skate[2]	*Malacoraja senta*	Low	Year-Round
Spotted wolffish[2]	*Anarhichas minor*	Moderate	Year-Round
Thorny skate[2]	*Amblyraja radiata*	High	Year-Round
White hake[2]	*Urophycis tenius*	Moderate	Year-Round
Witch flounder	*Glyptochepalus cynoglossus*	Moderate	Year-Round
Yellowtail flounder	*Limanda ferruginea*	Low	Year-Round
Pelagic			
Atlantic herring	*Clupea harengus harengus*	High	Year-Round
Atlantic salmon[2]	*Salmo salar*	Migratory/Transient	
Atlantic bluefin tuna[2]	*Thunnus thynnus*	Low	July to September
Arctic char	*Salvelinus alpinus*	Moderate	June to September
Basking shark[2]	*Cetorhinus maximus*	Low	Year-Round

Table 5.5 Key Fish Species from the Canadian RV Survey Sets Collected within the Labrador Shelf SEA Update Area 2007 to 2018

Common Name	Scientific Name	Potential for Occurrence in the Labrador Shelf SEA Update Area[1]	Timing of Presence
Blue shark	*Prionace glauce*	Low	June to October
Capelin	*Mallotus villosus*	High	Year-Round
Greenland shark	*Somniosus microcephalus*	Moderate	Year-Round
Porbeagle shark[2]	*Lamna nasus*	Low	Year-Round

Source: Reid et al. 1999; Block et al. 2005; COSEWIC 2008; COSEWIC 2009a, 2009b; COSEWIC 2010a, 2010b, 2010c, 2010d; COSEWIC 2011; COSEWIC 2012a, 2012b, 2012c, 2012e, 2012f; COSEWIC 2013; COSEWIC 2014; Moore et al. 2014; DFO 2018a, 2018b.

Note:

[1] This qualitative characterization is based on expert opinion, and an analysis of understood habitat preferences across life-history stages, available distribution mapping, and catch data for each species within the Labrador Shelf SEA Update Area.

[2] Includes species at risk (SAR) and species of conservation concern (SOCC)

Wells et al. (2021) analyzed and mapped the DFO multispecies RV survey datasets from two time periods: 1981-1995 and 1995-2017. Eight fish functional groups (a collection of species of similar size, diet and role in the ecosystem) were identified for the analysis: small benthivores, medium benthivores, large benthivores, piscivores, plank-piscivores, planktivores, shrimp, and forage. Table 5.6 provides a list of example species within each functional group. Relative densities for each functional group were described based on dominant and non-dominant species.

Table 5.6 Example of Functional Group Species: Average Relative Density Analysis

Functional Group	Common Name
Small benthivores	Mailed Sculpin
	Common Grenadier
	Daubed Shanny
	Northern Alligatorfish
	Seasnails
	Lumpsuckers
	Threebeard Rockling
	Hookear Sculpin
	Spatulate Sculpin
	Fourline Snakeblenny
	Common Alligatorfish
	Goitre Blacksmelt
	Fourbeard Rockling

Table 5.6 Example of Functional Group Species: Average Relative Density Analysis

Functional Group	**Common Name**
Medium benthivores	Yellowtail Flounder
	Witch Flounder
	Blue Hake
	Common Lumpfish
	Longhorn Sculpin
	Roundnose Grenadier
	Smooth Skate
Large benthivores	American Plaice
	Thorny Skate
	Roughhead Grenadier
	Haddock
	Atlantic Wolffish
	Spotted Wolffish
	Northern Wolffish
	Winter Skate
Piscivores	Atlantic Cod
	Greenland Halibut
	Greenland Shark
	White Hake
Plank-piscivores	Redfish
	Arctic Cod
Planktivores	Sand Lance
	Capelin
Shrimps	Northern Shrimp
	Striped Shrimp
Source: Wells et al. 2021	

Throughout the entire survey area, which includes the Island of Newfoundland but does not include the northern portion of the Labrador Shelf SEA Update Area (i.e., NAFO Division 2G), Arctic cod (which is in the forage and plank-piscivores functional group) has the highest densities in the northern portion of the survey area (i.e., the middle section of the Labrador Shelf SEA Update Area – NAFO Division 2H) compared to southern portions of the survey area around the Island of Newfoundland (Wells et al. 2021).

The southern portion of the Labrador Shelf SEA Update Area (i.e., NAFO Divisions 2J3K) has high densities of shrimp, piscivores, planktivores, and small benthivores, while in the middle of the Labrador Shelf SEA Update Area (i.e., NAFO Division 2H) small benthivores, piscivores, plank-piscivores and shrimp are dominant. Deeper waters along the continental shelf edge and slope are dominated by small, medium, and large benthivores, piscivores, and plank-piscivores. For the 1995-2017 dataset, there appeared to be no difference between the relative density of non-dominant large benthivores and all large benthivores throughout the Labrador Shelf SEA Update Area (Wells et al. 2021).

Some functional groups show restricted ranges (e.g., medium benthivores, plank-piscivores, shrimp), while other groups seem to be associated with specific habitat features. For example, banks and shelf edges host small benthivores, while deeper channels and troughs show higher densities of piscivores, and planktivores show highest densities in relatively shallower depths (Wells et al. 2021).

Focal species described in the following sections are of commercial importance, are SAR or SOCC species and/or are considered key species in ecosystem functioning. Spatial IK data from the NunatuKavut Community Council and Nunatsiavut Government were used to create fish harvesting maps and are provided in Chapter 9. These maps provide a summary of distribution for many of the fish species discussed below. For fish in general, the Nunatsiavut Government have noted larger and more plentiful fish since DFO made the mesh size for nets bigger (net type not specified) about 10 to 15 years ago (Nunatsiavut Government 2018). Note that this section includes discussion of populations that may not directly overlap with the Labrador Shelf SEA Update Area, but have been considered for one or more of the following reasons:

- They may be neighbouring populations that are known to intermix
- Edges of the population overlap with the Labrador Shelf SEA Update Area
- The populations migrate through the area of interest
- They are expected to expand into the Labrador Shelf SEA Update Area with changing environmental conditions

As indicated above, some species, such as Atlantic halibut, may be found in the Labrador Shelf SEA Update Area but are at the northern limit of their range and as such may represent stray fish, or are limited to the Strait of Belle Isle. Climate change may result in their expansion into the southern section of the Labrador Shelf SEA Update Area during warmer trends, and their retreat during cooling trends. Thus, they do not represent a resident population in the area. The following species descriptions provide a summary of the finfish species likely to occur in the Labrador Shelf SEA Update Area. Species that are listed under Schedule 1 of the *Species at Risk Act* (SARA) or listed as Species of Conservation Concern (SOCC) by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) are described in Section 5.6.

5.4.1 Demersal Species

5.4.1.1 Yellowtail Flounder

Yellowtail flounder (*Limanda ferruginea*) are distributed from Labrador to Chesapeake Bay and are most frequently found on sandy substrates at water depths less than 100 m (Walsh et al. 2000). Yellowtail flounder declined from the late 1980s to early 1990s, but since that time has shown stable and increasing population trends (Walsh et al. 2000; Maddock-Parsons 2009). Yellowtail flounder are most densely distributed in the warmer waters of the Tail of the Grand Banks and along the Laurentian Channel slope (Walsh et al. 2001), although historically their distribution also included the northern Grand Banks. This species is relatively sedentary and does not undergo migrations. Spawning occurs primarily on the central and southern areas of the Grand Banks, although it can occur in the northern area, and spawning is thought to occur between April and June (Ollerhead et al. 2004, Maddock-Parsons 2009). Yellowtail flounder eggs are deposited on the bottom and float to near the surface once fertilized (Scott and Scott

1988). Newly settled juveniles select mud- and sand-dominated substrate. The yellowtail flounder diet in the North Atlantic is composed mainly of polychaetes and amphipods (Walsh 1992, Methven 1999).

5.4.1.2 Atlantic Halibut

Atlantic halibut (*Hippoglossus hippoglossus*) are distributed from north of Labrador to Virginia and are typically found along the slopes of the continental shelf. The species seasonally migrates between deep channels between banks in winter and shallow waters of the banks in summer. They prefer temperatures from 3°C to 5°C, and larger individuals move to deeper water in winter (DFO 2015a). They prefer sand, gravel, or clay substrates. The species can grow to sizes of over 2.5 m in length and reach weights of over 300 kg. The Atlantic halibut is the largest and most commercially-valuable groundfish in the Atlantic Ocean (DFO 2009). This species preys on benthic organisms and shifts from invertebrates to fish as the halibut grows larger in size. Small halibut (<30 cm) feed on hermit crabs, shrimp, crabs, and mysids, while larger fish (>70 cm) consume various species of flatfish, redfish, and pollock (DFO 2013b).

Females mature at 10 to 14 years with spawning occurring from December to June in deep water depths ranging from 300 to 700 m. Large females may lay up to several million eggs. The eggs are 3 to 4 mm in diameter and float freely in the ocean until they hatch 16 days later. Larvae are approximately 7 mm in length and survive on a yolk sac for four to five weeks until they begin feeding on plankton. Atlantic halibut may live up to 50 years, with a typical lifespan of 25 to 30 years (DFO 2009).

5.4.1.3 Greenland Halibut

Greenland halibut (*Reinhardtius hippoglossoides*), also commonly known as turbot, is a deep-water flatfish that, in the Northwest Atlantic, has a range from Greenland to the Scotian Shelf. Greenland halibut prefer temperatures of 0ºC to 4.5ºC (Food and Aquaculture Organization of the United Nations [FAO] 2007a; Healey et al. 2010). Their depth range is from 90 to 2,000 m, though most are taken from depths greater than 450 m. Larger individuals typically occur in deeper waters. Unlike most flatfishes, Greenland halibut spend much of their time off the bottom, behaving as a pelagic fish (Scott and Scott 1988).

The spawning grounds of Greenland halibut (Boje 2002) are believed to be located southwest of Iceland (Sigurdsson 1979) and cover an extended area from Davis Strait, south of 67ºN (Jensen 1935; Smidt 1969) to the south of the Flemish Pass off Newfoundland (Junquera and Zamarro 1994) between depths of 800-2,000 m. Studies on the maturation and spawning of Greenland halibut have revealed a great deal of variability with the proportion of adult fish at size and age that maturation and spawning occurs, exhibiting a high degree of geographic and temporal variation (Morgan and Bowering 1997). Tagging studies indicate that a substantial degree of genetic mixing in Greenland halibut may be a result of long-distance movement of reproductive adults among populations or extensive larval drift (Lear 1984, in Vis et al. 1997). It is known that Greenland halibut migrate between eastern Newfoundland waters and the Davis Strait area (Bowering 1984, in Vis et al. 1997).

Eggs tend to drift northward in the West Greenland Current; however, those that get engulfed by the Baffin Island / Labrador Current drift southwards along the coast of Baffin Island, Labrador, and northeastern Newfoundland, colonizing continental banks and slopes along the way (Bowering 1982). Eggs are benthic, but upon hatching, the young move up into the water column and remain at depths near 30 m until they reach approximately 70 mm in length. As they grow, young Greenland halibut are thought to move to deeper water and migrate north to the spawning area, suggesting a continuous stock throughout the range (Bowering 1982). Greenland halibut in the Northwest Atlantic are thought to be a relatively homogenous genetic stock; however, there is some evidence that genetic mixing does occur with stocks in the Gulf of St. Lawrence (Bowering 1982). As juveniles (<20 cm), Greenland halibut mainly feed on small crustaceans and squid, and as they grow (20 to 69 cm) they mainly feed on capelin. As large adults (>69 cm), Greenland halibut feed mainly on demersal fish (Bowering and Lilly 1992).

Nunatsiavut Government reported in 2007 that Greenland halibut are fished within the Labrador Shelf SEA Update Area, and it was noted as an important commercial fishery species. Greenland halibut is harvested at Hawke Channel (SEM 2008).

The NunatuKavut Community Council observed an increase in halibut (species not specified) in recent years (NunatuKavut Community Council 2019).

5.4.1.4 Sand Lance

Sand lance (*Ammodytes spp.*) is a small fish found on sandy seabeds and is known to be an important forage species for other species of groundfish and pelagic fish and marine mammals. For example, sand lance have been identified as an important part of the diet of Arctic char (Dempson et al. 2002). Sand lance live partially buried in the sand and occasionally rise into the water column to feed. Sand lance are found in the North Atlantic from Greenland to the Gulf of St. Lawrence and are typically found at depths of less than 91 m. The species of sand lance present in the Labrador Shelf SEA Update Area is the northern sand lance; however, there is speculation about whether there are one or two species of sand lance in the area (DFO 2004a).

There is no information available regarding the time of spawning in the Labrador Shelf SEA Update Area, but in general, sand lance spawn during winter months in shallow waters (SEM 2008). Sand lance are not commercially fished but are an important part of the marine food web as they serve as prey species for higher trophic levels.

5.4.1.5 Hake (Longfin and Blue)

Longfin Hake

Longfin hake (*Phycis chesteri*) are found in the Northwest Atlantic along the coast of North America from North Carolina to Newfoundland. Longfin hake occurs at depths of 150 to 1,250 m on the continental slope (Wenner 1983). Throughout its latitudinal distribution from Cape Hatteras to the slope off Atlantic Canada, this species shows a size-depth relationship, with small fish occurring on the upper continental slope (Wenner 1983). Longfin hake feed on both benthic and pelagic species, including amphipods, euphausiids, crustaceans and fishes (Wenner 1983).

This species has high fecundity and spawns from late September to April (Wenner 1983).

Blue Hake

Blue hake occurs in oceans worldwide, and in the Northwest Atlantic occurs off the coast of Atlantic Canada north to Baffin Island (Fossen and Bergstad 2006). Based on trawl and longline experiments, blue hake were found at depths of 669 to 3,059 m (Fossen and Bergstad 2006). Blue hake feeds on free-living macrofauna.

Little is known about the life cycle of these fish, but it is thought that they might migrate into deeper waters to spawn. Captured mature individuals were found with ripe gonads in The Labrador Sea Frontier Area at depths between 800 and 2500 m (Coté et al. 2019). Females grow up to 75 cm, while males only grow to about half that length (Fossen and Bergstad 2006). It is believed that this species lives a maximum of 25 years. Females of this species grow larger than males and seem to live longer as well (Fossen and Bergstad 2006).

5.4.1.6 Witch Flounder

Witch flounder (*Glyptocephalus cynoglossus*) are a deep-water flatfish, also known as grey sole, that occur from Greenland south to Cape Hatteras. Witch flounder are plentiful in the Hawke Channel (DFO 2006b). Witch flounder prefer living in gullies where the bottom is composed of clay, muddy sand, or pure mud rather than the hard tops of the banks and inshore ground. In summer, they usually move up onto the soft mud and in winter move down into deeper gullies. Witch flounder are usually found offshore, in moderately deep water, mainly at depths of 45 to 275 m, in water temperatures of 2°C to 6°C, and they do not migrate (Scott and Scott 1988; Cargnelli et al. 1999). Witch flounder are a slow-growing, long-lived species that have been aged over 20 years old (Maddock-Parsons 2005a, 2005b).

The prey of witch flounder are marine worms, as well as small crustaceans and shellfish (DFO 2006b). Small pieces of clam shells are found in witch flounder stomachs, and occasionally, small fish are found in large witch flounder (DFO 2006b).

Witch flounder spawning occurs throughout the Northwest Atlantic from late spring to late summer, depending on the geographical area of the spawning grounds (DFO 2006b). Spawning usually takes place in deep waters where temperature conditions are more stable than on the surrounding banks. The spawning period is less extensive in northern areas than in southern areas. The pelagic or mid-water stage in the life history of witch flounder is longer than other of the pleuronectine flatfishes and may continue anywhere from four months to one year (DFO 2006b). During this time, eggs and larvae from spawning grounds in the northern areas drift southward in the Labrador Current over great distances to settle in water where temperature is suitable for survival. Eggs and larvae on the southern banks probably do not drift far because of the slow currents which move in a more circular fashion. On occasion, however, eggs have been found floating over oceanic depths (DFO 2006b).

Data collected from witch flounder research vessel surveys conducted in 2016 and 2017 were used to determine abundance and biomass indices, which indicated that both abundance and biomass reached their highest levels since 1990, but were still below levels recorded in the mid-1980s (DFO 2019a, 2019b). However, based on the abundance index, recruitment of fish < 23 cm has improved since 2013. It was also observed that the distribution of the stock has expanded, returning to deep channels occupied in the mid-1980s and following a contraction of the stock to shelf slope areas through the 1990s. The majority of the witch flounder stock is located along the Newfoundland shelf edge in Division 3K and based on abundance and biomass indices from the RV surveys (DFO 2019a, 2019b). Witch Flounder were noted to consistently occupy warmer waters (i.e., within 3.2 to 3.6°C across Divisions 2J, 3K and 3L) than the median available water temperatures (-0.3 to 2.7°C) (DFO 2019b).

5.4.1.7 Black Dogfish

Black dogfish (*Centroscyllum fabricii*) are distributed along the slopes of the Atlantic Canadian Basin, ranging from Greenland south to Cape Hatteras (and possibly Florida), and into the Gulf of Mexico (Kulka 2006). Black dogfish are a bathydemersal species, resident in waters as shallow as 300 m but are generally found in water deeper than 500 m. Similar to other squaliform sharks, they are characterized by their slow growth, longevity, and late maturation (Hedeholm et al. 2019). Males and females become sexually mature at 15 and 27 years of age, respectively (Qvist 2017). Female black dogfish have ovoviviparous reproduction, with embryos receiving nutrition from a yolk sack within the uterus and can give birth to 14-31 embryos (Qvist 2017).

Relative abundance estimates are problematic as large portions of the black dogfish population occupy depths that exceed the depth range of surveys (pre-1995) (Kulka 2006). However, bottom trawl surveys in the 2000s offer insight on abundance in NAFO Division 3L (see Román-Marcote et al. 2020). From 2015 to 2019, the biomass of black dogfish declined from approximately 7,000 tonnes to 2,000 tonnes in NAFO Division 3L (Román-Marcote et al. 2020). Black dogfish exhibit a highly-structured distribution with a high degree of separation by life stage. Large pregnant females migrate to shallow waters in the Laurentian Channel, where pupping occurs. Young black dogfish migrate into deeper waters of the Laurentian Channel, and as they mature, they migrate out of the Laurentian Channel into the slope waters. Black dogfish young may migrate considerable distances to the Labrador Shelf. As they continue to grow, they continue to migrate into deeper waters.

5.4.1.8 Haddock

Haddock (*Melanogrammus aeglefinus*) are a member of the cod family and are found in both the Northeast and Northwest Atlantic Ocean. In the Northwest Atlantic, haddock are found from North Carolina to Greenland.

Haddock are generally associated with substrates consisting of gravel, pebbles, sand and shell beds. Haddock are most commonly found at water depths of 50 to 250 m (DFO 2013c). Haddock feed on molluscs, polychaetes, crustaceans, echinoderms and fish eggs, and adults sometimes also prey upon small fish including herring, skates, spiny dogfish and groundfish, including other haddock (National Ocean and Atmospheric Association [NOAA] 2013a).

Haddock reach maturity at one to four years of age and generally live from three to seven years. The spawning period for haddock is from January to July over rock, sand, gravel and mud bottoms. Haddock produce on average 850,000 eggs, with larger fish producing up to 3 million eggs (NOAA 2013a). Eggs are pelagic, as are larvae, until they reach 25 mm in length and then migrate to deeper waters.

5.4.1.9 Rock Cod

Rock cod (*Gadus ogac*), also known as Greenland cod, is an Arctic to subarctic species whose distribution includes the Labrador Shelf SEA Update Area. Rock cod are found inshore at water depths ranging from 0 to 200 m depth but are rarely found in deeper water or offshore (Nielsen and Andersen 2001; FAO 2007b; DFO 2021a). Rock cod are tolerant of low salinities; however, there is no evidence that they enter freshwater environments (FAO 2007b).

Rock cod are relatively short lived, seldom living beyond nine years. Rock cod aged five to six years attain lengths of approximately 50 cm and rarely exceed 60 cm total length (FAO 2007b). Rock cod mature at approximately three to four years of age before spawning in shallow waters from February to May. After fertilization, eggs sink to the seabed.

Rock cod spawn their demersal eggs in close proximity to nursery areas, resulting in the larvae remaining in the area they were spawned (Laurel et al. 2003a). As juveniles, rock cod associate with complex habitats and in particular eelgrass, for protection from predators (Laurel et al. 2003b). The structurally-complex habitats impair the visual and swimming capabilities of predators, which in turn can reduce the effectiveness of encountering, attacking, and capturing prey (Laurel et al. 2003b). High densities of rock cod have been found associated with eelgrass, suggesting it was the preferred nursery habitat (Laurel et al. 2004). Eelgrass often supports higher densities of food, namely in the form of pelagic and epiphytic zooplankton. Macrophytes also reduce the risk of predation for young fish from larger fish (Laurel et al. 2003b, 2004).

Rock cod are omnivorous opportunists (Nielsen and Andersen 2001), very similar to Atlantic cod. An adult diet is primarily comprised of capelin as well as other demersal species (Nielsen and Andersen 2001). Crustaceans, polychaetes, molluscs and echinoderms are important prey for juvenile and small rock cod and become less important as they grow larger (Nielsen and Andersen 2001).

Nunatsiavut Government, in 2007, reported cod fishing, but did not indicate the species, around the Horse Rocks and Aillik Banks and a former fishery at George’s Island, little used now since the cod left. Nunatsiavut Government observed that the low numbers of cod are due to commercial fishing boats (SEM 2008). Nunatsiavut Government observed a reduction in rock cod abundance in recent years; in particular, tomcod have reduced abundances in the past three years in areas surrounding Snook’s Cove and in ponds near Rigolet. Additionally, tomcod near English River and Postville have reduced in size (Nunatsiavut Government 2018). The size of rock cod depends on the abundance of bait in the area and some locations have been reported to have no food/bait in the stomachs of rock cod (Nunatsiavut Government 2018).

The NunatuKavut Community Council indicated that rock cod are an important food and commercial species caught in winter by ice fishing and in open water by trout net and angling. Rock cod were historically an abundant and commercially important species and were harvested through the ice by jigger (NunatuKavut Community Council 2019). The NunatuKavut Community Council rock cod fishery is described in Section 9.4.3.

5.4.1.10 Roughhead Grenadier

The roughhead grenadier (*Macrourus berglax*) is a benthopelagic species that is closely associated with the seafloor. They are commonly found in water depths of 400 to 1,200 m on or near the continental slope of the NL shelves, the northeastern slope of the Grand Banks and off the Flemish Cap; however, they have been observed from Davis Strait south to Georges Bank (COSEWIC 2018). The biomass of roughhead grenadier is estimated to be 2.1 metric tonnes in depths greater than 500m in NAFO divisions 2G and 2H (Coté et al. 2019). In the waters off Newfoundland, densities tend to be highest at depths of 500 to 1,500 m and in water temperatures between 2.0-5.4 ºC (COSEWIC 2018). The range of depths it has been recorded in suggests that it prefers full salinity (i.e., 34 to 35 ppt), while it may tolerate 32-35 ppt (Simpson et al. 2017). This species is an opportunistic predator feeding on invertebrates, small fish, and squid (COSEWIC 2018). Román et al. (2004 in Simpson et al. 2017) conducted studies on the Flemish Cap and reported that the most important prey items included *Pandalus borealis*, scyphozoans, and *Lampadena speculigera*. On the Grand Banks, González et al. (2006 in Simpson et al. 2017) reported that the main prey items consisted of scyphozoans, polychaetes, and other fish species.

Roughhead grenadier is a slow-growing and late-maturing fish species with a long life cycle and low population turnover rate (COSEWIC 2018). Females mature at approximately 13 to 15 years of age, and generation time is calculated to be 19 years (COSEWIC 2018). The maturation time corresponds with total length of approximately 67 cm (Simpson et al. 2017). Spawning may occur within the southern Grand Banks during the winter and early spring, although it is possible that the species spawns year-round. Females lay over 25,000 pelagic eggs over a lengthy spawning period (COSEWIC 2007).

Roughhead grenadier is listed as Not at Risk due to an increasing trend demonstrated by the Labrador Shelf – northern Grand Bank survey, covering water depths to 1500 m (COSEWIC 2018). Bycatch of roughhead grenadier in the Greenland Halibut fishery remains a threat but is not unlikely to cause major declines in the population (COSEWIC 2018).

5.4.1.11 Abyssal Grenadier

Abyssal grenadier (*Coryphaenoides armatus*) are a bathypelagic (i.e., found along the deep-slope / upper continental rise) species common in most oceans at depths between 282 and 5,280 m. Abyssal grenadier have a low metabolic rate due to living in a food-limited environment, and play an important role in energy transfer in the deep-sea food chain (Haedrich and Henderson 1974; Collins et al. 1998; Drazen and Sutton 2017). Their diet shifts as they age, with younger individuals feeding on benthic invertebrates (e.g., crustaceans, sea cucumbers) and adults consuming sea urchins, pelagic and benthopelagic fish and cephalopods. Abyssal grenadiers mature late and are slow-growing compared with most fish species and reproduce once during their life (MarineBio 2021).

5.4.1.12 Glacier Lanternfish

Benthosema glaciale, commonly known as glacier lanternfish, are a small meso-pelagic species distributed through the eastern and western North Atlantic, as well as in the Mediterranean Sea. They are one of the most abundant fish species in the Labrador Shelf SEA Update Area and are the most dominant planktivore in the region (Coté et al. 2019; DFO 2021c). Lanternfish-dominated fish communities in the

Labrador Shelf SEA Update Area extend from the shelf break to coastal fiords (Pepin 2013; Coté et al. 2019).

Glacial lanternfish migrate diurnally moving to depths of more than 457 m and greater, while during the night they tend to move to shallower depths to feed and are most commonly found between 46 and 91 m (Scott and Scott 1988). Their diet is dominated by calanoid copepods and euphausiids (Scott and Scott 1988), and they play an important role in energy transfer from secondary producers (zooplankton such as copepods) to higher levels of the Labrador Sea food chain (Pepin 2013).

5.4.2 Pelagic Species

5.4.2.1 Arctic Cod

Arctic cod (*Boreogadus saida*) are circumpolar in distribution, and in Canadian waters are found in the Beaufort Sea, the Arctic Archipelago, Hudson Bay, Baffin Bay, along the Labrador coast, the eastern Newfoundland coast, and the northern and eastern areas of the Grand Banks. Temperatures of 0°C to 4°C are believed to be preferred by this species, but they are also usually found in water colder than 0ºC and frequently near drifting ice (DFO 1990). Off northern Labrador, the common length range of Arctic cod is 25 to 30 cm with diminishing sizes in southern Labrador (10 to 25 cm) and off eastern Newfoundland (10 to 18 cm). Arctic cod are found close to shore among the ice floes and also offshore in depths greater than 900 m (DFO 1990).

Both male and female Arctic cod are mature when they about 20 cm long and three years of age. In northern Canadian waters, spawning is thought to occur in late autumn and winter. Fully mature, female Arctic cod produce eggs ranging from 1.5 to 1.9 mm in diameter, and release 9,000 to 21,000 eggs (DFO 1990). Spawning occurs under the Arctic ice cover, and spawning is external.

Arctic cod are the main consumers of plankton in the Arctic seas (DFO 1990). Small Arctic cod, 4 to 6 cm long, feed mainly on the eggs and larvae of copepods and adult amphipods. Intermediate sized fish (8 to 12 cm) feed on copepods, amphipods, and euphausiids. Arctic cod more than 12 cm in length feed on copepods, amphipods, and arrow worms. Large Arctic cod feed on planktonic organisms and are cannibalistic, feeding on smaller Arctic cod (DFO 1990). The abundance of Arctic cod in the Canadian Arctic is unknown.

5.4.2.2 Atlantic Herring

Atlantic herring (*Clupea harengus*) are a pelagic, schooling fish that usually occur in shallow inshore waters. In the northwest Atlantic, they are found from the continental shelf and coastal waters of Labrador to Cape Hatteras (DFO 2015b). Data regarding distribution of Atlantic herring in the Labrador Shelf SEA Update Area are limited. However, landings data between 2011-2019, primarily focused around the Island of Newfoundland, shows presence along the southern coast of Labrador (DFO 2018b). Herring also occur offshore from the surface down to depths of 200 m. There are a number of separate herring populations in the Northwest Atlantic and each has preferred spawning, feeding, and wintering grounds. The species has a life expectancy of 15 years and matures at four years of age. Atlantic herring primarily feed on zooplankton, krill, and fish larvae (NOAA 2013b).

The time and location of spawning depends on the herring stock. Most stocks spawn in spring of fall (Scott and Scott 1988). Herring are demersal spawners, depositing their eggs on stable substrates in high energy environments with strong tidal currents (Iles and Sinclair 1982 in Stevenson and Scott 2005). Spawning can occur on offshore banks at depths of 40 to 80 m; however, most herring stocks spawn in shallow coastal waters at depths of less than 20 m. In Newfoundland waters, it appears that herring spawn in coastal waters only. For coastal spawning stocks, spring spawning usually occurs in shallower water than fall spawning (LGL Limited 2005). Tibbo (1956) found that the main spawning locations in Newfoundland waters are found at the heads of bays and deep-water inlets. Herring larvae are pelagic, and the larval stage of fall-spawned herring is much longer than spring-spawned herring, lasting through the winter months (Scott and Scott 1988). The larvae of some stocks have been shown to stay very close to where they were hatched; a result of the formation of tidally-induced retention areas that prevent larvae from being dispersed by water currents. The length of time it takes for larvae to metamorphose into juvenile herring is dependent on water temperature and food availability. Larvae are light sensitive, seeking deeper waters on bright days (Scott and Scott 1988).

The NunatuKavut Community Council indicated that the herring fishery was a historically important commercial harvest (NunatuKavut Community Council 2019). Netted herring were often sold and used for bait or dog food. The NunatuKavut Community Council observed that herring is an important prey species for seals. The NunatuKavut Community Council also indicated that changes to regulations and population decline have affected the harvest of herring. The NunatuKavut Community Council herring fishery is described in Section 9.4.3. Herring are more abundant Nunatsiavut-wide than they were historically.

The Nunatsiavut Government observed an increase in herring abundance within Nain Bay in recent years (Nunatsiavut Government 2018).

5.4.2.3 Atlantic Salmon

Atlantic salmon (*Salmo salar*) is an anadromous fish that lives in freshwater rivers for two to five years in Newfoundland and three to seven years in Labrador prior to undergoing smoltification and migrating to sea as smolts (DFO 2018a). In North America, the range of anadromous Atlantic salmon is from the Hudson River in the south to outer Ungava Bay and eastern Hudson Bay (COSEWIC 2010a). Estimates suggest that there are at least 700 rivers in Canada which either currently or previously supported Atlantic salmon populations in the past (COSEWIC 2010a).

Atlantic salmon is an iteroparous species, meaning it can spawn repeatedly, as opposed to most species of Pacific salmon (*Onchorhynchus* spp.), which are semelparous and die after one spawning event (Schaffer 1974 in O’Connell et al. 2006; Flemming and Reynolds 2004 in O’Connell et al. 2006). Atlantic salmon return annually to their native river or tributary for spawning and show a high degree of site fidelity, despite completing ocean scale migrations (COSEWIC 2010a). Nunatsiavut Government have observed late migrations, with salmon sometimes not migrating into rivers until September (Nunatsiavut Government 2018). Females typically lay their eggs in July and August, in freshwater by making a hole on the bottom and depositing eggs in shallow rapids (Clément 1998). If fish eggs are not eaten by predators (e.g., speckled trout and Arctic char), the small salmon migrate to the sea in October (Clément 1998). Both post-smolt (juvenile) and adult salmon migrate from northeastern North America in the spring and summer to waters off Labrador to overwinter. While at sea, adult salmon were found to spend a considerable amount of time in the upper portion of the water column (Reddin 2006). Tagging studies of post-smolts also showed that they spend most of their time near the surface, but undergo deep dives, likely in search of prey (Reddin 2006).

While still in rivers, post-smolts mainly eat aquatic insect larvae, including caddisflies and blackflies (Clément 1998). Adults at sea consume euphausiids, amphipods, and fish such as herring, capelin, small mackerel, sand lance and small cod. Salmon do not eat when they return to fresh water to spawn (Scott and Scott 1988). The mortality sources of salmon while at sea are poorly known (Reddin 2006), but it is known that they are prey for seals, sharks, pollock, and tuna, as well as seabirds such as northern gannet (Montevecchi et al. 2009; Scott and Scott 1988). Other threats to Atlantic salmon, identified by Innu Nation, include overfishing and mining pollution (tailings) (Clément 1998).

There are four populations of Atlantic salmon that are currently listed as not at risk that have the potential to occur within the Labrador Shelf SEA Update Area: the Labrador population, the Northeast Newfoundland population, the Northwest Newfoundland population, and the Southwest Newfoundland population. The Nunavik population also occurs within the Labrador Shelf SEA Update Area and has a COSEWIC status of Data Deficient. Details regarding the at risk populations are provided in Section 5.5.1.2. The Labrador population and the Nunavik population breed in rivers along the coast of the Labrador Shelf SEA Update Area. Rivers along the Atlantic coast of Labrador and southwest along the Quebec coast to the Napetipi Rivers are breeding grounds for the Labrador population, while the Nunavik population breeds in rivers flowing into Ungava Bay and eastern Hudson Bay (Government of Canada n.d.). Abundance data for the Labrador population are limited; however, an increase of 380% in the number of mature individuals is evident over the last three generations. The Nunavik population, separated by approximately 650 km from the nearest population to the south, is the northernmost population of the species in North America. Although limited catch per unit effort data suggest increased abundance in recent years, abundance trends in this population are unknown (Government of Canada n.d.). The Southwest Newfoundland population, the Northeast Newfoundland population, and the Northwest Newfoundland population breed in rivers along the southwest, northwest and northeast coast of Newfoundland but undertake lengthy feeding migrations in the North Atlantic Ocean as older juveniles and adults (Government of Canada n.d.), and therefore, have the potential to occur within the Labrador Shelf SEA Update Area. Bradbury et al. (2015) indicate that the majority of the individuals in the Labrador salmon fishery is comprised of individuals from local stocks (96% to 97%) and individuals from Newfoundland and Quebec comprise <1%, primarily in southern Labrador, which is consistent with migration through the Strait of Belle Isle. Bradbury et al. (2021) indicated that the Labrador Sea is an important aggregation area in the Northwest Atlantic, detecting over 70% of the Northwest Atlantic reporting groups.

In the 2018 Assessment of NL Atlantic salmon, four rivers were assessed in Labrador; the English River (near Postville), Sand Hill River, Muddy Bay Brook (Dykes River), and Southwest Brook (a tributary of Paradise River). The English River, Sand Hill River, and Muddy Bay Brook showed an increase in total returns, while Muddy Bay Brook showed no change compared to previous years. However, a decrease in large salmon returns was reported for all four assessed rivers in Labrador (DFO 2020b). In comparison, the 2019 Assessment of NL Atlantic Salmon showed declines in total returns (both small and large salmon) on all four rivers in Labrador (DFO 2020c).

In 1997, Nunatsiavut Government shared that char and salmon were caught by net along the coast. In the spring, ice fishing camps can be found at the head of Anaktalak Bay. Nunatsiavut Government reported in 2007 that salmon fishing occurs in the West Bay, Fish Cove area as well as the south side of Groswater Bay, around Kunnocks Cove and the Cranforhead area (SEM 2008). Nunatsiavut Government has observed an increase in salmon abundance in some locations in recent years, after having declined years ago (number of years not specified) as a result of the commercial fishery (Nunatsiavut Government 2018). However, other reports by Nunatsiavut Government indicate a recent decline. For example, Nunatsiavut Government observed a reduction in salmon abundance in the past three years in areas surrounding Snook's Cove (Nunatsiavut Government 2018). Nunatsiavut Government conducts salmon surveys and noted that in a 2013/2014 study, 200 salmon were caught, measured, weighed, and tagged within six weeks. Based on salmon fence counts, rivers have experienced a decline in salmon abundance in the summer of 2019, and a reduction in the amount of young salmon returning to the rivers (Nunatsiavut Government 2018; DFO 2021a). Nunatsiavut Government attributes this decline to changes in ice conditions, the food fishery having many nets out, and changes in climate (Nunatsiavut Government 2018). A change in salmon colour was also observed, becoming paler in recent years, attributed to a change in diet (Nunatsiavut Government 2018).

The commercial and traditional importance of Atlantic salmon is discussed further in Section 9.4. Atlantic salmon is also one of the main species for the aquaculture industry in the province, as well as a recreationally-important species, as discussed in Section 9.2.8 and Section 9.3, respectively.

5.4.2.4 Arctic Char

Arctic char (*Salvelinus alpinus*) have a circumpolar distribution in the northern hemisphere (DFO 2001). Char are either anadromous or a resident freshwater fish. There is a higher predominance of resident fish further south, while anadromous populations are common in northerly regions (DFO 2001). In Labrador, anadromous populations increase in frequency with latitude as they are replaced by sea-run brook char (trout) and Atlantic salmon in southern areas (DFO 2001).

Arctic char in northern Labrador, overwinters in lakes and migrates seaward with spring runoff and ice break-up in coastal rivers (May) (DFO 2001; Clément 1998). Migrations consist of both first-time and repeat migrants with first-time migrants being between two to seven years and 10-20 cm in length. Seaward migration for Arctic char is short and irregular, with both juveniles and adults spending only one to four months at sea, with a two month period commonly observed by Innu Nation, before returning to fresh water (or nutshimit) (DFO 2001; Clément 1998). Ocean migrations are also spatially limited (Layton et al. 2020), with few Arctic char moving less than 100 km from home rivers. The return migrations occur from July to September, with large mature char returning first, followed by non-mature adults then juveniles.

Arctic char in northern Labrador mature at younger ages and smaller sizes than other char stocks from northern Canada (DFO 2001). Spawning takes place in the fall, commencing by mid-October, occurs in either lakes or streams, and is not dependent on substrate type (DFO 2001). However, Innu Nation have observed females depositing their eggs in June-July, sometimes August, on sandy and rocky bottom at some outlets of lakes (Clément 1998). Females lay approximately 290 eggs per 100 g of body mass (DFO 2001). Growth rates are slow during the freshwater stage of the life cycle, with the adult size-at-age being highly variable, dependent of age at first sea migration and the number of migrations the char has taken (DFO 2001). In Labrador, female char begin to mature at approximately six years, with most spawning at least once by the age of nine (DFO 2001).

Arctic char are opportunistic predators while at sea, with diet varying over spatial areas. Within the Labrador Shelf SEA Update Area, sand lance, sculpins, capelin, and hyperiid amphipods are the four main prey sources for Arctic char (DFO 2001). Inuit participants in Williamson and LIA (1997) reported that Arctic char rely more on lance and small amphipods for food.

Arctic char is very important to Labrador Inuit culture. Nunatsiavut Government reported in 2007 that char fishing occurs in the West Bay, Fish Cove area, as well as the south side of Groswater Bay, around Kunnocks Cove and the Cranforhead area (SEM 2008). Nunatsiavut Government (2018) reported that the number of char caught through the ice in winter and spring dropped substantially in the past 10 years and attributed the change to the commercial fishery in Nain Bay and there being no quotas/limits in place. For fish in general, Nunatsiavut Government have noted larger and more plentiful fish since DFO made the mesh size for nets bigger about 10 to 15 years ago (Nunatsiavut Government 2018). However, in recent years, a reduction in char abundance was observed in the summer months, and especially in areas that are heavily fished. For example, char was plentiful near Mason Island a few years ago but has been declining since then and abundances have decreased in Saltwater Pond over the past 15 years (Nunatsiavut Government 2018). Fluctuations in char abundance have occurred for many years and Nunatsiavut Government recall elders discussing the change in abundance from year to year (Nunatsiavut Government 2018). A change in char movement has been observed in the summer over the last five to six years, with char staying in the bay, as opposed to moving through the bay and out to sea (Nunatsiavut Government 2018). Coté et al. (2021, as cited in DFO 2021c) links this to availability of capelin (fish stay in bays if capelin are abundant). This has increased the catch in the bay (Nunatsiavut Government 2018). A change in the size of char was also observed from approximately 2.7 to 3.2 kg (6 to 7 pounds) down to 1.4 kg (3 pounds) char in some locations. However, Nunatsiavut Government have also observed very large char (9 kg [20 pounds]) in some locations (Nunatsiavut Government 2018).

The NunatuKavut Community Council, in 2009 reported char fishing in Rabbit Island, Bob’s Brook, Traverspine River, Mud Lake, Metchin River, Muskrat Falls and Gull Island (Minaskuat 2009). The NunatuKavut Community Council observed that depending on the region, char populations have been higher in past years but declined recently, remained stable or even rebounded a bit at some locations (NunatuKavut Community Council 2019). Arctic char populations fluctuate for many reasons including overfishing, change in migration patterns, prey availability, industrial activities, regime shifts, and prey availability (Clément 1998; Dempson et al. 2002; Layton et al. 2020). The NunatuKavut Community Council Arctic char fishery is described in Section 9.4.3.

The commercial and traditional importance of Arctic char is discussed further in Section 9.2.5.4 and Section 9.4.

5.4.2.5 Capelin

Capelin (*Mallotus villosus*) are a small pelagic species that has a circumpolar distribution in the northern hemisphere (DFO 2006c) and are found along the coasts of NL and on the Grand Banks. Capelin are members of the smelt family (Osmeridae), are olive in colour, have an elongated body, and exhibit pronounced sexual dimorphism during spawning. Although this Arctic-boreal species has adapted to living and exploiting feeding opportunities at the edge of Arctic waters, capelin require higher temperatures for successful reproduction (Rose 2005). Populations in cold water are not free of risk as capelin have been observed to freeze to death off Labrador, presumably when they contact ice crystals in super-cooled water (Rose 2005).

Migration towards the coast precedes spawning on beaches or in deeper waters (DFO 2006c). Capelin roll on sandy or fine gravel beaches in water temperatures ranging between 6ºC and 10ºC. Beach spawning is more prevalent at night. During spawning, the thermal range of capelin typically shifts upwards (Rose 2005). Beach spawning occurs at 2°C to 10°C, but deep-water spawning is restricted to temperatures of 2°C to 7°C, and most deep-water spawning likely occurs between 2°C and 5°C (Rose 2005). Beach spawning has been observed earlier in the south (DFO 2018c). In Division 3LK observations from 2015 to 2017 showed that beach spawning occurred at similar times and lasted for similar durations (with the exception of protracted spawning in 2016) (DFO 2018c). Indigenous knowledge from the Southern Inuit of NunatuKavut observed that in 2016 and 2017 no capelin spawned on their beach for the first time in known history (DFO 2018c). Capelin are able to spawn at the age of two, and males usually die following spawning. Spawning typically occurs in late June and early July, although it was somewhat later in the 1990s (Carscadden et al. 1997, 2001). Changes in the ecology of capelin occurred after the major decline in 1990-1991, including delayed and prolonged spawning (Lewis et al. 2019). Persistent later spawning period can have a profound impact on larval survival. The decrease in the number of onshore wind events during later spawning periods reduces the release of emergent larvae from beach sediment (Murphy et al. 2019).

In Division 3LK, biological samples from fish processing plants have been processed by DFO Science since 1980 (DFO 2018c). Over time, observations have shown that the mean length and weight of both male and female capelin has declined. This aligns with observations that have shown earlier age of maturity and delayed migration (Carscadden et al. 2000 in DFO 2018c).

Capelin eggs are 1 mm in diameter and are attached to the substrate. Incubation varies with ambient temperature and lasts approximately 15 days at 10°C. Larval capelin is planktonic and remains near the surface until the onset of winter. Capelin have a short life span (usually five years or less) and abundances are linked to a few age classes.

Capelin are major components in marine ecosystem dynamics as their position in the food chain transfers energy between trophic levels by converting secondary production (zooplankton) into primary trophic levels (fish), which then feed large numbers of predators (Carscadden et al. 2013). They also move energy across regions by bringing important resources to coastal areas of Labrador to species such as Arctic char (DFO 2021a). Capelin prey consist of planktonic organisms comprised of primarily euphausiids and copepods. Capelin feeding is seasonal with intense feeding in late winter and early spring leading up to the spawning cycle when feeding ceases. Feeding recommences several weeks after the cessation of spawning.

Predators to capelin include most major fish species including Atlantic cod, haddock, herring, flatfish species, dogfish, Arctic char, and others (Dempson et al. 2002). Several marine mammal species, including minke whales, fin whales, harp and ringed seals, and a variety of seabird species also prey on capelin. They are considered to be a key forage species (DFO 2018c). Because of this, management of capelin fisheries tends to be conservative because of the prominent role of capelin in the marine ecosystem.

Carscadden et al. (2013) reviewed research that has been conducted on capelin in three areas (Barents Sea, around Iceland, and off eastern NL). While changes in distribution have been observed in each area, the timing and degree of changes have varied. Changes in the NL area have been the most extreme. While a number of reasons for this shift in distribution have been suggested (e.g., decline in number of finfish predators, changes in plankton concentrations, water temperature), the exact cause remains unknown (Carscadden et al. 2013).

In the 1930s, capelin underwent dramatic changes in distribution, size and age at maturity, and time and duration of spawning (Carscadden et al. 1997). Together, these changes represent biological responses to a colder, less favourable environment. Capelin avoid cold Arctic water in which the copepod fauna is dominated by *Calanus hyperboreus* and *Metridia longa* (Anderson et al. 2002). There appears to be a lag in the distributional response of capelin to improved environmental and feeding conditions (Anderson et al. 2002). In general, as water temperatures rise, northward shifts in capelin distribution can be expected, with more southerly grounds abandoned (Rose 2005). Thus, changes in capelin distribution may be expected to have a direct impact on the many species that feed on them. During the early 1990s, capelin exhibited large-scale changes in distribution within and outside their normal range that have been linked to colder ocean temperatures (Carscadden et al. 2002). During this period, capelin essentially disappeared from NAFO division 2J adjacent to the Labrador coast, to occupy an area to the south on the northern Grand Banks (Carscadden et al. 2001).

The NunatuKavut Community Council has observed a decline in capelin numbers and size over the past few decades (NunatuKavut Community Council 2019). Capelin range is also reduced, and they do not appear to stay around as long as they once did. Population decline may be a result of overfishing in the 1980s and the continued fishing of capelin after the cod fishery closed, rather than due to habitat degradation. Rolling has not been observed in recent years. The NunatuKavut Community Council observed that seabirds and mammals accompanied the rolling events and these used to last for weeks (NunatuKavut Community Council 2019). The NunatuKavut Community Council capelin fishery is described in Section 9.4.3.

Nunatsiavut Government observed an increase in capelin abundance within Nain Bay in recent years and capelin have been observed mid-way out in the bay as well as in shallow waters (Nunatsiavut Government 2018). However, reports regarding capelin abundance compared with many years ago, indicate a decline. Nunatsiavut Government have expressed concern regarding the cascading effects this might have on other marine animals that rely on capelin as a main source of food (Nunatsiavut

Government 2018). Additionally, capelin were observed moving further north compared with many years ago, attributed to the change in temperature (Nunatsiavut Government 2018).

5.4.2.6 Greenland Shark

Greenland shark (*Somniosus microcephalus*) is a large epibenthic pelagic species that is common in the Hudson Strait, Labrador Sea, Baffin Bay, and Davis Strait nearshore and offshore (Coad and Reist 2004). In the North Atlantic, Greenland sharks are found from Lancaster Sound south to the Scotian Shelf, and occasionally further south in the Gulf of Maine. A tagging study conducted by Campana et al. (2015a) have shown that movement patterns of the Greenland shark are greater than previously thought. Sharks that were tagged for their study travelled a minimum of 300 km over a one to two-month period. The mean distance travelled was 1,015 km over a five-month period. The species occurs from shallow water depths down to 1,067 m deep (Coad and Reist 2004). Sharks in Arctic waters have been found in water with a mean temperature of 2.7°C, while sharks in Atlantic waters have been found in water with a mean temperature of 7.9°C (Campana et al. 2015a). Greenland shark are a mixture of scavenger and predator that feed on marine mammals, fishes, and invertebrates (Coad and Reist 2004; DFO 2021a). Lydersen et al. (2016) found that sharks studied in Norway have had seal tissue and minke whale tissue in their intestinal tract, while their predominant food sources were Atlantic cod, Atlantic wolffish, and haddock. The body length at maturity for males is approximately 2.8 m for males and 4.2 m for females (Nielsen et al. 2013). Greenland sharks are ovoviviparous and can have an estimated 200 to 324 pups per pregnancy, depending on the size of the female (Nielsen et al. 2013).

Greenland shark are substantive bycatch caught in longline commercial fisheries for Greenland halibut (Coad and Reist 2004).

5.4.2.7 Blue Shark

Blue sharks (*Prionace glauca*) are widespread, highly migratory and can be found worldwide in temperate and tropical oceans, generally in the offshore surface water (COSEWIC 2006a). They are the most frequently caught large pelagic shark in the North Atlantic (Campana et al. 2011). The age at maturity for males is approximately four to six years and for females it is approximately five to seven years (Campana et al. 2015b). Blue sharks typically mate in the spring to early summer (COSEWIC 2006a). The female may store sperm for months to years while waiting for ovulation to occur. The gestation period lasts 9 to 12 months, with birth usually occurring in the spring to fall. Blue sharks are viviparous (bearing live young) with litters typically consisting of 25 to 50 pups (Campana et al. 2015b). The length of newborn pups averages 40 to 50 cm, taking four to five years to mature to a length of 193 to 210 cm. Abundance indices based on catch rates in or near Canadian waters show varying declining rates of blue sharks between near 0% to 53% since the mid-1990s (COSEWIC 2006a). Blue sharks are opportunistic predators and feed on bony fish, squid, birds, and marine mammal carrion.

Blue sharks are commonly found in offshore waters in depths up to 350 m during summer and fall from June to October. They have been noted as being very common in inshore waters of NL during the summer months (DFO 2021c). Howey et al. (2017) studied movement patterns of blue sharks in the Atlantic Ocean. They observed that vertical behaviours of the sharks varied depending on the locations. Blue sharks off the continental shelf showed significantly more depth use including increases in the frequency of deep-diving when compared to periods of aggregation on the continental shelf (Howey et al. 2017). It has also been observed that blue sharks display spatial structuring and segregation by sex and size (Howey et al. 2017; Vandeperre et al. 2014). They can be found in water temperatures between 5.6°C to 28°C but prefer temperatures of 8°C to 16°C. Temperature is believed to be a primary factor in migration (COSEWIC 2006a). Canadian waters provide habitat for primarily immature individuals although mature species are occasionally observed (COSEWIC 2006a).

The NunatuKavut Community Council observed that sharks (species not specified) are abundant and can get caught in trout and seal nets (NunatuKavut Community Council 2019).

5.4.2.8 Other Fish

Speckled / brook trout (*Salvelinus fontinalis*) are anadromous, and females lay their eggs around June-July in shallow water (60 cm) on a substrate mixture of sand and small stones at the bottom of brooks, small lakes or their inlets. Their diet includes small fish, fish eggs, invertebrates, and small / young mammals or birds. Threats to this species identified by the Innu Nation include overfishing and mine tailings (Clément 1998). The lake whitefish (*Coregonus clupeaformis*) can migrate great distances to spawn, but they are not anadromous. They spawn at the end of summer, between August and October. Females deposit their eggs on sandy bottoms, in deep, inland water. The fish eggs are eaten by speckled trout. Whitefish migrate toward coastal waters in spring (May or June). Pollution is a threat identified by the Innu Nation (Clément 1998).

In multiple locations across southern Labrador, the NunatuKavut Community Council observed few striped bass in 2018 but many in 2017 (NunatuKavut Community Council 2019). The NunatuKavut Community Council observed less trout, or no change in trout abundance from recent years, depending on the geographical location in Labrador. However, in some locations the NunatuKavut Community Council reported that it is difficult to gauge because the fishing season for trout is too late, and the trout migrate before they are able to fish them (NunatuKavut Community Council 2019). The NunatuKavut Community Council observed fewer smelt in recent years in some locations throughout southern Labrador (NunatuKavut Community Council 2019).

Nunatsiavut Government reported smelt and trout in Miran Lake are often prey to seal and observed a reduction in trout and smelt abundance in recent years in areas surrounding Snook’s Cove and in ponds near Rigolet (Nunatsiavut Government 2018). A decrease in abundance and reduction in size of trout in the Goose Brook area was also observed (Nunatsiavut Government 2018). An increase in sunfish abundance have also been observed in the Postville area, which is reported to be unusual and has been attributed to the migration of jellyfish along the coast of Labrador (Nunatsiavut Government 2018).

5.4.3 Data Constraints for Marine Fish

There are a variety of uncertainties that may affect the information provided on certain species in the Labrador Shelf SEA Update Area. Two areas that are not well studied include deep ocean areas and coastal areas (DFO 2021a). Descriptions and details on a variety of species are limited, including incomplete information with respect to life histories. The impact of environmental variations (in particular temperature variations) on natural mortality, production and recruitment is poorly understood. Non-commercial species have more data constraints, particularly for their life histories and ecology in the Labrador Shelf SEA Update Area, including spawning locations, abundance, and distribution, as there have been limited scientific studies conducted. The information on the biology, life histories, and ecology is often inferred from research conducted in other areas. While this provides a basis upon which to build, it is not region-specific, and differences can occur.

There are also data constraints related to the movement of fish within the Labrador Shelf SEA Update Area. Most of what is known comes from commercial fishery data, which is often grouped into NAFO divisions used in fisheries management (i.e., 2J3KL). Additionally, the distribution of fish eggs and larvae in the Labrador Shelf SEA Update Area is not well understood. This is an important life stage for fish species offshore, and there is currently a low amount of research on this subject.

Climate change and species-specific impacts is another evolving area of research. Environmental events that may be related to climate change have the potential to alter species distributions, health, and overall success, and more research and monitoring should be incorporated to monitor these effects as the climate evolves over time.

While there are data gaps / constraints, their relation to offshore oil and gas activities is dependent on the nature and timing of the particular activity, and the need to collect additional data will be determined at the project-specific EA stage. Each project-specific EA will need to consult with DFO and industry groups, such as the Groundfish Enterprise Allocation Council (GEAC), about current-year plans for the relevant areas.

5.5 SPECIES AT RISK AND SPECIES OF CONSERVATION CONCERN

A number of fish species occur within the Labrador Shelf SEA Update Area that have varying degrees of conservation concern. This includes species that have been granted formal federal protection under the SARA, or provincial protection under the NL *Endangered Species Act* (NL ESA). For the purposes of the SEA Update, SAR include species that are designated and formally protected under either or both provincial and federal regulations, including the NL ESA and SARA, respectively. SOCC include those species identified as Endangered, Threatened or of Special Concern by COSEWIC.

At the time of writing, there are five fish SAR and 30 species of SOCC that may be present in the Labrador Shelf SEA Update Area. Their protection and conservation status are provided in Table 5.7.

Table 5.7 Listed Species that May Occur in the Labrador Shelf SEA Update Area

Common Name	Scientific Name	SARA Schedule 1 Status	COSEWIC Designation	NL ESA Designation
Acadian redfish	*Sebastes fasciatus*	No Status	Threatened	Not Listed
American eel	*Anguilla rostrata*	No Status	Threatened	Vulnerable
American plaice (NL population)	*Hippoglossoides platessoides*	No Status	Threatened	Not Listed
Atlantic bluefin tuna	*Thunnus thynnus*	No Status	Endangered	Not Listed
Atlantic cod (NL population)	*Gadus morhua*	No Status	Endangered	Not Listed

Table 5.7 Listed Species that May Occur in the Labrador Shelf SEA Update Area

Common Name	Scientific Name	SARA Schedule 1 Status	COSEWIC Designation	NL ESA Designation
Atlantic salmon (South Newfoundland population)	*Salmo salar*	No Status	Threatened	Not Listed
Atlantic salmon (Gaspe-Southern Gulf of St. Lawrence population)	*Salmo salar*	No Status	Special Concern	Not Listed
Atlantic salmon (Outer Bay of Fundy population)	*Salmo salar*	No Status	Endangered	Not Listed
Atlantic salmon (Eastern Cape Breton population)	*Salmo salar*	No Status	Endangered	Not Listed
Atlantic salmon (Nova Scotia Southern Upland population)	*Salmo salar*	No Status	Endangered	Not Listed
Atlantic salmon (Quebec Eastern North Shore population)	*Salmo salar*	No Status	Special Concern	Not Listed
Atlantic salmon (Quebec Western North Shore population)	*Salmo salar*	No Status	Special Concern	Not Listed
Atlantic salmon (Anticosti Island population)	*Salmo salar*	No Status	Endangered	Not Listed
Atlantic wolffish	*Anarhichas lupus*	Special Concern (under consideration for status change)	Special Concern	Not Listed
Basking shark (Atlantic population)	*Cetorhinus maximus*	No Status	Special Concern	Not Listed
Cusk	*Brosme brosme*	No Status	Endangered	Not Listed
Lumpfish	*Cyclopterus lumpus*	No Status	Threatened	Not Listed
Deepwater redfish (Northern population)	*Sebastes mentella*	No Status	Threatened	Not Listed
Northern wolffish	*Anarhichas denticulatus*	Threatened (under consideration for status change)	Threatened	Not Listed
Porbeagle shark	*Lamna nasus*	No Status	Endangered	Not Listed
Roundnose grenadier	*Coryphaenoides rupestris*	No Status	Endangered	Not Listed
Smooth skate (Funk Island Deep Population)	*Malacoraja senta*	No Status	Endangered	Not Listed
Shortfin mako shark (Atlantic population)	*Isurus oxyrinchus*	No Status	Endangered	Not Listed
Spiny dogfish (Atlantic population)	*Squalus acanthias*	No Status	Special Concern	Not Listed

Table 5.7 Listed Species that May Occur in the Labrador Shelf SEA Update Area

Common Name	Scientific Name	SARA Schedule 1 Status	COSEWIC Designation	NL ESA Designation
Spotted wolffish	*Anarhichas minor*	Threatened (under consideration for status change)	Threatened	Not Listed
Thorny skate	*Amblyraja radiata*	No Status	Special Concern	Not Listed
White hake (Atlantic and Northern Gulf of St. Lawrence population)	*Urophycis tenuis*	No Status	Threatened	Not Listed
White shark (Atlantic population)	*Carcharodon carcharias*	Endangered	Endangered	Not Listed
Winter skate (Eastern Scotian Shelf-Newfoundland population)	*Leucoraja oscellata*	No Status	Endangered	Not Listed

Notes: Data from the SARA registry (http://sararegistry.gc.ca/sar/index/default_e.cfm) as of October 2020.
With the exception of Atlantic bluefin tuna and shortfin mako (Atlantic population), the species with no status under SARA Schedule 1 are under consideration for addition (as per the SARA registry).

While the information in Table 5.7 is considered current at the time of writing, readers should be aware that provisions and associated listings can change over time due to influencing factors on species health and status. Therefore, new species can be added to Schedule 1 of SARA, and new recovery strategies, action plans, and/or management plans may be released or updated with the most up-to-date information on certain species. This can include information such as updated population statistics, and newly identified or enforced critical habitat. Therefore, it is important to refer to the SARA public registry during project-specific EAs, to obtain the current up-to-date information on legally protected fish species in Canada.

While there are multiple species that have been identified as being of conservation concern that may exist within the Labrador Shelf SEA Update Area, Schedule 1 of SARA is the mechanism that provides legal protection to species that have been listed under the Act. The following section provides descriptions of these species and provides updated information on the current status of the species, and new or updated recovery strategies, action plans, or management plans that have been published for the species since the original SEA Report was published.

5.5.1 Species at Risk

5.5.1.1 Wolffish (Atlantic, Northern, and Spotted)

Atlantic Wolffish

Atlantic wolffish (*Anarhichas lupus*) can occur in the Labrador Shelf Sea Update Area and are typically found inhabiting the seafloor in water depths of <100 to 400 m at temperatures ranging from -0.5°C to 6.5°C (COSEWIC 2012a). Wolffish are found from the Davis Strait and northern Labrador to the southern Grand Bank and Flemish Cap (Simpson et al. 2012). Atlantic wolffish occupy more shallow waters when compared to the northern and spotted wolffish (Simpson et al. 2014). DFO spring (1971-2012) and fall (1977-2011) surveys show a persistent concentration of this species on the northern Grand Banks, the Flemish Cap, and the northeast NL shelves, while other wolffish species (northern and spotted) show concentrations north of the Grand Banks (DFO 2013c; Simpson 2014). Data from the DFO multispecies RV surveys (1981-1995 and 1995-2017) highlight the importance of northern regions for Atlantic wolffish, and the difficulty in sampling the species' preferred habitat (complex, rocky habitats) may provide an incomplete picture of their distribution (Wells et al. 2021).

Juvenile and adult Atlantic wolffish can be found on a variety of substrates. Atlantic wolffish feed on mostly invertebrates (85%), including whelks, sea urchins, hermit crabs, crabs, and scallops. A smaller portion of their diet consists of fish with their main prey being redfish (COSEWIC 2012a).

Wolffish movements change with the seasons (Simpson et al. 2014). In the spring and summer, they have been frequently found in the open water during the day and at night. In the fall and winter, wolffish have been observed being active for a few hours a day, typically at dawn and dusk. It is thought that the increased activity in the spring and summer is related to warmer water temperatures and increased availability of prey. Fall and winter movements of Atlantic wolffish suggest feeding patterns are associated with vertical movement of prey species at dawn and dusk (Simpson et al. 2014). Movements were also observed relative to size, where larger individuals travelled distances greater than 20 km and small to intermediate sized fish stayed within an area of 4 to 20 km (Simpson et al.2014).

Atlantic wolffish make short migrations to spawning grounds, which are generally boulder and cave habitat in shallow waters, during the fall (COSEWIC 2012a). Eggs / larvae may be present on the seafloor in fall to early winter. The eggs are deposited in narrow spaces and crevices on rocky substrates and are guarded by males until they hatch. Juvenile Atlantic wolffish are capable of wide dispersion, while adults are sedentary (COSEWIC 2012a; Simpson et al. 2014). The number of Atlantic wolffish individuals in Canadian waters is estimated to exceed 49 million, with over 5 million mature individuals (COSEWIC 2012a). In Canadian waters, the abundance of mature individuals has declined by 87% since 1970, while the abundance of immature individuals has increased over the same period (LGL 2014).

Abundance of Atlantic wolffish in Canadian Atlantic and Arctic waters have been stable since the mid-2000s (DFO 2014a). Atlantic wolffish are listed as Special Concern under Schedule 1 of SARA and by COSEWIC. Although there is no directed fishery for Atlantic wolffish in Canadian waters, bycatch is thought to be the leading cause of mortality, and bottom trawling and dredging may also cause alteration to wolffish habitat (DFO 2013c). In addition, seismic surveys, oil and gas activities, sewage sludge, fish waste, dredging spoils, cables and pipelines, marine and land-based pollution, global climate change, and natural mortality have been identified as potential threats to Atlantic wolffish (DFO 2013c). A Management Plan has been developed for Atlantic wolffish (DFO 2020d). In 2015, the Atlantic wolffish was classified on the IUCN Red List as Data Deficient (Collette et al. 2015a).

At the time of writing, critical habitat has not been identified or established for Atlantic wolffish. However, due to similarities between species, it can be assumed that Atlantic wolffish would likely occupy similar areas as the spotted wolfish.

Northern Wolffish

Wolffish are found from the Davis Strait and northern Labrador to the southern Grand Bank and Flemish Cap (Simpson et al. 2012). In Newfoundland, northern wolffish (*Anarhichas denticulatus*) can be found in the deep waters (150 to 1,000 m) along the continental shelf in spring and fall. Deep areas along the slope of the continental shelf are important habitat for northern wolffish (Wells et al. 2021). DFO annual spring (1971-2012) and fall (1977-2011) surveys show persistent concentrations of northern wolffish north of the Grand Banks through the northeast Newfoundland shelf to the southern Labrador shelves (DFO 2013c, 2020d; Simpson et al. 2013). Bottom trawl surveys have suggested that northern wolffish are absent in the southernmost area surveys and that when they are caught, it occurs along the shelf slope of the Grand Banks and Laurentian Chanel (Simpson et al. 2013).

NL waters are at the center of the distribution range of this species, with their highest densities and largest distribution on the northeast Newfoundland and southern Labrador shelves (DFO 2013c).

Before the decline of the northern wolffish, they were caught in areas that contain different types of substrate. They are now most often found on sand and shell hash (COSEWIC 2012b). Scientific surveys from parts of the western Atlantic range indicate declines in the abundance of northern wolffish over the past 20 years. Since the 1990s there has been a reduction in fishing effort, and since 2003, there has been a mandatory release of northern wolffish within Canada’s EEZ, resulting in a decline in fishing related mortalities (Collins et al. 2015).

The northern wolffish is a benthopelagic species, feeding on pelagic jelly-like invertebrates (e.g., comb jellies like *Beroe cucumis*), but lives in the open ocean (C. Miri, pers. comm. 2021 in DFO 2021c; COSEWIC 2012b). Spawning occurs in the later portion of the year, with females laying upwards of 27,000 demersal eggs. The species matures at five years of age or older. They are a non-schooling, non-migratory species which are territorial and make nests in which they guard their eggs.

Abundance of northern wolffish in Canadian Atlantic and Arctic waters have been stable since the mid-2000s, although numbers have remained low in NAFO Division 2J3K, where the majority of the population was once found (DFO 2013c). Northern wolffish is listed as Threatened under Schedule 1 of SARA and by COSEWIC. Bycatch in fisheries is believed to be the leading cause of mortality to northern wolffish, and bottom fisheries also have the potential to alter wolffish habitat (DFO 2013c). Other potential threats to northern wolffish include: seismic surveys; oil and gas activities; sewage sludge; fish waste; dredging spoils; cables and pipelines; marine and land-based pollution; global climate change; and natural mortality (DFO 2013c). In 2015, the northern wolffish was classified on the IUCN Red List as Endangered (Collette et al. 2015b).

Critical habitat for northern wolffish was identified in a Recovery Strategy (DFO 2020d). The Critical Habitat of the Northern Wolffish (*Anarhichas denticulatus*) Order (Registration SOR/2020-185) was promulgated in the Canada Gazette Part II on September 16, 2020 (Government of Canada 2020). This critical habitat overlaps with portions of the Labrador Shelf SEA Update Area and is illustrated in Figure 5-9. An Action Plan has been published for northern wolffish (DFO 2020e).

Spotted Wolffish

Wolffish are found from the Davis Strait and northern Labrador to the southern Grand Bank and Flemish Cap (Simpson et al. 2012). Spotted wolffish (*Anarhichas minor*) can be found in the waters of NL, including within the Labrador Shelf SEA Update Area. The main range of the species consists of the west of Greenland to the Grand Banks (COSEWIC 2012c). DFO annual spring (1971-2012) and fall (1977-2011) surveys show persistent concentrations of spotted wolffish north of the Grand Banks, Labrador shelf, and the Flemish Cap (DFO 2013d, 2020; Simpson et al. 2013). Bottom trawl surveys throughout NAFO Division 3K had low densities (Simpson et al. 2013). Like northern wolffish, NL waters are at the center of the distribution range of this species (DFO 2013d).

The species is commonly found inhabiting the seafloor in water depths of 50 to 800 m. The species prefers a substrate of coarse sand and a sand and shell mix with rocks to provide shelter. In the waters off Newfoundland, spotted wolffish are found in deep water, in a water temperature range of -1°C to 6°C, and it is believed that temperature is a limiting factor in their distribution. The spotted wolffish grows slower than other wolffish species. Females mature at seven years and spawning occurs in the summer to late fall / early winter. Approximately 50,000 large eggs are laid on the seafloor and are guarded by the male until they hatch (COSWEIC 2012c).

Abundance of spotted wolffish in Canadian Atlantic and Arctic waters have been stable since the mid-2000s, although numbers have remained low in NAFO Division 2J3K, where the majority of the population was once found (DFO 2013d). Spotted wolffish is listed as Threatened under Schedule 1 of SARA and by COSEWIC. The leading cause of mortality to spotted wolffish is bycatch in fisheries, and bottom fisheries also have the potential to alter wolffish habitat (DFO 2013d). Since the 1990s there has been a reduction in fishing effort and since 2003 there has been a mandatory release of spotted wolffish within Canada’s EEZ, resulting in a decline in fishing related mortalities (Collins et al. 2015). Seismic surveys, oil and gas activities, sewage sludge, fish waste, dredging spoils, cables and pipelines, marine and land-based pollution, global climate change, and natural mortality have also been identified as potential threats to spotted wolffish (DFO 2013d). In 2015, the spotted wolffish was classified on the IUCN Red List as Near Threatened (Collette et al. 2015c).

Critical habitat for spotted wolffish was identified in a Recovery Strategy (DFO 2020d). The Critical Habitat of the Spotted Wolffish (*Anarhichas minor*) Order (Registration SOR/2020-186) was promulgated in the Canada Gazette Part II on September 16, 2020 (Government of Canada 2020) This critical habitat overlaps with portions of the Labrador Shelf SEA Update Area as shown in Figure 5-6. An Action Plan has been published for spotted wolffish (DFO 2020f).

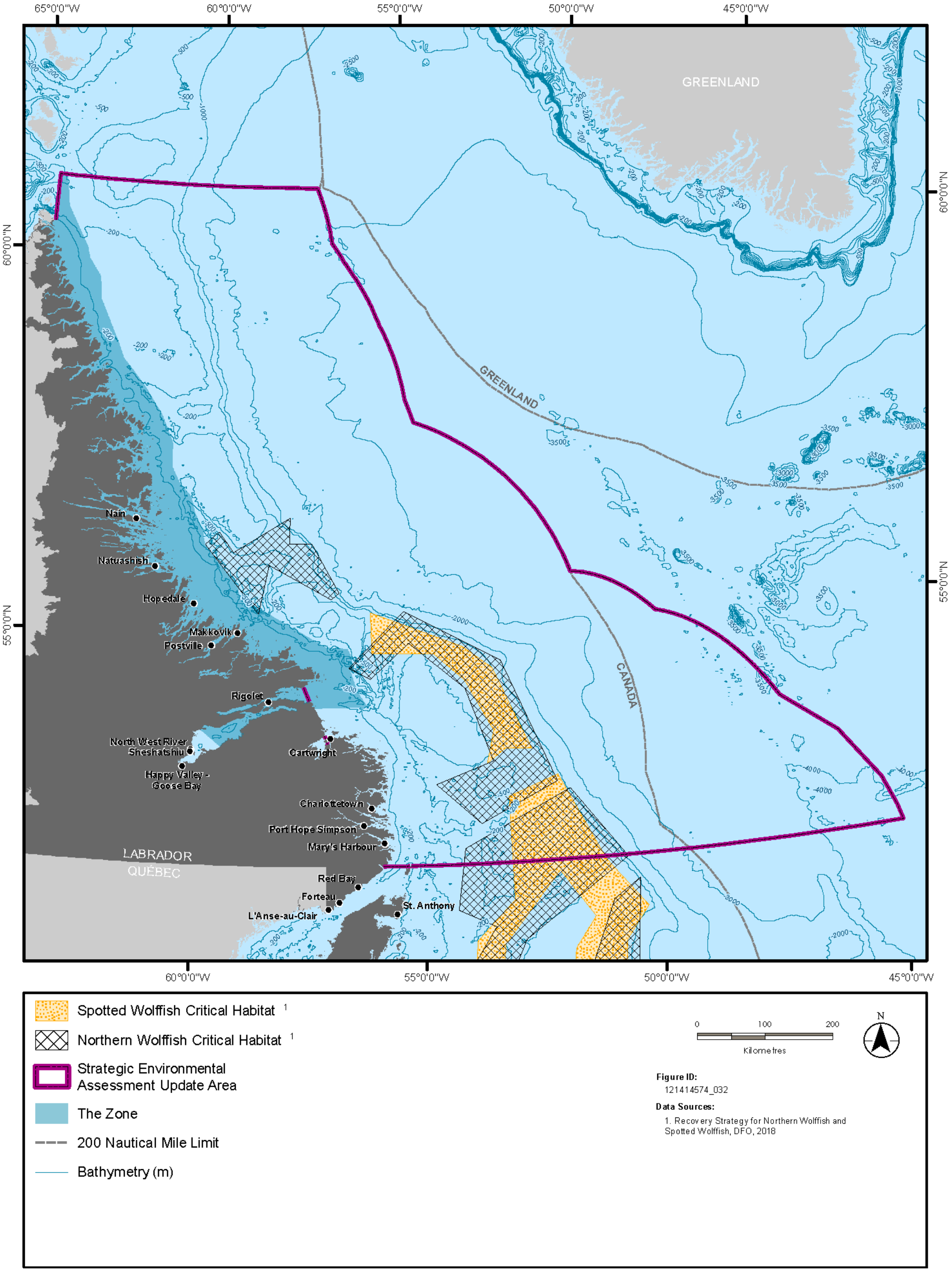

Figure ID:
121414574_032

Data Sources:
1. Recovery Strategy for Northern Wolffish and Spotted Wolffish, DFO, 2018

Figure 5-9 Location of Defined Critical Habitat for Northern and Spotted Wolffish

5.5.1.2 Atlantic Salmon

Information regarding life history and biology of Atlantic salmon is provided in Section 5.4.2.3. There are nine populations of Atlantic salmon that are listed as SAR with potential to occur in the Labrador Shelf SEA Update Area, and these are provided in Table 5.5 along with their listings. Of these, the Inner Bay of Fundy population is the only one listed under Schedule 1 of SARA. Tagging studies have shown that this population undertakes more localized migrations compared to other populations in Atlantic Canada (Lacroix 2013), though it still has the potential to occur as a transient in the Labrador Shelf SEA Update Area. As the only SARA listed population, critical habitat has been designated as per the Critical Habitat of the Atlantic Salmon (*Salmo salar*) Inner Bay of Fundy Population Order (SOR-2019-322) (Government of Canada 2019). A Recovery Strategy was issued in 2010 (DFO 2010a) and an Action Plan was published in 2019 (DFO 2019c).

As described in Section 5.4.2.3, there are other populations of salmon that occur within the Labrador Shelf SEA Update Area that are not currently assessed as SAR or are data deficient. Salmon populations in Atlantic Canada and originating from the United States of America (ICES 2021) have been shown to migrate up the coast of Labrador to Greenland or the Labrador Sea to overwinter (e.g., Lacroix 2013). As described in Section 5.4.2.3, the Labrador Sea has been identified as an important aggregation area for multiple populations of Atlantic salmon from North America and Europe (Bradbury et. al. 2021).

The Recovery Strategy published for Atlantic salmon from the Inner Bay of Fundy Population in 2010 identified critical habitat for freshwater environments, located in Nova Scotia and New Brunswick and well outside the Labrador Shelf SEA Update Area. There were no areas of marine critical habitat identified for this species due to uncertainty of distribution and habitat use of the species in marine environments (DFO 2010a).

Threats to Atlantic salmon include climate change, changes to ocean ecosystems, fishing (commercial, subsistence, recreational, and illegals), dams and other obstructions in freshwater, agriculture, urbanization, acidification, aquaculture, and invasive species (COSEWIC 2010a).

5.5.1.3 White Shark

In the Northwest Atlantic, white sharks are found in inshore temperate waters over the continental shelves, and in Atlantic Canadian waters, they have been recorded from Northeast Newfoundland Shelf, the Strait of Belle Isle, the St. Pierre Bank, the Sable Island Bank, the Fochu Misaine Bank, in St. Margaret’s Bay, off Cape La Have, in Passamaquoddy Bay, in the Bay of Fundy, in the Northumberland Strait, and in the Laurentian Channel (COSEWIC 2006b). In recent years OCEARCH has been conducting a tagging program in Nova Scotia off of Cape Breton and near the LaHave Islands. These areas appear to be hotspots for white sharks during the summer and fall (OCEARCH 2020). They have the potential to occur within the Labrador Shelf SEA Update Area. White Shark can range in water depth from the surface to 1,300 m, are highly mobile, and migrate seasonally (COSEWIC 2006b). Individuals in Atlantic Canada are likely seasonal migrants belonging to a widespread Northwest Atlantic population (COSEWIC 2006b). It appears that white sharks undertake a seasonal north-south migration, where they have been shown to spend the winter months off Georgia, Florida, and in the Gulf of Mexico, while they spend the summer months off Massachusetts and Atlantic Canada. It is hypothesized that the migration is driven by environmental preferences (e.g., temperature), as well as prey availability (Curtis et al. 2014).

Females are ovoviviparous with a gestation period of 14 months, giving birth to an average of seven pups. It is believed that pupping takes place in the Mid-Atlantic Bight (COSEWIC 2006b). There have been no surveys in Canadian waters to determine the population size of the white shark. Information on the global population size is sparse, although most sources agree that the species is relatively rare (COSEWIC 2006b).

White shark is listed as Endangered under Schedule 1 of SARA and by COSEWIC. A “White Shark Recovery Strategy for Atlantic Canadian waters” was proposed in 2020, while an Action Plan is being formulated in 2021. Critical habitat has not been identified at the time of writing this SEA Update.

Human-induced mortality is the greatest threat to white sharks, and this species is caught as bycatch in commercial fisheries, as sport fish, and caught intentionally for international trade of their valuable body parts (COSEWIC 2006b). In the Northwest Atlantic, this species is commonly caught as bycatch in pelagic longline fisheries (COSEWIC 2006b).

5.5.2 Species of Conservation Concern

The following provides species descriptions of fish species in Table 5.5 that have been identified as SOCC. These are not legally protected but have been recognized as species that could potentially receive protection if conditions for that species do not improve or decline further.

5.5.2.1 Atlantic Cod

Atlantic cod (*Gadus morhua*), including the distinct Gilbert Bay Atlantic cod population, are found in coastal, nearshore, and offshore areas from water depths of a few metres up to 500 m. Atlantic cod from the NL population range from the southern Grand Banks to the northern tip of Labrador, north of Cape Chidley (COSEWIC 2010b). This species is generally found in water temperatures ranging from 2°C to 11°C, though cod in some areas of Newfoundland are found in temperatures as low as -1.5°C.

The NL population of Atlantic cod has declined since the 1990s and currently remains in the Critical Zone (DFO 2019d). There is a high probability that the stock will continue to decline. Data from the DFO multispecies RV surveys show that Atlantic cod were found throughout most of the NL waters during 1981-1995 survey years, which roughly corresponds to the pre-collapse period. However, during 1995-2017 survey years, NAFO Divisions 2J3K show the highest relative densities, with high densities also occurring in 3P and along the southwest portion of the Grand Bank (Wells et al. 2021).

Atlantic cod have been observed to spawn throughout the year in both offshore and inshore waters, depending on the location (COSEWIC 2010b). Peak spawning occurs during the spring. Fish from the NL population reach sexual maturity at five to seven years of age. The eggs and larvae are pelagic and float on the surface, drifting with the oceanographic conditions at the time of spawning (COSEWIC 2010b). Females produce several million eggs, though only one egg typically survives to maturity. Eggs and larvae may be present in the upper water column of the Grand Banks year-round (COSEWIC 2010b).

For the first few weeks of life, Atlantic cod reside in the upper 10 to 50 m of the water column (COSEWIC 2010b). In general, prey availability and temperature are the primary factors determining habitat selection for cod. Juvenile cod prefer habitats that provide protection and cover such as nearshore waters with eelgrass or areas with rock and corals (COSEWIC 2010b).

Atlantic cod are designated as vulnerable by IUCN (Sobel 1996a) and the NL population of Atlantic cod is listed as Endangered by COSEWIC. The overall decline of Atlantic cod range-wide was primarily caused by overfishing, which was exacerbated by life history changes such as reductions in individual growth and age at maturation (COSEWIC 2010b). Current threats to Atlantic cod include ongoing exploitation through directed commercial fisheries, recreational fisheries, and bycatch in fisheries for other groundfish (COSEWIC 2010b).

The NunatuKavut Community Council described historical cod fishing commercially and for food by jigging, angling, gill nets and traps in the 1960s and 1970s and observed a decline in populations in the 1980s (NunatuKavut Community Council 2019). Trapping was done in May/June to August. Cod were historically so abundant that a day of trapping could produce a two-year supply for a family, and NunatuKavut Community Council observed that cod populations are rebounding. The NunatuKavut Community Council observed that cod “leave the land” in September / October and go offshore. Winter cod are caught by ice fishing or with a jigger (NunatuKavut Community Council 2019). The NunatuKavut Community Council cod fishery is described in Section 9.4.3.

Atlantic cod are harvested and distributed Nunatsiavut-wide and is a very important species to Labrador Inuit for cultural and subsistence purposes. In some locations, Nunatsiavut Government observed an increase in Atlantic cod abundance in the past two to three years, and cod have been noted as getting bigger each year. This has been attributed to the moratorium, which allowed the cod fish population to recover (Nunatsiavut Government 2018).

Fluctuations are also reported and have been linked to changes in capelin abundances (Nunatsiavut Government 2018). Some locations have seen decreases in cod abundance and cod size, and Nunatsiavut Government observed less food in the bellies of cod in recent years, highlighting reduction in capelin abundance as a potential reason for the declining cod abundance and size. However, Nunatsiavut Government noted that capelin do not come into shore anymore, and the fluctuating abundances could be a matter of change in cod distribution, as opposed to abundance (Nunatsiavut Government 2018). Change in weather has also been noted as a potential cause of the declining cod abundance (Nunatsiavut Government 2018).

The commercial and traditional importance of Atlantic cod is discussed further in Section 9.2. There is also a recreational fishery for Atlantic cod, as indicated in Section 9.3.

5.5.2.2 Atlantic Bluefin Tuna

Atlantic bluefin tuna are distributed throughout the North Atlantic Ocean from Newfoundland to the Gulf of Mexico and are typically found in Canadian waters during the summer (Maguire and Lester 2012). Adults migrate seasonally to Canadian waters, including the continental shelf off Newfoundland, from June to October and may remain until December (COSEWIC 2011).

Bluefin tuna is a pelagic species that typically occupies waters up to 200 m in depth, though it has been shown in tagging studies that it can dive to depths of 500 to 1,000 m and can tolerate a wide range of temperatures (3°C to 30°C) due to its ability to regulate its own body temperatures (COSEWIC 2011). Bluefin tuna typically prey upon herring, mackerel, capelin, silver hake, white hake, and squid (NOAA 2013c). Bluefin tuna may also feed on jellyfish, salps, and demersal and sessile fish and invertebrate species (NOAA 2013c).

This species has a life expectancy of up to 20 years and reaches sexual maturity at approximately eight years of age. In the Northwest Atlantic, spawning takes place in the Gulf of Mexico and the Slope Sea (Richardson et al. 2016). Female tuna produce up to ten million eggs a year, which are fertilized in the water column by males, and these eggs may hatch as early as two days after spawning (COSEWIC 2011).

The population estimates for adult bluefin tuna show a decline in the 1970s and 1980s, followed by a small increase until the late 1990s, followed by another decline until 2010, which were the most recent data available at the time of the estimate (COSEWIC 2011). The population estimate in 2010 was 65,923 individuals (COSEWIC 2011). Natural mortality rates are considered low (Block et al. 2019).

Atlantic bluefin tuna are listed as Endangered by COSEWIC. Historical and present-day overfishing remains the single largest threat to the Northwest Atlantic population of bluefin tuna (COSEWIC 2011). In 2011, the Atlantic bluefin tuna was classified on the IUCN Red List as Endangered (Collette et al. 2015d).

5.5.2.3 American Plaice

American plaice (*Hippoglossoides platessoides*) is a bottom-dwelling flatfish that resides on both sides of the Atlantic (COSEWIC 2009a). American plaice that reside in the Northwest Atlantic range from the deep waters off Baffin Island and western Hudson Bay southward to the Gulf of Maine and Rhode Island (Scott and Scott 1988). Data from the DFO multispecies RV surveys show that American plaice were distributed widely throughout NAFO Division 2J south to 3P during 1981-1995, while the more recent survey data (1995-2017) indicate that the highest relative densities occur on the southern portion of the Grand Bank (Wells et al. 2021). In NL waters, American plaice occurs both inshore and offshore over a wide variety of bottom types (Morgan 2000). They are tolerant of a wide range of salinities and have been observed in estuaries (Scott and Scott 1988; Jury et al. 1994). They are typically found at depth of approximately 90 to 250 m, but have been found as deep as 713 m. Most commercially harvested plaice are taken at depths of 125 to 200 m. American plaice is a cold-water species, preferring water temperatures of 0°C to 1.5°C (Scott and Scott 1988). Tagging studies conducted on juvenile and adult plaice on the Grand Banks and in St. Mary’s Bay showed that the species is sedentary, with most recaptures occurring within 48 km of release (Pitt 1969). However, older plaice have been known to move up to 160 km (Powles 1965). Migrations have been observed from Canadian waters to deeper offshore waters in the winter, returning to shallower water in the spring (Hebert and Wearing-Wilde 2002, in Johnson 2004).

American plaice spawn during the spring in Newfoundland waters. The current age of sexual maturity for females in the area (NAFO divisions 2K and 3K) is approximately eight years with a length at maturity of approximately 30 cm (Busby et al. 2007). During spawning, large quantities of eggs (between 250,000 and 300,000) are released on the seabed (Johnson 2004). Once fertilized, eggs become buoyant and drift into the upper water column, where they are widely dispersed, allowing time for some intermingling of stocks. Among adults, there is minimal intermingling of stocks. Hatching time is temperature dependent, occurring between 11 and 14 days at temperatures of 5°C (Scott and Scott 1988). Larvae are non-dorsally flattened and are 4 to 6 mm in length when they hatch. Larvae begin to settle to the seabed when they reach 18 to 34 mm in length and their body flattens (Fahay 1983).

Larval plaice feed on phytoplankton and zooplankton while in the upper water column (Pitt 1989). Once larvae have settled on the seafloor, their diet changes as their grow, ingesting larger benthic organisms depending on location. Small plaice (less than 30 cm) consume crustaceans and small echinoderms (Pitt 1973). Adult plaice generally consume large quantities of fish. Feeding intensity is highest during the spring and summer, likely to replenish energy stores lost during gonad development during the winter (Zamarro 1992).

The NL population of American plaice is listed as Threatened by COSEWIC; it has no IUCN designation. the major cause of the decline in American plaice is overfishing; however, there may be other contributing factors, such as increased natural mortality from a period of unusually cold ocean temperatures in the 1990s (COSEWIC 2009a).

5.5.2.4 Basking Shark

Basking sharks (*Cetorhinus maximus*) are found throughout the North Atlantic Ocean, with observations in the coastal waters of Newfoundland and near the mouth of the Bay of Fundy. There is limited information on the population size and trends of basking sharks; conservative total population estimates for Atlantic Canada range between 4,918 and 10,125 individuals (COSEWIC 2009b).

Habitat requirements for basking shark in Canadian waters have not been investigated but is believed that this species lives primarily in ocean fronts where zooplankton, their main food source, congregates (COSEWIC 2009b). Tagging studies have shown basking sharks occupying surface waters to depths of over 1,200 m (Bizzarro et al. 2017).

The life span of basking sharks is believed to be 50 years, with males maturing earlier than females; males mature between 12-16 years of age while females mature at 16-20 years of age (COSEWIC 2009b). Basking sharks can reach lengths of up to 9.8 m (Bizzarro et al. 2017). Males and females pair up during summer months to mate; females have a gestation period of 2.6 to 3.5 years and give birth to approximately six pups with an average length of 1.5 to 2 m (COSEWIC 2009b).

The global population of basking shark are designated as endangered by IUCN (Rigby et al. 2021). The Atlantic population of basking shark is listed as Special Concern by COSEWIC. Characteristics of this species' life history, such as a late age of maturity, low fecundity, long gestation periods, and overlapping habitats with commercial fisheries make this species vulnerable to human impacts (COSEWIC 2009b). In the Northwest Atlantic, the single biggest threat to basking sharks is bycatch in domestic and foreign offshore fisheries in Atlantic Canada (COSEWIC 2009b). Ship collisions may be another threat given the surface-living habits of this species and its maximum length of over 15 m (the second largest living fish) (COSEWIC 2009).

5.5.2.5 Cusk

Cusk (*Brosme brosme*) is a northern species that inhabits subarctic and boreal shelf waters of the North Atlantic (COSEWIC 2012d). Cusk occurs in the deep waters along the edge of the continental shelf off NL, though its occurrence is rare (COSEWIC 2012d).

Cusk are found in water with temperatures of 0°C to 14°C, with a preference of 6°C to 10°C (COSEWIC 2012d). Cusk are rarely found in the nearshore and occur mostly at depths of 150 to 450 m over hard, rough and rocky substrates (COSEWIC 2012d). Cusk have swim bladders that are disconnected from their esophagus, which makes them susceptible to injury if brought to the surface quickly (Chen and Runnebaums 2014). Sudden surfacing events (e.g., being hauled up to the surface in a lobster trap) can result in overexpansion or rupture of the swim bladder, stomach eversion, exophthalmia, intestinal protrusion through the cloaca, external hemorrhaging, organ torsion, subcutaneous gas bubbles, and ocular gas bubbles. Juveniles and adults are slow-moving, sedentary, and solitary and are strongly associated with substrate (COSEWIC 2012d). Their diet is generalized and has been found to include crab and krill species, a variety of fish species, molluscs, and shortfin squid (*Illex illecebrosus*) (DFO 2014b).

Cusk are a slow-growing and later-maturing species with males maturing at five years and females at seven (SAR 2013a). Based on observations from egg and larval surveys, spawning appears to be widespread, and this species does not form spawning aggregations (COSEWIC 2012d). Spawning occurs between May and August with females laying from 100,000 to over a million eggs. The eggs are buoyant and hatch 4 mm larvae that remain buoyant until settling to the bottom at a size of 50 to 60 mm. Population trends for the species indicate a decline of 93.4% from 1970 to 2001 (COSEWIC 2003).

Cusk are listed as Endangered by COSEWIC and have no designation under IUCN. Overfishing is the most important threat to cusk, and this species is caught as bycatch in fisheries for Atlantic cod, haddock, pollock and Atlantic halibut, and can also be caught in lobster traps (COSEWIC 2012d). There are no known additional anthropogenic threats that have reduced cusk habitat quantity or quality (DFO 2014b). Cusk numbers are observed through the Halibut Industry Survey, which tracks the commercial catch per unit effort (CPUE). The CPUE for cusk has fluctuated since 1999; no trends have been observed (Harris et al. 2018). This appears to suggest that population abundance has stabilized. The three-year geometric mean from 2017 to 2019 showed that cusk biomass has remained above the Limit Reference Point (LRP) of 17.7 kg. The mean cusk biomass has remained above 17.7 kg since 2008 (DFO 2020g). The effects of climate change are expected to result in loss of habitat for cusk, which will result in further pressures on population numbers (Hare et al. 2012).

5.5.2.6 Lumpfish

Lumpfish (*Cyclopterus lumpus*) are widely distributed on both sides of the North Atlantic Ocean, as well as in the Arctic Ocean (Simpson et al. 2016a). In the Northwest Atlantic, lumpfish range from south Greenland, off of Baffin Island south to Chesapeake Bay (Simpson et al. 2016a). Data from the DFO multispecies RV surveys show that NAFO Division 3P have been important for lumpfish. However, northern areas (i.e., NAFO Divisions 2J3K) have become more important for this species in the recent years (1995-2017) (Wells et al. 2021).

Lumpfish are a benthic species found on rocky substrates between 50 to 150 m, and occasionally as deep as 400 m and prefer water temperatures of ≤4°C (Simpson et al. 2016a). Young of the year lumpfish may also occur in floating seaweed. Larvae and young of the year lumpfish are typically found in waters at temperatures of 4 to 12°C, while juveniles and adults have been found in waters with temperatures between -1.9 and 12°C (COSEWIC 2017). Lumpfish is distinguished by its short, stout body, which is covered by hard, wart-like protrusions (tubercles). The caudal fin is broad based, and square tipped. The pectoral fins are larger on males, are rounded, and nearly meet on the throat (Bigelow and Schroeder 2002). The pelvic fins of the species are modified and united by a circular flap of skin that forms a sucking disc that enable lumpfish to adhere to the bottom or to floating objects, such as rocks, lobster traps, and other solid objects (DFO 2006d).

Lumpfish undergo a coastal migration for spawning, which takes place in May and June (DFO 2006d). Lumpfish exhibit sexual dimorphism, with male lumpfish being considerably smaller than the females. Males arrive on the spawning grounds several weeks in advance of the females to establish their territories. Females lay two to three egg masses at intervals ranging from 8 to 14 days. Once the eggs are deposited, females migrate back to deeper water, leaving males to guard and fan the egg masses (DFO 2002b, 2006d). Egg masses may contain more than 100,000 to 130,000 eggs measuring 2 mm in diameter with one oil globule and are light green to yellowish in colour. Juveniles are semi-pelagic, remaining in the top metre of the water column for their first year, during which they are often associated with floating algae.

Lumpfish feed on a wide variety of pelagic and benthic prey, including fish eggs and larvae, ctenophores, amphipods, copepods, euphausiids, mysids, small fish, polychaetes, and molluscs (Simpson et al. 2016a).

Lumpfish are listed as Threatened by COSEWIC and have no designation under IUCN. Review of studies and fisheries landings suggest that the lumpfish population in Canada has been depleted (Kennedy et al. 2018). Natural and anthropogenic threats to lumpfish include changes in seawater temperature and salinity, physical destruction of spawning/nesting habitat, pollution in shallow-water nursery grounds, directed fishing and bycatch of adults, and seismic exploration (Simpson et al. 2016a; COSEWIC 2017). In Canada, species management includes measures such as vessel, gear, and seasonal restrictions (COSEWIC 2017).

5.5.2.7 Porbeagle Shark

In the Northwest Atlantic, porbeagle sharks occur in temperate waters from northern NL south to New Jersey, and possibly South Carolina, with mature females ranging further south to the Sargasso Sea (COSEWIC 2014; Campana et al. 2015c). The porbeagle shark population primarily inhabits Canadian waters (Campana et al. 2015c). Porbeagle sharks are a pelagic species that can be found from the coast to the open sea; however, they are known to commonly inhabit continental shelves and ocean basins at water depths up to 700 m. They have also been found closer to shore, although this is more occasional (SAR 2013b). Generally, porbeagle sharks in Canadian waters can be found at temperatures ranging from 5°C to 10°C, with little variation from one season to the next, suggesting that they travel about to remain in the cold waters they prefer (SAR 2013b). They are generally found in depths less than 200 m along the shelf edge, though porbeagles are among the deepest diving of pelagic sharks, with a maximum recorded depth of 1,360 m (COSEWIC 2014).

Male porbeagle sharks mature at eight years with females maturing at 13 years and have a life expectancy of 25 to 46 years. Mating occurs from late September to November and females are ovoviviparous having a gestation period of eight to nine months. Porbeagle sharks are known to have low fecundity, with females only having an average of four pups per year (Simpson and Miri 2014). It has been determined that females in the northwest Atlantic population do not reproduce annually, but every other year (biennially) (Natanson et al. 2019). Females leave the continental shelf in December travelling at great depths (>500 m), swimming up to 2,500 km to the Sargasso Sea (DFO 2013e). Females give birth there in March and April inhabiting the deep, cool waters. The young start appearing in Atlantic Canadian waters in June and July. It is believed that the young sharks “hitch a ride north” on the deep, cool sections of the Gulf Stream (DFO 2013e).

Immature porbeagle sharks inhabit the Scotian Shelf with mature individuals migrating along the shelf waters to mating grounds located on the Grand Banks, off the mouth of the Gulf of St. Lawrence, and on Georges Bank from September to November. There is a population which undertakes extensive annual migrations and from January to February; this population can be found in the Gulf of Maine, Georges Bank, and the Southern Scotian Shelf. By the spring they can be found on the edge of the Scotian Shelf and in offshore basins. In the summer and fall, they can be found off the southern coast of Newfoundland and in the Gulf of St. Lawrence (Campana et al. 2013).

The population estimate for this species in 2009 was thought to be approximately 197,000 to 207,000 individuals, which included 11,000 to 14,000 spawning females (COSEWIC 2014). Since 1961, the abundance of this species has declined by 56% to 70% (COSEWIC 2014). This decline has been reduced over the last decade, due to a reduction in this fishery, and Nunatsiavut Government (2018) have observed an increase in porbeagle sharks in some locations in the past 10 years.

Porbeagles are listed as Endangered by COSEWIC and are designated as vulnerable under IUCN (Rigby et al. 2019a). The overfishing of porbeagles in the Northwest Atlantic in 1960s and then again in the 1990s led to two successive population collapses (COSEWIC 2014). Though the directed fishery for porbeagles was discontinued in 2013, porbeagle is still taken as bycatch in swordfish and tuna longline fisheries, groundfish longline fisheries, as well as gillnet and bottom trawl fisheries (COSEWIC 2014). Unknown and unregulated catches may further undermine population recovery for this species (COSEWIC 2014).

5.5.2.8 Redfish (*Sebastes* spp.)

Redfish, or ocean perch, are benthic fish that inhabit areas with rocky or clay-silt substrates along the slopes of banks and in deep channels at water depths of 100 to 700 m and temperatures of 3°C to 8°C. Redfish are distinguishable by their large eyes, a bony protrusion on the lower jaw, and a fan of bony spines around the gill covers. Redfish remain on or near the seabed during the days, rising into the water column at night to feed. Redfish are stratified by size, with smaller fish occupying shallow waters, and larger fish in deeper waters (McKone and LeGrow 1984; Scott and Scott 1988).

The three species of redfish found in the Northwest Atlantic are Acadian redfish (*Sebastes fasciatus*), Atlantic redfish (*S. marinus*), and deepwater redfish (*S. mentella*). These species are nearly impossible to distinguish by appearance and are managed as a single fishery (Power and Mowbray 2000; Gascon 2003). Data from the DFO multispecies RV surveys (1981-1995 and 1995-2017) show that distribution of redfish (*S. mentella* and *S. fasciatus*) is consistent across both survey periods, with high relative density found along the continental shelf edge and slope (Wells et al. 2021).

Populations of Acadian and deepwater redfish are allopatric and are separated geographically. The vast majority of redfish occupying the north of the Labrador Sea are deepwater redfish, whereas Acadian redfish is more prevalent in the Gulf of Maine and Scotian Shelf (COSEWIC 2010c). The ranges for deepwater and Acadian redfish overlap in the Laurentian Channel and the Grand Banks (Gascon 2003). In areas where deepwater and Acadian redfish intermix, deepwater redfish is generally distributed deeper than Acadian redfish (Power and Mowbray 2000; Gascon 2003). The Gulf of St. Lawrence, the Laurentian Channel, Grand Banks, southern Labrador Sea, and Flemish Cap comprised an area of symmetry separating the two allopatric species.

Redfish are slow-growing and long-lived, with specimens having been aged at least to 75 years (Campana et al. 1990). Acadian redfish grows slower than deepwater redfish, with females growing faster than males. Growth in southern areas is usually faster when compared to that in northern areas (Branton et al. 2003).

On the continental slopes of Labrador, redfish mature between 10 to 12 years. Mating likely occurs during the late fall and early winter. Redfish are ovoviviparous with internal fertilization, which means that the fertilized eggs hatch inside the females and they give birth to live young (Scott and Scott 1988; Gascon 2003). Females carry developing embryos until spring (St. Pierre and de Lafontaine 1995; Gascon 2003; Morin et al. 2004). Following birth, larvae remain in shallow waters until they are approximately 25 mm in size, after which they move to deep waters over mud and rock substrates.

Redfish are pelagic or bathypelagic feeders, feeding primarily on zooplankton, including copepods, amphipods and euphausiids. As redfish increase in size, fish and crustaceans become more important in the diet. Feeding is believed to occur at night when redfish rise off the bottom and feed on pelagic organisms in the water column (Scott and Scott 1988). Although this diel vertical migration is well documented, it is poorly understood (Gascon 2003). Redfish larvae feed along exclusively on calanoid copepods (Runge and de Lafontaine 1996). Variability in the annual production cycles of these copepods can be an important factor in interannual differences in growth and survival of redfish larvae (Anderson 1994).

Redfish stock structure and resulting management strategies are complex due to the recognition of three species, as well as the occurrence of introgressive hybridization individuals (Morin et al. 2004). The stock structure of redfish has been examined via parasite tagging and genetic analyses. The parasite tagging studies confirmed distinct redfish stocks occurred off Labrador and the Flemish Cap (Marcogliese et al. 2003; Morin et al. 2004). The results of the parasite tagging study are only partly supported by population genetic studies (Morin et al. 2004).

The Acadian redfish is designated as endangered by IUCN (Sobel 1996b), while the deepwater redfish has been designated as least concern (Acero et al. 2010). The Atlantic population of Acadian redfish and the northern population of deepwater redfish are both listed as Threatened by COSEWIC. Long life spans, late maturation, and slow growth are considered limiting factors in redfish species having low resilience (COSEWIC 2010c). The primary threats to redfish have been directed fisheries, with substantial catches taken in various regions since the 1950s; directed fisheries are closed in some areas but continue in others and redfish are also caught as bycatch in other fisheries (COSEWIC 2010c). Like other groundfish, unfavourable environmental conditions may have also contributed to the decline of redfish, and seal predation also contributes to mortality in some areas (COSEWIC 2010c).

5.5.2.9 Roundnose Grenadier

The roundnose grenadier is a continental slope species with the deeper part of its geographic range not well surveyed (COSEWIC 2008). It is more abundant in the northern portion of its Canadian range including Labrador and Northeast Newfoundland shelves and Davis Strait. It is closely associated with the seafloor and commonly found inhabiting waters 800 to 1,000 m in depth but has been found in water depths of up to 2,600 m. They are known to form aggregations (Bergstad 1990 in Bergstad et al. 2013). Data from the DFO multispecies RV surveys show that the species are found throughout the surveyed areas of Labrador Shelf SEA Update Area (i.e., NAFO Divisions 2HJ) (Wells et al. 2021). Distribution patterns of roundnose grenadier have remained consistent throughout time (1981-2017), and they are found in deeper waters than were sampled during 1981-1995 survey years (Wells et al. 2021).

Like the roughhead grenadier, the roundnose grenadier is a relatively long-lived, slow-growing species that can reach a total length of over 100 cm (Simpson et al. 2011). Females reach maturity at about 10 years of age and have been reported with a maximum age of 60 years, although maturity appears to be related to size more so than age (Simpson et al. 2011; COSEWIC 2008). Spawning is believed to occur year-round with peaks at different times for different areas. Females will spawn 12,000 to 25,000 pelagic eggs.

Roundnose grenadier off northern NL have been observed moving up and down continental slopes, moving to deeper water in the winter and shallower water in the summer. They have also been observed to carry out diurnal vertical migrations of 1,000 m off the bottom. The species feeds in the water column on a variety of prey items including: crustaceans (e.g., copepods, shrimp, amphipods, mysids), squid, and small fish (e.g., lantern fish, deep-sea smelts, sculpins) (COSEWIC 2008; Simpson et al. 2011). In the northwest Atlantic they are typically found in waters at temperatures between 3.5 and 4.5°C, but have also been found in waters at 6°C (Simpson et al. 2011).

Roundnose grenadier are listed as Endangered by COSEWIC. As mentioned above, this species is long-lived, slow-growing, late to mature, and have low fecundity; which are limiting factors to population recovery (DFO 2010b). The main source of mortality to roundnose grenadier is commercial fisheries, as this species is captured as bycatch in fisheries inside and outside Canadian waters. Natural mortality rates are considered high as they are poor swimmers which makes them vulnerable to predation (Simpson et al. 2011). There may also be direct and indirect threats to the survival and recovery of this species as a result of environmental changes such as shifts in temperature (DFO 2010b). The roundnose grenadier is classified on the IUCN Red List as Critically Endangered (Iwamoto 2015).

5.5.2.10 Shortfin Mako

Shortfin makos are distributed circumglobally in tropical and temperate seas; in Atlantic Canadian waters, the shortfin mako is typically associated with warm waters such as in and around the Gulf Stream. Makos have been recorded from Georges and Browns Banks, along the continental shelf of Nova Scotia, the Grand Banks, and Gulf of St. Lawrence (COSEWIC 2006c). The North Atlantic population is considered to be a discrete population (Showell et al. 2017).

The shortfin mako is a pelagic species that migrates north following food stocks (i.e., mackerel, herring, and tuna) during the late summer and fall. They are associated with continental shelf and offshore waters (Showell et al. 2017). The species prefers warm-water temperatures ranging from 17 C to 22°C, is typically associated with Gulf Stream waters, and occurs from the surface down to 500 m (COSEWIC 2006c). It is rarely found in waters with temperatures less than 16°C. Mako are apex opportunistic predators with a wide prey base that include fish such as tuna, mackerel, and swordfish, as well as squid (COSEWIC 2006c).

Females mature at 2.6 to 3.0 m, which corresponds to a median weight of 275 kg. Males mature at 1.7 to 2.2 m, which corresponds to a median weight of 64 kg (COSEWIC 2006c; Natanson et al. 2020). Few mature individuals are found in Canadian waters (COSEWIC 2006c). Longevity is estimated to be between 24 to 45 years. Females are ovoviviparous and have litters of 4 to 25 pups after a 15- to 18-month gestation period and have an estimated three-year parturition cycle. Pups are born at a length of 70 cm. Shortfin makos have a life span ranging from 25 to 45 years (COSEWIC 2006c). There are no reliable population-level stock estimates available for the shortfin mako in the North Atlantic. Trend estimates, based on declines in catch rates in the entire Northwest Atlantic, suggest that the shortfin mako populations may have decreased by 50% to 79% (COSEWIC 2006c).

The Atlantic population of shortfin mako is listed as Endangered by COSEWIC. Makos are caught as bycatch in pelagic fisheries worldwide and fishing is the single largest threat to mako populations (COSEWIC 2006c). A tracking study conducted between 2016 and 2020 showed that individuals tagged in the northwest Atlantic travelled through at least 12 different jurisdictions, which exposed individuals to a variety of fishing pressures and harvest regulations (Gibson et al. 2021). Their low fecundity and late age at maturity make population recovery a slow process (Byrne et al. 2017). In 2019, the shortfin mako was classified on the IUCN Red List as Endangered (Rigby et al. 2019b).

5.5.2.11 Smooth Skate

Smooth skate (*Malacoraja senta*) is found along the Atlantic coast of North America, ranging from the Gulf of St. Lawrence and Labrador Shelf to South Carolina (Packer et al. 2003). Data from the DFO multispecies RV surveys show that distribution of high relative density areas for smooth skate are quite different across the two time series (1981-1995 and 1995-2017), with a shift in high density, important areas in the earlier time series to low relative densities in the later time series. This may be due, in part, to sampling effort. However, the change from high to low relative densities for the Funk Island Deep stock of smooth skate may also be due to its assessment as endangered and a decrease in overall abundance (DFO 2017), which would show shifts of important areas over time (Wells et al. 2021). Smooth skate live on soft mud and clay bottoms, often in deep troughs and basins (Scott and Scott 1988). The smooth skate occurs over a fairly wide range of depths with the shallowest and deepest records of this species at 25 and 1,436 m, respectively. Ninety percent of survey sets containing smooth skate occur between 70 and 480 m and prefer temperatures between -1.3°C and 15.7°C (COSEWIC 2012e). The densest concentrations occur in the troughs surrounding the banks where the temperature is warmer. This includes habitat within the Hopedale Channel, the Hawke Channel and Funk Island Deep Bank, at least in certain seasons. Feeding studies indicate that smooth skate is quite selective in its diet, eating primarily small crustaceans throughout most of its life, and fish only at the largest sizes (McEachran 1973, 2002; McEachran et al. 1976; González et al. 2006; COSEWIC 2012e). DFO conducted a zonal review of information on the smooth skate in 2006, at which time it was decided that individuals 48 cm and above would be considered adults and those under 48 cm would be considered immature (Swain et al. 2012). Reproduction appears to occur throughout the range, with egg cases having been found on the bottom throughout the year within the habitat range (Simon et al. 2012; COSEWIC 2012e). Fully mature females, some containing partially or fully formed egg cases, have also been observed in most parts of the Canadian range including from the Hopedale Channel and Funk Island Deep off the coast of Labrador.

There are five populations of smooth skate in Atlantic Canada, and two of these occur within the Labrador Shelf SEA Update Area. The Hopedale Channel and the northern portion of the Funk Island Deep Bank populations have a range which overlap with the Update Area. The Funk Island Deep population is listed as Endangered by COSEWIC due to declines in abundance of both adult and young individuals. DFO fall surveys in the Funk Island area show that indices have been above average since 1995 (DFO 2017). The Hopedale Channel population is considered data deficient and no status has been designated. Data to date suggest that the habitat range has fluctuated over time, with an increase since 1990, and that the abundance of mature individuals has fluctuated without trend. Globally smooth skate are designated as vulnerable under IUCN (Kulka et al. 2020a).

Though smooth skate are not targeted in commercial fisheries, and incidental catches of this species in Canadian waters have declined since the mid-1990s, bycatch in fisheries remains the biggest threat to smooth skate (COSEWIC 2012e). Increased natural mortality may also be a limiting factor in some areas (COSEWIC 2012e).

5.5.2.12 Spiny Dogfish

Six species of small dogfish are resident in Canadian waters, with the spiny dogfish and black dogfish being the most abundant. Other demersal sharks in Canadian waters include the smooth dogfish (*Mustelus canis*), Portuguese shark (*Centroscymnus coelolepis*), deep sea cat shark (*Apristurus profundorum*), and great lantern shark (*Etmorpterus princes*).

Spiny dogfish (*Squalus acanthius*) is a widely distributed, boreal to warm temperate species distributed over continental and insular shelves and upper slopes of the Pacific and Atlantic Oceans (Kulka 2006). In the Northwest Atlantic, its distribution ranges from southern NL to North Carolina, with its centre of abundance located between the southern Scotian Shelf and Cape Hatteras (COSEWIC 2010d; DFO 2014c). The Atlantic Canadian population of spiny dogfish is thought to consist of both resident and migrating components (COSEWIC 2010d).

Spiny dogfish have been observed from the surface down to 730 m water depth, though this species mainly concentrates at depths of 10 to 200 m in water ranging between 5°C and 15°C (COSEWIC 2010d). Thus, spiny dogfish are at the northern limit of their distribution in NL waters. Mature adults congregate in the warmest available water (>5°C).

Spiny dogfish distributions are patchy and they form dense aggregations, causing high variability in survey indices. They tend to form aggregations based on their sex and size, with adult females being larger and found in shallower waters and males being smaller and found in deeper waters (Compagno et al. 2005 in Dell'Apa et al. 2014). The absence of young juveniles coupled with survey abundance variability suggests that the early life history stages (pupping and juveniles) occur elsewhere, and as such, the spiny dogfish on the Grand Banks are not an independent stock.

Spiny dogfish are omnivorous and opportunistic feeders whose diet consists of small fish (capelin, cod, haddock, hake [*Urophycis tenuis*], and herring) and invertebrates (krill, crabs, polychaete worms, jellyfish ctenophores, amphipods, squid, and octopus) (Campana 2007). Spiny dogfish are preyed upon by larger sharks and marine mammals (Grimm et al. 2004).

Spiny dogfish mate during the fall and early winter and have internal fertilization (COSEWIC 2010d). After a gestation period of 18-24 months, an average of six pups are born live in the winter (COSEWIC 2010d). This is a long-lived, slow-growing species with late maturing females (approximately 11 to 17 years of age) (DFO 2016b).

The Atlantic population of spiny dogfish is listed as Special Concern by COSEWIC. Overfishing is considered the only proximate threat to spiny dogfish at a population level, both in Canadian waters and globally (COSEWIC 2010d). Canadian landings have been low since 2008, dropping from 2,500 mt annually from 2000 to 2008 to 5 mt in 2010 and remaining low since that time (DFO 2014c). Life history characteristics, such as long gestation period, low fecundity, and late age of maturity contribute to this species' vulnerability to fishing (COSEWIC 2010d). In 2016, the spiny dogfish was classified on the IUCN Red List as Vulnerable (Finucci et al. 2020).

5.5.2.13 Thorny Skate

There are 13 species of skate (Family Rajidae) found in the Northwest Atlantic; however, many are rare and do not make an important contribution to the fishery. Of these, the two most abundant species are thorny skate and smooth skate (described above). These two species, along with spinytail skate (*Bathyraja spinicauda*), account for approximately 98% of the RV data landings from 2007 to 2017 and are described in greater detail in the following sections.

Thorny skate (*Amblyraja radiata*) is a temperate to Arctic species that is widely distributed in the North Atlantic from Greenland to South Carolina (COSEWIC 2012f). In Canadian waters, it is distributed continuously from Baffin Bay, Davis Strait, Labrador Shelf, Grand Banks, Gulf of St. Lawrence, Scotian Shelf, and Bay of Fundy to Georges Bank (COSEWIC 2012f). Data from the DFO multispecies RV surveys show its presence in the Labrador Shelf SEA Update Area in NAFO Divisions 2JH (2G was not surveyed) (Wells et al. 2021). Thorny skate have been observed over a wide range of depths, from nearshore down to 1,700 m, with most of its biomass occurring between 50 to 150 m (Kulka and Miri 2003). Thorny skate are found in water temperatures of 0°C to 10°C (COSEWIC 2012f). While they are known to occur on a variety of substrate types, including sand, shell hache, gravel, pebble, and soft mud (COSEWIC 2012f; Curtis 2017), they are primarily associated with muddy, sandy, and pebble substrates (Kulka and Miri 2003).

The life span of the thorny skate has not been studied, but data from tagging studies indicate that they may live for 20 years or more (Kulka and Miri 2003). Information is lacking on most aspects of thorny skate population dynamics. Thus, it is not possible to undertake age-based analyses or estimate the spawning stock biomass with certainty. Males have been found to mature at smaller sizes than females, with size at maturity increasing from north to south. Maximum total lengths vary depending on location, where lengths of 90 cm have been observed on the Labrador Shelf and lengths of 110 to 110 cm have been observed in the Gulf of Maine (COSEWIC 2012f; Curtis 2017). Ovaries of sexually mature females hold 10 to 12 pairs of eggs in various developmental stages (Kulka and Miri 2003). Thorny skate deposit 6 to 40 egg cases per year. Larger females produce larger egg cases, but it is not known if egg case size is related to survival rates (Kulka and Miri 2003).

Larger thorny skate feed on a variety of prey including fish, polychaetes, crabs, shrimp, and whelks, while smaller skates feed on copepods, krill, polychaetes, and amphipods (Skjaeraasen and Bergstad 2000 in Curtis 2017; Dolgov 2002 in Curtis 2017; Kulka and Miri 2003). Considerable amounts of fish offal have been found in skate stomachs, and this, coupled with the ventral mouth location, suggests that thorny skate are opportunistic bottom feeders.

The thorny skate is listed as a species of Special Concern by COSEWIC. Incidental capture of thorny skate in commercial fisheries is likely a limiting factor, though this has not been directly linked to population declines (COSEWIC 2012f). DFO-NL survey data from NAFO Division 2H has been inconsistent, showing a high degree of variability. While biomass in recent years has been higher than the 1996 to 2015 average, there have been low numbers of large skates suggesting that the majority of the current population in this area are immature individuals (DFO 2017). The population in division 2J3K showed biomass increases of immature and mature thorny skates between 2004 and 2014, with decreases in 2015. Recovery in the southern part of this species range may be due to the increased mortality of predator species (COSEWIC 2012f). Catches of thorny skate in Canadian waters have declined since the 1990s with the closure of the skate fishery on the Scotian Shelf and the general reduction of fisheries where this species is caught as bycatch (COSEWIC 2012f). Recent work in the U.S. has suggested that climate change will continue to negatively impact thorny skate populations by reducing the quantity of thermally suitable habitat in the southern portion of their range (Grieve et al. 2020). Their sedentary behaviour makes them vulnerable to such impacts; however, it may also make spatial closures an efficient recovery strategy (Kneebone et al. 2020). It is estimated that between 1977 and 2010 the southern Labrador Shelf population decreased by 30% (COSEWIC 2012f; Curtis 2017). In 2016, the thorny skate was classified on the IUCN Red List as Vulnerable (Kulka et al. 2020b).

5.5.2.14 White Hake

White hake (*Urophycis tenuis*) occurs in the Northwest Atlantic from North Carolina to Labrador (Scott and Scott 1988; COSEWIC 2013). Data from the DFO multispecies RV surveys suggest a range shift for white hake, as low density areas emerged in the more recent time series (1995-2017) in the southern areas of the Labrador Shelf SEA Update Area (i.e., NAFO Divisions 2J3KL) (Wells et al. 2021). This species is found near the bottom and is commonly caught over fine sediment substrates including mud, sand, and gravel and prefer water temperatures of 4°C to 8°C in waters up to 800 m in depth (COSEWIC 2013). Larger fish occur in deeper waters while juveniles typically occupy shallow areas close to shore or shallow offshore banks (COSEWIC 2013). Both juvenile and adults feed mostly on crustaceans and fish.

Spawning is known to take place from the Gulf of Maine to waters off of Newfoundland and occurs in early spring or summer in Newfoundland (COSEWIC 2013; DFO 2016c; Simpson et al. 2016b). White hake have high fecundity and have buoyant eggs that generally occur in the water layer. Larvae remain in the upper water layer for two to three months (depending on water temperature) until reaching approximately 50 mm in length prior to settlement on the bottom (COSEWIC 2013). Newly settled juveniles are associated with a variety of substrate types including gravel, mud, and sand off Newfoundland (Methven et al. 2001) and off Labrador (Wrobleski et al. 2007). Inshore areas and eelgrass beds are important nursery habitats for demersal juveniles (DFO 2016c). White hake grow to a maximum size of 133 to 135 cm and a maximum weight of 21.5 to 22.3 kg (Markle et al. 1982).

The Atlantic and Northern Gulf of St. Lawrence population of white hake is listed as Threatened by COSEWIC; it has no IUCN designation. Overfishing in the late 1980s and early 1990s was the main reason for the decline in abundance of this population (COSEWIC 2013). It is hypothesized that seismic surveys may affect various life stages of white hake prey (Simpson et al. 2016b).

5.5.2.15 Winter Skate

Winter skate (*Leucoraja ocellata*) are endemic to the Northwest Atlantic and from the northern Gulf of St. Lawrence and Labrador south to Cape Hatteras, North Carolina (Scott and Scott 1988; COSEWIC 2015; Kulka et al. 2020c). In Canadian waters, they are concentrated in three areas: the Gulf of St. Lawrence; Eastern Scotian Shelf / Southern Newfoundland, and the Western Scotian Shelf / Bay of Fundy / Canadian portion of Georges Bank (COSEWIC 2015). Data from the DFO multispecies RV data show very few records of winter skate; however, low densities were observed in the Labrador Shelf SEA Update Area (NAFO Divisions 2JH) in the 1995-2017 time series (Wells et al. 2021). A recent study involving passive acoustic telemetry revealed that winter skate is a highly mobile species. Contrary to previous belief, they were found to occupy a large geographic range and move extensively throughout these areas (Frisk et al. 2019).

They occur primarily in the warmest available water and avoid temperatures less than 2°C (COSEWIC 2015). The winter skate is a bottom-dwelling species, most common at water depths less than 111 m but can occur at depths of up to 371 m (COSEWIC 2015). Most winter skates are caught in water temperatures of 5°C to 16°C (COSEWIC 2015). Winter skate prefer to prey on rock crab and squid; however, they also prey on sea urchins, annelid worms, amphipods, shrimp, razor clams, and eat whatever small fish that are readily available (Scott and Scott 1998; COSEWIC 2015). As skates increase in size, crustaceans become a less important part of their diet, while fish become more important (DFO 2017).

Females are thought to deposit 40 to 70 egg cases annually and the eggs can take 18 to 22 months to develop (COSEWIC 2015). Egg cases and juvenile winter skates are regularly being found by citizen scientists in nearshore areas and on shorelines around the Island of Newfoundland and a few from southern Labrador (C. Miri, pers. comm. In DFO 2021c). Winter skates outside the Gulf of St. Lawrence mature at 75 cm total length and at 13 years; within the Gulf, they mature at 42 cm and at 5 years of age (COSEWIC 2015). The generation time is estimated to be 18 years outside the Gulf and 10 years in the Gulf (COSEWIC 2015). Based on available survey data for the Eastern Scotian Shelf over the last 2.4 generations, the abundance of mature individuals was estimated to have declined by 98% (COSEWIC 2015).

The Gulf of St. Lawrence and Eastern Scotian Shelf-Newfoundland populations of winter skate are listed as Endangered by COSEWIC. The life history of winter skate has characteristics, such as slow growth, late maturity and low rates of reproduction that make this species vulnerable to over-exploitation and reduce their rate of recovery (COSEWIC 2015; DFO 2017). Overfishing has contributed to the decline of this species, but it is also unusually high numbers of non-fishing mortality, possibly due to natural predation from increasing numbers of grey seals that poses a threat to winter skate (COSEWIC 2015). In the Eastern Scotian Shelf-Newfoundland population there was an estimated reduction in biomass of 98% between 1970 and 2015 (DFO 2017). In 2020, the winter skate was classified on the IUCN Red List as Endangered (Kulka et al. 2020c).

5.5.2.16 American Eel

American eel is a migratory species that is widely distributed in freshwater habitats, estuaries, and coastal marine water of the Northwest Atlantic Ocean coastline (COSEWIC 2012g). The range for this species in the western Atlantic goes from South America in the south to Greenland and Iceland in the north (COSEWIC 2012g). In Canada, it occurs as far north as the mid-Labrador coast (COSEWIC 2012g). On the mid-Labrador coast, eels regularly occur up to Hamilton Inlet-Lake Melville and occasionally as far north as Kaipokok Bay, near Postville (COSEWIC 2012g).

Mature silver eels spawn only once during their lives, and this occurs in the Sargasso Sea (COSEWIC 2012g). Hatching occurs from March to October and peaks in August. Larvae are transparent and willow-shaped and are transported to North American coastal waters by the Gulf Stream (COSEWIC 2012g). After approximately 7 to 12 months, larvae enter the continental shelf area and become glass eels taking on an eel shape while remaining transparent (COSEWIC 2012g). As glass eels migrate towards freshwater coastal streams, they are known as elvers and will run into the freshwater streams, peaking from April to June in Newfoundland. Elvers eventually transform into yellow eels, which is the major growth phase for the species. Yellow eels will spend years maturing in freshwater streams and coastal areas before making a major transformation to return to the Sargasso Sea to spawn (COSEWIC 2012g). Yellow eels will remain in coastal areas or fresh water on average for 9 to 22 years before metamorphosing both morphologically and physiologically into silver eels (COSEWIC 2012g). Newfoundland silver eels begin their outmigration to the Sargasso Sea in November travelling over 2,000 km to spawn.

The population of American eels was examined using time-series data to estimate the percent change in indices of abundance from the 1950s to the 2000s. This examination resulted in an almost uniformly negative (-7.1% to -96.2%) trend within the species' North American western range, while trends were mixed within the eastern portion of its range (COSEWIC 2012g).

American eel is listed as Threatened by COSEWIC but is not listed under SARA and are designated as endangered under IUCN (Jacoby et al. 2017). American eel is also listed as Vulnerable under the NL ESA. The Government of NL (Wildlife Division 2010) released a management plan for American eel in the province. To date, there has been no identification of critical habitat for the species in both marine and freshwater areas.

In fresh water, barriers erected in watercourses have severely impeded on upstream migrations of juvenile eels if no fish passage is possible (COSEWIC 2012g). The turbines of hydroelectric dams also cause substantial mortality as maturing fish migrate downstream. Other threats to American eels include bycatch in fisheries, bioaccumulation of contaminants, a swim bladder nematode parasite, and climate change and shifting oceanographic conditions (COSEWIC 2012g).

5.6 SENSITIVE BIOLOGICAL PERIODS FOR FISH AND INVERTEBRATES

Sensitive times for fish include spawning periods and larval periods. Table 5.8 outlines the spawning times of commercially-harvested species. Most commercially-harvested species spawn during the spring and summer, but cod and skate reproduce throughout most of the year. Most larval and juvenile pelagic life stages are present in the Labrador Shelf SEA Update Area in the late summer and fall.

Table 5.8 Spawning Times of Fish and Shellfish Species in the Labrador Shelf SEA Update Area

Species	Spawning Period
American plaice	May / June
Atlantic cod	February / March to May
Atlantic halibut	February to April
Greenland halibut	Winter or early spring
Redfish	March to July
Iceland scallop	April to August
Skate	Year-round
Snow crab	Eggs produced in the spring, brooded by the mothers for up to two years, and hatched late spring to early summer
Witch flounder	March to September
Wolffish	April to October / late autumn to early winter
Roughhead grenadier	Winter to early spring
Northern shrimp	Mating late summer and fall, carried seven to eight months and hatch in spring
Sources: Scott and Scott 1988; DFO 2016a, This Fish n.d. [a], n.d. [b]	

Specific mitigation measures for avoidance of sensitive times would likely need to be established in consultation with authorities for project-specific EAs.

5.7 POTENTIAL EFFECTS - FISH AND FISH HABITAT

As mentioned in Section 5.5, a number of fish species occur within the Labrador Shelf SEA Update Area, including demersal and pelagic species that occupy the region either permanently, or seasonally during specific life stages (e.g., overwintering spawning, nursing). There are areas within the Labrador Shelf SEA Update Area that have been identified as places that provide important habitat or other ecological functions for fish. These areas are discussed in Section 8.0.

The sections below provide a high-level description of potential effects on fish and fish habitat related to offshore oil and gas exploration and production activities that may occur in offshore waters of the Labrador Shelf SEA Update Area. This includes interactions and effects associated with seismic and other geophysical exploration surveys, exploration and production drilling, and production activities. Effects of potential accidents or malfunctions on fish and fish habitat are assessed separately in Accidental Events (Chapter 12). Below, pathways are identified for interactions with routine activities, and a general overview of known effects available through both existing scientific literature, public engagement sessions, and IK, where applicable, is provided. This discussion is meant to supplement that included in the original SEA Report (SEM 2008), providing new information that may have become available since that time. While effects are identified and summarized, a detailed assessment to determine significance of effects has not been conducted. Detailed effects assessments and predictions of significance will be conducted during potential future project-specific EAs, when project-specific information, such as components and location, is available to help further guide the assessment.

5.7.1 Potential Pathways

Potential interactions between fish and fish habitat and potential routine oil and gas activities, including seismic and geophysical surveys, exploration and production drilling, and production activities, are related to the following identified pathways:

The potential for injury or mortality to fish species due to exposure to underwater sound (e.g., sound source arrays) at close ranges. This includes potential effects to both mobile and sedentary fish species that may be in the area at the time of a survey. For example, the NunatuKavut Community Council observed that seismic surveys and oil and gas development have been observed to affect crab populations (NunatuKavut Community Council 2019).

Avoidance or behavioral disturbance to fish species in areas that would otherwise be occupied, due to exposure of fish species to underwater sound, potentially affecting the presence and abundance of fish species in an area.

Potential contamination of fish and fish habitat due to environmental discharges from routine oil and gas activities.

Potential permanent destruction or alteration of fish habitat due to discharge and dispersion of drill cuttings from drilling activities, and/or the placement of project-related infrastructure in the marine environment. For example, the Nunatsiavut Government observed that crab live on the bottom of the ocean and drilling on their beds would negatively affect the stock (SEM 2008).

Potential direct impact on coral, sponges, bryozoans and other organisms in the surrounding area.

Attraction of fish species to offshore infrastructure due to the presence of artificial lighting and routine discharges.

The introduction of AIS such as the coffin box bryozoan (the presence of which has been confirmed in southern Labrador [DFO 2021a]), which may affect the presence and abundance of native fish species via indirect mortality or avoidance behaviour.

Offshore construction and installation of excavated drill centres would involve dredging for placement of subsea wells below the level of the sea floor to protect equipment from iceberg scour. Seafloor disturbance and dredge spoil may result in change in habitat quality, change in habitat quantity and/or potential mortality due to resulting sedimentation, contamination, increased noise and/or lighting.

5.7.2 Overview of Effects

Table 5.9 provides a summary of known environmental interactions and effects that have been documented through scientific literature, IK, and stakeholder engagement where possible. Operators can plan accordingly to reduce the potential for interactions through applicable mitigation measures (see Section 5.7.3).

With regards to potential interactions and effects from oil and gas activities and fish and fish habitat, the magnitude and characteristics of these interactions and potential effects will depend on the specific project and its activities. For example, interactions between oil and gas activities with shorter timeframes, such as seismic surveys, will have a shorter period of interaction and a larger area of effect with fish species and their associated habitats. Likewise, oil and gas activities such as production projects, which have a longer life span than exploration programs and can include more associated components and infrastructure, will likely have an increased potential for interaction, as aspects of the project (e.g., long-term infrastructure and drilling) will be carried out continuously and over a longer period. Therefore, project-specific EAs will carry out more detailed effects assessments to characterize potential effects, and their associated significance based on project-specific information.

Table 5.9 Summary of Potential Environmental Effects from Routine Activities on Fish and Fish Habitat, including Species at Risk

Components / Activities	Potential Environmental Interaction	Summary of Known and Potential Environmental Effects based on available Literature and IK
Geophysical Surveys		
Sound source arrays	• Injury or mortality • Disturbance or avoidance of an area • Behavioural changes	• Fish species can exhibit a range of effects, including physical injury or mortality, behavioural effects and physiological effects. • Behavioural and physiological responses vary by species and with the seismic array used. For example, deep lacking swim bladders (e.g., Greenland halibut) may be less vulnerable to effects from seismic surveys (Boertmann and Mosbech 2011). • Most of the sound energy produced by an air gun array is in the range of 10 to 300 Hz, with highest levels at frequencies of less than 100 Hz. Air gun emission frequencies therefore fall within the hearing band of most fish species, and could therefore be audible, and these may affect fish behaviour at distances where levels are sufficiently high (AMEC 2014). • Depending on environmental conditions and air gun source levels, effects from sound source arrays from surveys could be detected less than 1 km to over 10 km from the sound source (AMEC 2014). • Behavioural responses by fish species to underwater sound will depend on a number of factors, including but not limited to: species, life stage, intensity of sound, and distance from source. These behavioral effects include possible avoidance of individual fish, as well as possible physiological effects when fish are continually exposed to noise (Clark et al. 2016). • High levels of sound can elicit various types of behavioural responses in marine fish and invertebrates, some of which may negatively affect a population (e.g., reduced rate of foraging or predator avoidance), and others which may pose no overall risk (e.g., brief startle response) (Carroll et al. 2017). • Studies from multiple authors (McCauley et al. 2000a, 2000b; Parry and Gason 2006; Popper and Hastings 2009; Popper et al. 2014) have observed an array of behavioural response from fish species to underwater sound source arrays, including altered spatial and depth distributions, and changes in activity, such as increased refuge seeking or schooling of fish. • Solan et al. (2016) noted that marine invertebrates exposed to geophysical sounds have been observed to undergo startle or stress behaviours, but often do not necessarily undergo avoidance behaviours (Carroll et al. 2017). • Potential habituation to repeated air gun exposure has been demonstrated in different fish species throughout the world (Carroll et al. 2017), indicating some species can tolerate exposure to underwater sound over time. • Scallops have shown a distinct "flinching" response in reaction to seismic sound exposure (Day et al. 2016). • Studies by multiple authors have indicated that potential injury or mortality to plankton and fish species within early life stages (eggs and/or larvae) would be limited to within a few metres of a sound source array (Pearson et al. 1994; Payne 2004; Payne et al. 2009; Cox et al. 2011; Popper et al. 2014).

Table 5.9 Summary of Potential Environmental Effects from Routine Activities on Fish and Fish Habitat, including Species at Risk

Components / Activities	Potential Environmental Interaction	Summary of Known and Potential Environmental Effects based on available Literature and IK
		• There is little evidence existing that indicates physical injury or mortality to certain fish species occurs at distances greater than several meters from the source, due to the avoidance behaviour exhibited by mobile marine organisms (Popper and Hastings 2009; Popper et al. 2014). • DFO noted that there have not been documented cases of fish mortality under exposure to seismic sound under field operating conditions (DFO 2004b; Payne 2004), and overall, exposure to seismic sound is considered unlikely to result in direct fish mortality due primarily to behavioural responses in fish to avoid the affected area (McCauley et al. 2000a, 2000b). • Seismic sound sources have potential to kill fish and disrupt marine life within the area of activity (NunatuKavut Community Council 2019) • Seismic sound sources have the potential to have lethal or sublethal effects on plankton at short range (<5 m) from the sound source (Ostby et al. 2003, in Boertmann and Mosbech 2011). • Field-based studies on adult invertebrate populations found no increased mortality due to air gun exposure in scallops up to ten months after exposure (Parry et al. 2002; Harrington et al. 2010; Przeslawski et al. 2016), clams two days after exposure (La Bella et al. 1996), or lobsters up to eight months after exposure (Payne et al. 2007; Day et al. 2016). • There is little information available on permanent hearing loss in fish resulting from exposure to high-intensity sounds, although this type of physical response may be considered less likely to occur given the ability of fish to regenerate lost or damaged sensory cells of the ear (Smith 2016). • There is a growing body of literature that shows anthropogenic sounds exceeding normal ambient noise may result in a temporary change in hearing sensitivity from which the animal will recover over time, known as a temporary threshold shift (Carroll et al. 2017). • McCauley et al. (2003) demonstrated that exposure to repeated emissions of a single air gun (1 m of 222.6 dB re 1μPa) from 5 to 300 m caused damage to the sensory hair cells in the inner ear of caged pink snapper (*Pagrus auratus*). Although no mortality was observed, there was little evidence of repair or replacement of damaged sensory cells up to 58 days post-exposure. • Other studies have found no or limited evidence of hearing damage in fish following exposure to seismic air guns (despite some fish showing temporary hearing loss) (Popper et al. 2005; Song 2008; McCauley and Kent 2012). • Christian et al. (2003) found that there was no linkage of seismic surveys in the Canada-NL Offshore Area on the health of snow crab species as part of a commercial fishery (cited in Morris et al. 2018). • Changes in crab distribution and abundance have been observed due to seismic surveys in Labrador (NunatuKavut Community Council 2019).

Table 5.9 Summary of Potential Environmental Effects from Routine Activities on Fish and Fish Habitat, including Species at Risk

Components / Activities	Potential Environmental Interaction	Summary of Known and Potential Environmental Effects based on available Literature and IK
		• A Before-After-Control-Impact study from 2015 to 2017 based on positioning telemetry determined that seismic activity had quite small effects on male crab behaviour and not likely a major threat to the commercial crab fishery, although effects from seismic surveys could not be completely ruled out (Coté et al. 2020). • A Before-After-Control-Impact study in 2017 and 2018 could also not completely rule out effects from seismic surveys; however, those effects were determined to be small in scale both temporally (i.e., catch rates return to normal within a two-week period) and spatially (catch rates affected in a <30 km radius) (Morris et al. 2020). • Invertebrates are generally considered less vulnerable to noise-related trauma than marine mammals and fish species because they lack gas-filled spaces (Edmonds et al. 2016). • Other potential implications of seismic surveys on fish include chronic effects (e.g., elevation of neurohormones such as adrenaline and cortisol, which often occur in fish under stressful conditions), as well as the potential risk of effects on reproduction (Payne et al. 2008). • Scallop larvae that were exposed to playbacks of seismic pulses showed developmental delays and 46% showed body abnormalities (de Soto et al. 2013). • Sound exposure guidelines for eggs and larvae determined by Popper et al. (2014) suggest that potential mortality or physical injury to eggs and larvae from seismic sources may result from a cumulative sound effects level greater than 210 dB re 1 μPa^2s or a peak sound pressure level greater than 207 dB re 1 µPa. • Some species may become habituated to sound, with squid showing fewer alarm responses with subsequent exposure to noise from air guns (Fewtrell and McCauley 2012). • Larval responses to seismic surveys may vary quite dramatically from adults for some species. The larvae of some groups (e.g., flounders, soles, flatfishes, gobies) have swim-bladders that are lost on settlement as juveniles. These early life stages may therefore be more susceptible to underwater sound than older life stages (Carroll et al. 2017). • Vessels have been shown to be a primary pathway for the introduction of invasive species into the Arctic (Chan et al. 2019; DFO 2019e). • NunatuKavut Community Council expressed concern about the effects of seismic surveys on fish and fish habitat (NunatuKavut Community Council 2019).

Table 5.9 Summary of Potential Environmental Effects from Routine Activities on Fish and Fish Habitat, including Species at Risk

Components / Activities	Potential Environmental Interaction	Summary of Known and Potential Environmental Effects based on available Literature and IK
Support vessel / tanker movement	• Injury or mortality • Disturbance or avoidance of an area • Behavioural changes • Introduction of AIS	• Noise from marine vessels has been observed as masking the acoustic environment of fish species and affect fish behaviour (Slabbekoorn et al. 2010; Wale et al. 2013a, 2013b; Morley et al. 2014). • Noise generated by vessel traffic and use can be transmitted through water and may cause avoidance or attraction by some species (Røstad et al. 2006; De Robertis and Handegard 2013). • Vessel noise effects are temporary and are generally limited to the duration of the noise emissions or within days afterwards (Popper and Hastings 2009). • Lighting emissions from vessels have the potential to attract phototaxic plankton and foraging fish and may support foraging opportunities and increase predator-prey interactions (Keenan et al. 2007; Cordes et al. 2016). • Vessels have been shown to be a primary pathway for the introduction of invasive species into the Arctic (Chan et al. 2019; DFO 2019e).
Exploration and Production Activity		
Presence and operation of offshore and onshore structures, including drilling, lights, and noise	• Injury or mortality of fish species • Avoidance or attraction of fish species to offshore and/or onshore structures • Behavioural changes • Introduction of AIS	• The potential for colonization opportunities from the presence of infrastructure in the water, and the presence of lights on drilling and production installations, may create a reef effect where fish species can aggregate due to increasing feeding and shelter opportunities (Picken and McIntyre 1989; Røstad et al. 2006; Slabbekoorn et al. 2010). • Lighting from oil and gas infrastructure may attract phototaxic plankton and increase prey capture by fish and other species (Keenan et al. 2007; Cordes et al. 2016). • Hoolihan et al. (2014) noted that yellowfin tuna are known to gather around production platforms because they are sight feeders and can hunt more effectively in the better-lit surrounding waters. • Reef effects are more prominent at production platforms than drilling installations, as the amount of subsurface structure is less, and the duration of the interaction is much shorter (LGL Limited et al. 2000). • Noise is anticipated to affect fish and fish habitat in the vicinity of future activities (NunatuKavut Community Council 2019). • Offshore oil platforms enhance the establishment of a non-native (invasive) invertebrate species (Simons et al. 2016; Viola et al. 2019). • Exploratory drilling can result in physical (e.g., platform installation such as anchors, top hole drilling, equipment placement, well abandonment), sediment (e.g., anchoring activities, top hole drilling), and chemical (e.g., cement, drill cuttings) disturbances on corals and sponges (DFO 2021b). • Dredging for excavated drill centres may result in change in habitat quality, change in habitat quantity and/or potential mortality due to resulting sedimentation, contamination, increased noise and/or lighting (Van Dalfsen et al. 2000; Smith and Rule 2001; Board, Ocean Studies and National Research Council, 2002; Amoser and Ladich 2003; Smith et al. 2004, 2006, 2008; Slabbekoorn et al. 2010; Bell et al. 2015).

Table 5.9 Summary of Potential Environmental Effects from Routine Activities on Fish and Fish Habitat, including Species at Risk

Components / Activities	Potential Environmental Interaction	Summary of Known and Potential Environmental Effects based on available Literature and IK
Movement of support vessels, tankers, and aircraft	• Injury or mortality • Avoidance or attraction to vessels and aircraft • Behavioural changes • Introduction of AIS	• See above for summary of effects from vessel movement.
Vertical Seismic Profiling and other surveys	• Injury or mortality	• Similar as for geophysical surveys discussed above
Well flow testing and flaring	• N/A	• N/A
Routine discharges, including drill muds and cuttings, sewage, deck drainage, bilge / cooling water, wash fluids, produced water, and other waste	• Injury or mortality of fish species • Destruction or alteration of fish habitat • Avoidance or attraction to MODU • Behavioural changes	• Drilling operations have been showed to impact benthic communities (including corals) through physical disturbance and increased sedimentation (Bakke et al. 2013; Cordes et al. 2016). • Hurley and Ellis (2004) reviewed the results from EEM programs on the east coast of Canada and concluded that changes in the diversity and abundance of benthic organisms were generally detected within 1000 m of drill sites and most commonly within 50 to 200 m of dill sites, if at all. • Netto et al. (2008) indicate that the response to benthic communities to drill cuttings discharges is dependent on the types of drilling fluids used. • Exposure to WBMs at low concentrations has, for example, not shown toxicity to sea scallops, polychaetes, amphipods, shrimp, and various other fish species (Cranford et al. 1999; Neff 2010). • Continuous exposure of the sponge *Geodia barretti* to the barite component of WBMs resulted in evidence of toxic and stress effects. These effects were reduced or not observed at lower barite concentrations (less than 10 mg/L) or if the exposure was intermittent (Edge et al. 2016). • Mobile benthic feeders, including snow crab, are not expected to accumulate metals from WBM because of the relatively small area affected compared to the wider home range of the species (Bakke et al. 2013). • Degradation of organic components in the drill muds can result in eutrophication responses that can create localized anoxic environments (Schaanning et al. 2008, Trannum et al. 2010). These areas are generally localized, within 250 m to 500 m from the drill site (Bakke et al. 2013; DeBlois et al. 2014). • Toxicity experiments with fish indicated that acute toxicity of SBMs was generally low and below environmental guidelines; however, there were potential health effects with chronic exposure to SBM associated cuttings (Jagwani et al. 2011, Gagnon and Baktyar 2013, Vincent-Akpu 2013). • Potential effects of disposal of SBM-associated drill cuttings are possible alteration of marine habitats and creation of local anoxic environments through local eutrophication from degradation of SBM organic components (Schaanning et al. 2008; Ellis et al. 2012).

Table 5.9 Summary of Potential Environmental Effects from Routine Activities on Fish and Fish Habitat, including Species at Risk

Components / Activities	Potential Environmental Interaction	Summary of Known and Potential Environmental Effects based on available Literature and IK
		• Deblois et al. (2014) found no biological effects in Icelandic scallop or American plaice collected 1 km from the Terra Nova oil development field resulting from SBM discharges. • Potential environmental effects from the discharge of drilling fluids and associated drill cuttings are primarily relevant to the benthic environment and species that cannot move to avoid drill cuttings deposition (IOGP 2016). • Sessile species are often suspension feeding organisms with feeding structures that may become clogged with suspended and re-suspended sediments from the cuttings deposition (Neff et al. 2000; Smit et al. 2006). • Drill cuttings have the potential to influence the composition of the seabed, altering benthic community composition as it responds to changing fish habitat (Smit et al. 2006, 2008). • Potential effects of suspended sediments on sponges may include clogging of feeding structures, smothering, and abrasion (Bell et al. 2015). • Larval sponges are more sensitive to sedimentation, resulting in higher larval mortality and decreased settlement (Maldonado et al. 2008; Bell et al. 2015). • While a number of studies have shown that a burial depth of 6.5 mm and below is considered to be the predicted no effect threshold for nontoxic sedimentation based on benthic invertebrate species (Kjeilen-Eilertsen et al. 2004; Smit et al. 2006, 2008), other studies suggest that the threshold may be lower. Injury and polyp mortality were observed on the cold-water reef coral *Lophelia pertusa* in laboratory experiments with deposition of WBM drill cuttings of 6.5 mm (Larsson and Purser 2011). This is an average value, and some species may experience adverse effects at shallower or deeper burial depths. For example, sediment reworking by a brittle star and bivalve was reduced in a microcosm aquaria experiment with deposition of WBM drill cuttings of 2.5 mm (Trannum 2017). As the PNET threshold is based on average tolerances, the conservative approach as suggested by Kjeilen-Eilertsen et al. (2004) has been to set a lower threshold limit by subtracting 0.5 cm from the derived PNET value. Therefore, 1.5 mm is suggested as a more conservative predicted no-effect threshold (Kjeilen-Eilertsen et al. 2004). DFO is currently developing operational guidance for exploratory drilling to reduce potential impacts on corals and sponges offshore of Newfoundland and Labrador. The Canadian Science Advisory Secretariat (CSAS) coordinates the scientific peer review and science advice from DFO, and in January 2020, the CSAS held a peer review meeting to generate scientific advice on the avoidance and mitigation of significant impacts on corals and sponges during exploratory drilling programs in offshore NL. CSAS published a science advisory report on this topic in July 2021 (DFO 2021b)[1]. The scientific advice contained in the science advisory report (DFO 2021b) will inform DFO's operational guidance, along with other information sources, such as international best management practices, relevant policies and other considerations.

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[1] The full CSAS report can be viewed here: https://waves-vagues.dfo-mpo.gc.ca/Library/4098834x.pdf

Table 5.9 Summary of Potential Environmental Effects from Routine Activities on Fish and Fish Habitat, including Species at Risk

Components / Activities	Potential Environmental Interaction	Summary of Known and Potential Environmental Effects based on available Literature and IK
		• Recovery of areas of biological effect from drilling waste discharges varies considerably, as it is influenced by disturbance size and frequency, distance to source colonizers and local environmental conditions (Gates and Jones 2012). • Routine discharges from offshore infrastructures can result in localized organic enrichment, and potential attraction of fish species to the area. • The effects of produced water are not definitively known, but there are concerns over long-term effects, particularly from hormone disrupting phenols, radioactive components and nutrients (Boertmann and Mosbech 2011). One study documented evidence of polycyclic aromatic hydrocarbon residues in cod and mussels situated near oil rigs, but also noted that levels in cod remained below those found in coastal areas (Hylland et al. 2008).
Well abandonment	• Injury or mortality of fish species • Destruction or alteration of fish habitat	• If explosives are used during the well abandonment process, the sudden and acute shockwaves produced by the underwater explosion could result in fish injury and mortality in the vicinity of the explosion. • The use of explosives can result in destruction or alteration of fish habitat.

With regards to potential interactions and effects from oil and gas activities and fish and fish habitat, the magnitude and characteristics of these interactions and potential effects will depend on the specific project and its activities. For example, interactions between oil and gas activities with shorter timeframes, such as seismic surveys, will have a shorter period of interaction with fish species and their associated habitats. Likewise, oil and gas activities such as production projects, which have a longer life span than exploration programs and can include more associated components and infrastructure, will likely have an increased potential for interaction, as aspects of the project (e.g., long-term infrastructure and drilling) will be carried out continuously and over a longer period. Therefore, project-specific EAs will carry out more detailed effects assessments to characterize potential effects, and their associated significance based on project-specific information.

5.7.3 Mitigation Measures for Fish and Fish Habitat

Table 5.10 provides a list of mitigation measures that offshore oil and gas operators have identified in past and current EAs for oil and gas projects occurring in the Canada-NL Offshore Area, based on regulatory requirements and standard practice, and that can also be applied to potential oil and gas activities in the Labrador Shelf SEA Update Area. These mitigation measures build on those highlighted in the original SEA Report and are designed to reduce the potential for interaction and resulting environmental effects from potential future offshore oil and gas activities on fish and fish habitat. Standard monitoring and follow-up commitments and emergent mitigation measures are also considered in this section, following the table.

Table 5.10 Summary of Standard Environmental Mitigation Measures for Fish and Fish Habitat, Including Species at Risk

Mitigation	Applicability		
	Geophysical Surveys	Exploration & Production Drilling	Oil and Gas Production
Where technically and economically feasible[1], avoid known SAR and/or sensitive species and areas and/or times in planning and conduct of oil and gas activities. This includes periods of time that could be used for migration or other important activities. Mitigation measures may include potential buffer zones and/or temporal avoidance for fish species.	●	●	●
Use a gradual “ramp-up” period prior to a geophysical survey or vertical seismic profiling, in consideration of the Statement of Canadian Practice with Respect to the Mitigation of Seismic Sound in the Marine Environment, to allow mobile fish species to move away from the area if they are disturbed by the underwater sound levels associated with the sound source array.	●	●	
Conduct pre-drilling surveys of the seabed at the wellsite to assess the potential presence of hazards and sensitive benthic micro-habitats or sensitive benthic species (such as corals) prior to a drilling campaign, and the application of an appropriate set-back distance or other approved avoidance approaches if such hazards, habitats, or species are found.		●	●

Table 5.10 Summary of Standard Environmental Mitigation Measures for Fish and Fish Habitat, Including Species at Risk

Mitigation	Applicability		
	Geophysical Surveys	**Exploration & Production Drilling**	**Oil and Gas Production**
Treat operational discharges (such as sewage, deck drainage, bilge / cooling water, wash fluids, produced water, other waste) prior to release, in compliance with the OWTG and other applicable regulations and standards.	●	●	●
Where feasible, re-injection produced water and/or muds			●
Adherence to the International Maritime Organization's (IMO) International Convention for the Control and Management of Ships' Ballast Water and Sediments (IMO 2004) to reduce invasion risk by AIS	●	●	●
Install and use oil-water separators to treat contained deck drainage, with collected oil stored and disposed of in accordance with applicable regulatory requirements.		●	●
Water contaminated with hydrocarbons generated during flow testing can be atomized in the flare (using high efficiency burners) during well flow testing or shipped onshore for disposal.		●	●
Reduce environmental discharges and emissions from planned operations and activities to the extent technically and economically feasible[1] and comply with relevant regulations and standards.	●	●	●
Select and screen chemicals in accordance with the Offshore Chemical Selection Guidelines for Drilling and Production Activities on Frontier Lands.		●	●
Conduct appropriate handling, storage, transportation and onshore disposal of solid and hazardous wastes.	●	●	●
Select non-toxic drilling fluids, including the use of WBMs, where technically and economically feasible[1].		●	●
Return SBM-associated drill cuttings to the drill rig for treatment, in accordance with relevant guidelines and requirements, prior to their below surface discharge to the marine environment.		●	●
Dispose of spent or excess SBMs (that are not re-used) onshore at an approved facility and in accordance with applicable regulatory requirements.		●	●
Use local vessels, rigs and equipment where technically and economically feasible[1] and adhere to the International Maritime Organization's (IMO) *International Convention for the Control and Management of Ships' Ballast Water and Sediments* (IMO 2004) to reduce invasion risk by AIS, with ballast and de-ballasting activities conducted in compliance with the *Ballast Water Control and Management Regulations* under the *Canada Shipping Act.* Drake et al. (2020) recommended a protocol of exchange plus treatment to be conducted by vessels entering Canadian waters. It is recognized that this protocol conflicts with the current regulations of the IMO Convention.	●	●	●

Table 5.10 Summary of Standard Environmental Mitigation Measures for Fish and Fish Habitat, Including Species at Risk

Mitigation	Applicability		
	Geophysical Surveys	Exploration & Production Drilling	Oil and Gas Production
Regularly inspect ship hulls, drill rigs and equipment for AIS and conduct associated follow-up maintenance.	●	●	●
Reduce the amount, intensity, duration, and frequency of artificial lighting to the extent technically and economically feasible[1] without compromising safety. This may include methods such as avoiding use of unnecessary lighting, using strobe lights at night with minimum flashes per minute, shading, and directing lights towards the deck.	●	●	●
Implement the following measures to the extent that is technically and economically feasible[1]: reduce project-related vessel and aircraft traffic and use existing and common travel routes where possible; reduce vessel transiting speeds, except if not feasible for safety reasons; and avoid low-level aircraft operations.	●	●	●
Use mechanical procedures during well completion and abandonment activities where technically and economically feasible[1], and proactively design well structures to facilitate this.		●	●
Should the use of explosives be required (such as for blasting during well abandonment), appropriately schedule these activities to avoid biologically sensitive times; set charges below the sediment surface, reduce the amount of explosives utilized and the use of high-velocity explosives; and stagger individual blasts. Follow DFO Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters.		●	●
Develop and implement spill prevention and response plans and procedures. These plans and procedures should be developed in liaison with Indigenous groups, reviewed and approved by the C-NLOPB, implemented on an ongoing basis or as required, and updated regularly.	●	●	●
Develop and implement other required plans and programs, including for physical environment monitoring; the suspension of operations in respect to adverse meteorological and oceanographic conditions; collision and hazard avoidance; ice management; well control; capping stack availability and deployment procedures; and environmental effects monitoring in the event of a spill.	●	●	●

Note:

[1] Technical and economic feasibility are determined by the operator and reviewed by the C-NLOPB in consultation with expert departments, where and as applicable (e.g., DFO, ECCC, Transport Canada).

While a list of standard mitigation measures has been provided in this report relating to environmental interactions with marine fish and fish habitat, it does not assume that additional mitigation measures will not be needed or included within project-specific EAs. Technically and economically feasible mitigation measures, and the need for additional project-specific mitigation measures are determined on a case-by case basis, through regulatory review of proposed programs in the offshore environment. A number of factors would be considered, such as project location or proximity to sensitive areas (e.g., SBAs, EBSAs, etc.), time of year, and associated project components.

The recently completed Regional Assessment of Offshore Oil and Gas Exploratory Drilling East of Newfoundland and Labrador (Regional Assessment, Bangay et al. 2020) identified several standard monitoring and follow-up commitments/requirements that have been included in various project-specific EAs and/or EA approval conditions for offshore exploration drilling programs in the Canada-NL Offshore Area, including the following commitments/requirements that are of relevance to potential effects on fish and fish habitat:

- **Drill Cuttings:** For every well drilled, the operator must measure the concentration of SBM retained on discharged drill cuttings as described in the OWTG to verify that this meets relevant performance targets and report the results to the C-NLOPB.
- **Sediment Deposition and Benthic Habitats:** For the first well in each EL, any well located in an area determined by seabed surveys to be sensitive benthic habitat, any well located within a special area designated as such due to the presence of sensitive coral and sponge species, or any well located near such a special area for which drill cuttings modelling predicts possible adverse effects on the area, the operator must develop and implement, in consultation with DFO and the C-NLOPB, follow-up that includes:
  - Measurement of sediment deposition extent and thickness post-drilling to verify the drill waste deposition modelling predictions
  - Benthic fauna surveys to verify the effectiveness of mitigation measures
  - Reporting, including a comparison of modelling results to in situ results, within 60 days to the C-NLOPB
- **Underwater Noise:** For the first well in each EL, the operator must develop and implement, in consultation with DFO and the C-NLOPB, a follow-up program that describes how underwater noise levels will be monitored through field measurement during the drilling program, and the provision of that information prior to the start of the drilling program.

The Labrador Shelf SEA Update Area is outside of the area assessed by the Regional Assessment, but it is possible that mitigations identified in the report could be recommended for future exploratory drilling in the Labrador Shelf SEA Update Area. As described in the Regional Assessment (Bangay et al. 2020), information on any required follow-up programs must be developed and submitted to the C-NLOPB prior to their implementation, including information on the methodology, location, frequency, timing and duration of monitoring associated with the follow-up program, as well as requirements for reporting on its results, including any variation from EA effects predictions that would require the implementation of new or modified mitigation. The follow-up program is also updated as required in consultation with relevant authorities. In addition, within 90 days of the end of each calendar year of a multi-year drilling program, the operator must submit to the C-NLOPB and IAAC a report outlining its activities to comply with the EA approval, any consultations undertaken and an indication of how concerns were addressed, and the results of the follow-up and any additional mitigation requirements.

5.7.4 Environmental Planning Considerations for Fish and Fish Habitat

5.7.4.1 Fish Species at Risk

As noted in Section 5.5 of this update, there are fish species known to occur within the Labrador Shelf SEA Update Area that have been listed under Schedule 1 of SARA and are legally protected by the Government of Canada. These species include the following:

- White shark (Atlantic population) – Endangered
- Atlantic salmon (Inner Bay of Fundy Population) – Endangered
- Atlantic wolffish – Special Concern
- Northern wolffish – Threatened
- Spotted wolffish – Threatened

White shark is not a common species, but it has been known to occupy waters in eastern offshore Newfoundland (COSEWIC 2006b; Curtis et al. 2014; Skomal et al. 2017; OCEARCH 2020). If water temperatures continue to rise, then the potential exists for white shark to occur within the Labrador Shelf SEA Update Area during the temporal scope of this update. Atlantic salmon from the Inner Bay of Fundy population are also uncommon, as current literature suggests that they undertake more local migrations and remain within the Bay of Fundy and Gulf of Maine as opposed to travelling to the Labrador Sea or Greenland to overwinter (DFO 2019f). The three remaining species are wolffish (Atlantic, northern, and spotted), which are groundfish species associated with continental slope areas. Critical habitat has been identified and mapped for both northern and spotted wolffish (Figure 5-9 in Section 5.5).

5.7.4.2 Important Areas and Times for Fish and Fish Habitat

As discussed in Section 5.6 and 8.0 of this update, there are a number of areas that have been identified and considered as special or sensitive within the Labrador Shelf SEA Update Area. This includes areas that have been legally designated and protected under legislation. These areas have been identified as either highly productive areas, providing potential fish habitat, or provide areas important to species life stages (e.g., spawning and/or migration).

Marine Refuge Areas within the Labrador Shelf SEA Update Area include the Hatton Basin, Hopedale Saddle, Hawke Channel, and Newfoundland and Labrador Slope Closures. These were designed to protect sensitive benthic habitats that exist and provide refuge and foundations for fish populations. Multiple EBSAs within the Labrador Shelf SEA Update Area have been designated due to the presence of sensitive benthic species, and the ecological function they provide to multiple fish species that are present. Several Significant Benthic Areas (SBAs) have been identified within the Labrador Shelf SEA Update Area, primarily related to aggregations of sponges and large gorgonian corals (DFO 2021b). The Gilbert Bay MPA is legally protected under the *Oceans Act*, and has been designated due to its distinct Atlantic cod population, presence of algae beds, and unique salinity levels in the area. In September 2019, the Government of Canada and the President of Nunatsiavut announced the official launch of a feasibility assessment for the potential establishment of an Indigenous Protected Area under the *Canada National Marine Conservation Areas Act*, adjacent to Torngat Mountains National Park; Parks Canada is currently working with the Nunatsiavut Government to implement the feasibility assessment (Government of Canada 2019; DFO 2021a). These areas should be noted for operators during project-specific assessments during the project planning stages.

The continental shelf areas within the Labrador Shelf SEA Update Area are also important for fish and fish habitat, as these areas are typically the most productive for the marine environment, due primarily to upwelling that occurs along the shelf and the abundance of nutrients during times of the year (Drinkwater and Harding 2001).

5.8 DATA GAPS

One of the data gaps that still remains with regards to potential effects of oil and gas activities on fish and fish habitats is the differences between species-specific reactions to oil and gas operations. While studies have been conducted on fish species regarding effects from oil and gas operations, it only represents a small sample size of the various fish species that exist in the marine environment. Since different species have different biological compositions and behavioural patterns, effects from oil and gas activities may differ greatly for fish. For example, while certain fish species have been studied to measure the effects from seismic sound, there still remains a large gap in the potential effects on other species that may not have been studied. Effects of seismic activities on invertebrates are largely unknown, especially in consideration of how much more taxonomically diverse invertebrates are than fish. There also remains gaps in the effects that seismic surveys have on physiological and biological processes in fish, such as metabolic rate, reproduction, larval development, foraging and intraspecific communication (Carroll et al. 2017). A study is currently underway through the Environmental Studies Research Fund (ESRF) to assess the potential for seismic surveys to affect commercial catchability and fish behaviour of groundfish resources. The study is focusing on commercially important and culturally important groundfish species.

With regards to species abundance and distribution of fish species, particularly mobile species, there are data gaps related to species that are not of commercial importance. Some species include more information than others, and information for fish species is not available for various times of the year and in various areas. While DFO surveys are an indicator of presence of fish species, they are only indicative of species present during a set timeframe and within a defined survey area. As a result, it may not be a total representation of species presence within the Labrador Shelf SEA Update Area, as there are areas with poor coverage (e.g., coastal and offshore areas). A study is currently underway through the ESRF to better understand the migratory behaviour (location and habitat use) of Atlantic salmon while at sea, through use of acoustic and satellite telemetry. The results of this multi-party study, with more than 50 community partners, will provide additional insight into the potential interactions between Atlantic salmon and offshore oil and gas activity. The majority of data/knowledge on corals and sponges in the Labrador Shelf SEA Update Area has come from DFO trawl surveys and only represents information from trawlable substrates (i.e., soft / sandy ocean floor). Given that coral and sponge abundance is often positively correlated with hard substrate (Mortensen and Buhl-Mortensen 2004, 2005; Carney 2005; Mortensen et al. 2006), this represents a large data / knowledge gap regarding habitat types and species from these habitats. DFO does not survey coastal areas in northern Labrador and the Northern Shrimp Research Foundation surveys that are conducted do not have the same rigor as DFO multispecies surveys (e.g., training, staff, mandate, etc.). DFO surveys do cover southern Labrador, however, less frequently due to distance, weather and vessel availability. Increased survey and monitoring efforts, by both government, educational institutions, and the oil and gas industry, can help add to the existing body of knowledge of the offshore environment, and provide more clarity and certainty to the species presence within the Labrador Shelf SEA Update Area.

The effects of climate change on fish and fish habitat in Labrador Shelf SEA Update Area is also a data gap. Rising sea temperatures, changes in circulation patterns, invasive species, disease, sea ice, and storm intensity have the potential to affect fish and fish habitat and will alter species distributions and/or habitat use. The changing climate may also increase the potential for the introduction of invasive species via natural spread (changes in circulation patterns) and due to increased anthropogenic activity in northern, previously inaccessible regions (Chan et al. 2019). The potential cumulative effects of climate change and project-specific activities is not known and will need to be considered in project-specific EAs.

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