Strategic Environmental Assessment for Baffin Bay and Davis Strait

Environmental Setting and Review of Potential Effects of Oil and Gas Activities

Final

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Executive Summary

The Nunavut Impact Review Board (NIRB) is undertaking a Strategic Environmental Assessment (SEA) on potential oil and gas related development activities that might be proposed in the future within the Canadian waters of Baffin Bay and Davis Strait outside of the NSA. Strategic Environmental Assessment is a means to address regional scale issues associated with the analysis of effects of human activities on the environment, and openly and transparently engage local communities, stakeholders, and regulatory authorities in the process.

To support the NIRB in the preparation of the SEA report, Nunami Stantec was retained to prepare a literature review of the current state of knowledge of the physical, biological, and human environments of Baffin Bay and Davis Strait, as well as the associated potential effects that oil and gas activities could have on specific Valued Ecosystem Components (VECs) and Valued Socio-Economic Components (VSECs) in the region. Effects of routine activities, as well as effects of Accidents and Malfunctions are assessed. This report also considers the associated adverse effects, benefits, mitigation, and management strategies that could occur as a result of these activities.

The scope of the following report is based on the NIRB's Final Scope List for the Strategic Environmental Assessment in Baffin Bay and Davis Strait (NIRB 2018), which describes the scoping process and the final scope list that outlines the factors to be consider in the SEA. The final SEA report, which will be developed by the NIRB, will draw on information contained in this report, as well as from an additional report prepared by Nunami Stantec, Strategic Environmental Assessment in Baffin Bay and Davis Strait: Oil and Gas Life Cycle Activities and Hypothetical Scenarios (Nunami Stantec Ltd. 2018). A table of concordance indicates the report and section where each item identified in the NIRB's final scope list is discussed (see Table ES-1 and Table ES-2).

The geographic scope of the SEA includes offshore areas in Baffin Bay and Davis Strait, Lancaster Sound, Jones Sound, Smith Sound, and the southern part of Nares Strait. The temporal boundaries of the SEA extend through the typical life cycle of oil and gas exploration and development activities and is assumed to be 15–20 years for exploration and 30–60 years for field development and production.

To provide a context for the discussion of effects, four hypothetical scenarios of oil and gas activity were developed; 1) exploration with offshore seismic surveys, 2) exploration drilling, 3) field development and production drilling, and 4) no offshore oil and gas activity. These scenarios include a description of potential oil and gas exploration and development activities. The hypothetical scenarios consider approximate timelines, activities, financial feasibility, domestic policy and regulations, and environmental constraints. The scenarios provide the basis for identifying potential impacts pathways and associated environmental effects that could arise if oil and gas exploration and/or development were to proceed in the Area of Focus.

Project effects that could arise as a result of routine activities are discussed for the physical, biological, and human environments. Potential effects are initially screened to determine if there could be an interaction with a VEC or VSEC that could result in potential residual effects. If a VEC or VSEC is not expected to interact with oil and gas activities, or if potential effects are likely to be reduced or eliminated using standard mitigative approaches or planning considerations (i.e., existing regulations, temporal or geographic avoidance, industry best practice or policy), then it is assumed that effects on the VEC or VSEC would not occur (or be minimal). That interaction is then not included in the subsequent discussion of potential effects. If potential residual effects are identified for a VEC or VSEC, they are discussed in the context of the associated impacts. The prediction of potential residual effects associated with the hypothetical scenarios is based on a qualitative characterization of magnitude, geographic extent, frequency, and duration. Effects of the environment on oil and gas activities are also discussed. This is followed by a discussion of potential cumulative effects, transboundary effects, and potential effects of accidents and malfunctions.

Of note, Strategic Environmental Assessments are intended to generally discuss the types of effects that could occur as a result of interactions with different types of oil and gas activities, as well as to qualitatively describe the range of effects that might occur. Unlike project-specific environmental assessments, they are not based on detailed project description, nor do they focus on projects or project activities at specific locations or at specific future dates. All described activities are hypothetical based on experience by industry and professional judgement.

CLIMATE CHANGE

The full life cycle of a hypothetical oil and gas project in Davis Strait or Baffin Bay could be in the range of 45–80 years from the start of seismic exploration, through exploration drilling to production and eventually decommissioning. To provide perspective on how climate change might influence the application of oil and gas activities in the Area of Focus, and how the prediction of potential effects on VECs and VSECs may be altered by the influence of climate change, a prediction of future climate change is provided. The change in climate is presented from the standpoint of climate projections described in the literature and more specifically to the region, based on climate change projections using recent climate data (1999 to 2013) for Clyde River, Nunavut. The results of both the general IPCC projections and the projections made specifically for the Baffin Bay and Davis Strait region as part of this assessment are used to generate a set of conclusions regarding future climate change that are directly applicable to the Area of Focus for the SEA. Results of this analysis indicate that:

- Surface air temperature and number of frost free days are projected to increase
- Sea water temperatures near the surface in Baffin Bay and Davis Strait are projected to increase by 1.5 to 2.5°C by 2100
- Precipitation changes are projected to increase in Baffin Bay and Davis Strait by 40–60%.
- Snow cover is projected to decrease by 9–33%
- The sea ice extent is projected to decrease in the Arctic by 34% in February and 94% in September. This is likely to be similar for Baffin Bay and Davis Strait, except that the frozen Baffin Bay and Davis Strait already opens and is nearly ice free in September.

- Estimates of glacial ice loss (net) are -264 to -270 gigatonnes (Gt) per year, potentially resulting in more icebergs in Baffin Bay and Davis Strait initially; however, if sufficient warming occurs, this number may eventually decrease due to more rapid melting.
- The frequency of extreme events related to storms in the Baffin Bay and Davis Strait region is projected to stay similar to present values, or to decrease; however, intensity of storms may increase.

PHYSICAL ENVIRONMENT

Potential effects on the physical environment are primarily associated with air emissions, noise, routine discharge, drill and mud cuttings, and ice disturbance.

A **change in air quality** and greenhouse gases could result from air emissions associated with the release of air contaminants from combustion of fossil fuel for transportation and power, and processes associated with exploration and production drilling (e.g., flaring). Emissions of air contaminants and GHGs associated with the scenarios are likely to be approximately similar (same order of magnitude) to those from Nunavut in 2015. This is because the quantities of current emissions from Nunavut are relatively small, and any addition from activities associated with oil and gas exploration or production is likely to be a relatively large fraction of Nunavut's emissions. The existing air quality in Nunavut on land is generally good overall. It is inferred that air quality above the ocean on Baffin Bay and Davis Strait is similarly good. Potential effects of air emissions on ambient air quality are not expected to exceed regulatory standards at any onshore receptors. Potential effects would be small in geographic extent and, with dispersion over a large area, would result in a small magnitude of change in ambient air quality at receptors onshore. There would be rapid recovery once emissions cease.

A **change in noise levels** would result from underwater noise associated with seismic exploration, drilling activities, and vessels used to transport products, personnel, and equipment or undertaking ice-breaking activities. Atmospheric (in-air) noise is anticipated to be associated with vessels used for seismic exploration, as well as survey and drilling support, or from aerial support (i.e., helicopters) for crew transfers to and from seismic vessels and drilling platforms. Noise associated with these activities is expected to be localized and attenuate to background levels within 1–5 km from the noise source.

A **change in water quality** could result from routine discharge associated with oil and gas activities. Routine discharges from maritime operations could include domestic wastewater (greywater), sewage (blackwater), wash down and drainage from decks and exposed structures, cooling water, ballast water and bilge water. All vessels in a drilling program would be subject to international maritime law, including the MARPOL 73/78 International Convention for the Prevention of Pollution from Ships and the provisions of the Arctic Shipping Pollution Prevention Regulations, the Arctic Waters Pollution Prevention Regulations and the International Code for Ships Operating in Polar Waters (Polar Code). All discharges must be approved as part of a program-specific waste management plan (WMP). Based on results from Environmental Effects Monitoring (EEM) programs in Atlantic Canada, potential effects of routine discharges are expected to be negligible and any change in water quality that did occur would be localized and disperse and dilute into the water column quickly.

The disposal of drill and mud cuttings associated with exploration and production drilling operations may result in a **change in sediment quality** in a small localized area immediately surrounding the drilling activity. The use of appropriate drill muds (water-based and synthetic-based) limits potential effects both geographically and temporally.

The use of icebreakers to support oil and gas activities, and the placement of semi-permanent drilling platforms in offshore environments where sea ice forms, is expected to result in **change in sea ice and iceberg conditions**. Changes in extent and quality would be localized to the area surrounding the icebreaker transit route, and/or the footprint of the drilling platform. Given the limited geographic nature of the change, effects on sea ice dynamics and extent within the Area of Focus are expected to be minimal.

Effects of routine activities on the physical environment are generally localized around the source of the impact or dissipate to background levels within a small radius of the source. Given the offshore location of oil and gas activities associated with the scenarios and the small scale of potential effects, it is not anticipated that residual effects from routine oil and gas activities would interact with other activities to result in **cumulative effects**. Exceptions include Scenario activities that would contribute to global GHG emissions and those contributing to underwater noise. While representing a small contribution when compared to global emissions, activities in the hypothetical scenarios that contribute to GHG emissions would require mitigation to manage emission levels. This includes using best available technologies to maintain efficiency for the activities that burn fuels such as diesel fuel, aviation fuel or fuel gas. Underwater noise can affect a large area and has been identified as an impact of concern for the sustainability of marine organisms.

Potential residual effects of routine activities on the physical environment are not expected to result in **transboundary effects** in neighboring jurisdictions. The prevailing winds in the Area of Focus are from the North and Northwest and so, for most of the time, the probability of air contaminants drifting outside of the Area of Focus in any appreciable quantities is quite low. In cases where oil and gas activities are occurring close to the border on federal waters, the probability is a bit higher. In those cases, it is recommended that a more detailed study be done to assess the potential effects.

The primary concern with effects of **accidents and malfunctions** on the physical environment is associated with the effects of an oil spill on water quality, sediment quality, and sea ice. While the likelihood of an oil spill occurring is small, the effects would be adverse. The effects of the release of hydrocarbons in the marine environment are largely dependent on oceanographic conditions, exposure duration, oil type, oil containment, and treatment methods. Effects could include increased concentrations of the more toxic components of the oil in the water column, flocculation and sinking events associated with plankton and microbial pathways to marine sediments, and contamination of sea ice. A potential release of hydrocarbons may change the nearby sea ice in terms of albedo (reflecting capacity); in turn, this could increase the rate of ice melting in the area of the spill. The ice may help contain the hydrocarbons to some extent initially, but in time, the contaminants would be released to the water column.

BIOLOGICAL ENVIRONMENT

Potential effects of routine activities on the biological environment are primarily associated with underwater noise, routine discharge, drill and mud cuttings, and habitat alterations. Accidents and malfunctions are considered separately.

A **change in behavior** could result from in-air or underwater noise associated with seismic surveys, icebreakers, and exploration and production drilling platforms. Benthic invertebrates, fish, mammals and birds all have varying sensitivity to underwater noise and may respond with startle response, suspension or alteration of behavior (e.g. feeding, resting, hunting), reduced ability to communicate, or adjusting patterns of habitat use. By implementing standard mitigation measures to reduce potential effects of high intensity sound (i.e. seismic noise) and limit the duration and magnitude of exposure of marine organisms to noise levels above recommended thresholds, effects are anticipated to be moderate in magnitude but are not anticipated to affect the viability of the marine populations in the Area of Focus.

Underwater noise can also result in **change in mortality risk**, if it is loud enough to cause injury or acute tissue damage (i.e. noise associated with seismic surveys). As described above, standard mitigation is used during seismic surveys to limit exposure of marine organisms to underwater noise at levels high enough to cause injury or mortality. Seismic vessels are not permitted to operate air gun arrays if marine mammals are within a specified safety radius to protect them from noise levels that could otherwise result in injury. Fish and birds are expected to avoid areas of intense underwater noise, which reduces the likelihood of injury or mortality from seismic noise.

Routine discharges and drill and mud cuttings can result in **change in health** for marine organisms including benthic fauna, fish, waterbirds, and marine mammals. Strict guidelines exist in Canada for monitoring of environmental effects from routine discharges from exploration drilling and offshore platforms. Although there could be near field effects, there is little evidence of severe, far reaching, or lasting effects on marine organisms. Potential effects are expected to be below environmental thresholds, and are not anticipated to adversely affect the viability of marine organisms present within the Area of Focus.

A **change in habitat** could result from drill and mud cuttings, vessel movement and sea ice disturbance. Discharge of drill cuttings can cover the local benthic environment in direct proximity of the drilling activity. This can alter the benthic habitat and, in turn, alter habitat use by benthic invertebrates and fish. Local reefs, topographic variation, substrate diversity, or other important habitat may be lost under the pile (cone) of cuttings. Local increases in turbidity and suspended sediments can take place both directly from the initial discharge of cuttings, and subsequently from resuspension of cuttings during strong currents and storms. These can decrease the available sunlight for benthic flora and alter habitat usage by marine invertebrates and fish. Vessel traffic and artificial lighting has potential to cause sensory disturbance to waterbirds. Several studies investigating patterns of bird displacement from transiting vessels suggest marine traffic can elicit a diving or flushing (i.e., avoidance) response in waterbirds. Ice disturbance can affect the production and location of sea-ice algae, disrupt birthing lairs and breathing holes for seals, and/or alter habitat usage by polar bears. The physical presence of drilling platforms and other marine infrastructure could result in physical removal of habitat, but also have the potential to create new habitat (e.g., use of platforms by fish as artificial reefs). Overall, changes in habitat for benthic flora and fauna due to habitat alterations is expected to be low to moderate, local, and long term. Changes may occur immediately around the development footprint, but these are likely to be small areas when compared to the large study area.

Effects of routine activities on the biological environment are generally localized around the source of the impact or dissipate to background levels within a small radius of the source. Given the offshore location of oil and gas activities associated with the scenarios and the small scale of potential effects, it is anticipated that **cumulative effects** would be low in magnitude. Exceptions include oil and gas activities that would contribute to underwater noise. Underwater noise can affect a large area and has been identified as an impact of concern for the sustainability of marine organisms. Given the large geographic footprint of underwater noise, the footprint of underwater noise from one activity could overlap with the footprint from another activity. Given the effect that climate change may have on sea ice extent and seasonality, increased vessel traffic associated with many human activities in the region is likely to result in magnified cumulative effects on marine populations into the future. Depending on the frequency, intensity, and duration of noise, and species-specific sensitivities, waterbirds or marine mammals may be displaced from suitable breeding, foraging, staging, or roosting habitats.

Transboundary effects may occur if effects on a component of the biological environment is substantial enough to affect long-term health or population density; seasonal migration or general distribution extends outside the region; and the component is an important ecological, subsistence or commercial resource in that jurisdiction. However, as potential residual effects from oil and gas activities on the biological environment are expected to be low to moderate magnitude and not threaten the long-term viability of marine populations or habitat, transboundary effects are expected to be negligible.

The primary concern with effects of **accidents and malfunctions** on the biological environment is associated with the effects of an oil spill on marine and shoreline habitat, and on behaviour, health, and/or mortality risk of marine organisms. The extent and magnitude of these effects can range from moderate to high depending on the type and volume of hydrocarbons released, the sensitivity of the receptor to crude oil exposure, seasonal and environmental conditions, and oceanographic conditions (e.g., currents, water temperature, extent and type of ice cover). The proximity of the spill to shorelines, and the vulnerability of shorelines to spills is also important. Effects from oil spills on plankton would be moderate to high, local to regional, restricted to the single event, and be medium to long-term in duration depending on the type of oil and time of year. An oil spill would likely result in mortalities for benthic fauna, fish, waterbird and marine mammal mortalities and reduced health affecting regional populations, and changes in the local abundance of prey and predator species. Potential effects from a small spill could result in localized effects on marine organisms similar to those described above. Potential effects would likely be limited to a small number of individuals; dilution and dispersion of the spill into the water column would reduce the magnitude of effects. Spill response and clean-up activities would also help to reduce the effects of small spills

Effects from a prolonged spill would be experienced across large areas (potentially with the product travelling hundreds of kilometres). Response measures (e.g. in-situ burning, dispersents, mechanical containment and removal) would be implemented to limit the release and extent of oil if a blowout or spill were to occur. Generally, changes to population abundance would be recoverable in the long term (typically within several years but possibly more than a decade), following the natural recovery of habitats and prey populations and boosts in recruitment associated with temporary declines in natural mortality rates of density dependent life stages. An oil spill would not be expected to substantially affect the long-term sustainability of regional fish, waterbird or mammal populations, unless those populations are otherwise compromised prior to the incident, or large portions of their range or habitat are affected by the incident. There is also a risk of accidental vessel strikes with marine mammals. The probability of a vessel striking a marine mammal depends on the frequency, speed, and route of the marine vessels, and the distribution of marine mammals in the area. Although vessel strikes are adverse, they would be rare and they would not likely affect the viability of species within the Area of Focus.

HUMAN ENVIRONMENT

Potential effects of routine activities on the human environment are primarily associated with ice disturbance, employment and expenditures, and exclusion zones through direct interference, and indirect interference. Accidents and malfunctions are considered separately.

Employment and expenditures associated with routine activities of oil and gas could result in a **change in economy, employment, and business** in the Area of Focus. The increase in direct and indirect local employment, and the increase in expenditures on goods and services from local businesses, represents an increase of economic activity in local communities. This could include individuals, families, and households having higher levels of disposable income, which they may spend locally and provide an economic stimulus to local businesses. The income from these businesses can then be further spent and re-invested into the local region, creating further indirect benefits to the area. The degree of interaction of oil and gas activity related to economy, employment, and business will be dependent on the ability and capacity of local workers and businesses to take advantage of the opportunities, and on the type of activity.

The use of infrastructure to service routine activities associated with (e.g. ports for servicing supply vessels and drilling rigs, and airports to transport workers between their home communities and offshore locations) could result in a **change in capacity of infrastructure and services**. The potential effects on local services and infrastructure will be more pronounced in the case of activities that have more interaction with land, and which last longer. Seismic activities (Scenario A) typically involve little onshore interaction, because the vessels are typically based elsewhere in the world and remain offshore for the relatively short duration of the program. Drilling programs (Scenarios B and C) have a longer duration and often see operators having the opportunity to drill wells over a multi-year period. Because there is a larger workforce associated with drilling compared to a seismic program, there would likely be increased activity at local airports and communities with workers coming in and out of Nunavut, and helicopters taking them to and from drilling rigs. This could place increased pressure on community infrastructure and services but, given the lead-time to respond to this, new investments would be justifiable given the duration of the new demand. Personal, company and corporate taxes and royalties could contribute to paying associated costs. New infrastructure built because of such demand may represent a positive legacy after the end of oil and gas activity, providing the costs of maintaining it can be met.

Some routine activities associated with oil and gas could affect land and marine use and result in a **change in access to resources**. There is intensive human usage along the coasts and adjacent marine areas within the Area of Focus to, approximately, the edge of the outer land-fast ice zone. The breaking of ice to enable ships to reach harbours on Baffin Island has the potential to affect over-ice travel for traditional harvesting and other activities. Given the prediction that offshore oil and gas in this region would be largely self-reliant, with very little shore-based support required, exclusion zones and ice disturbance in the nearshore area and the land fast ice are not expected to limit access to resources. Discussion between operators and harvesters, hunting and trapping organizations, and the Qikiqtani Inuit Association regarding potential effects and recommended mitigations measures would be required to reduce interference with traditional use and practices, including traditional harvesting and travel over ice.

A **change in perceived community health and well-being** is difficult to quantify or measure, and can differ based on community composition, existing services and infrastructure, and the level of interaction between the community and the routine activities associated with oil and gas. Perceived health and well-being of a community is based on several external factors, that may alter the perception of effects. Positive effects could include new economic activity and increased disposable income, improved sense of well-being, and a higher sense of confidence in an individual knowing that they can support themselves through employment, with less or no reliance on social assistance or income support. They may also benefit from greater access to food, both through traditional harvesting and being able to afford market foods, as well as having greater financial flexibility. Taxes, royalties, and benefits agreements may also allow governments to invest in new or upgraded infrastructure and services. Negative effects could include a reduced ability to partake in traditional hunting activities for individuals working in the oil and gas industry or a decrease in opportunities for cultural transmission or community cohesion and identity if family members or Elders are away from the community working in the oil and gas industry. Routine activities associated with oil and gas can also have adverse effects if it results in higher housing costs, further exacerbating the housing issues that currently exist in Nunavut. This can further lead to physical and mental health issues, negatively affecting health and well-being. Changes to traditional use and practices, changes in access to harvesting sites, changes in harvesting site locations, and changes in quality of harvest can also result in changes to perceived community health and well-being.

Nunavummiut have expressed concern over a **change in quality of harvest** resulting from contamination of harvested species and changes in their distribution due to discharges during routine activities associated with oil and gas. Actual or perceived contamination of species or a change in their distribution could result in a decrease to harvesting activity or consumption of country foods, as well as effects to other activities such as wildlife focused marine tourism. These potential changes could also affect the economy, food security and perceived well-being.

Current and past Inuit land and marine use intensity is greatest within the land-fast ice zone and adjacent onshore areas. Given that new onshore infrastructure is not expected to be required to support routine activities associated with oil and gas, a **change in heritage resources** is not expected. If any new infrastructure was required onshore, Heritage Resources are protected under the Nunavut Act, with the Nunavut Archaeological and Palaeontological Sites Regulations governing the investigation and protection of archaeological or palaeontological resources. Any onshore development would be subject to the environmental assessment process which would include investigation of heritage resources and, if necessary their preservation.

Routine activities associated with oil and gas in the Area of Focus could contribute to **cumulative effects** in the region. Other human activities such as mining activity and increases in shipping and tourism due to declining sea ice will have some effects on employment, because of the likely requirement of local workers. This will draw down both the trained and entry level resources, which may lead to labour shortages and wage inflation. Community infrastructure and services could be affected cumulatively should construction of onshore components for oil and gas projects, and another large project such as a mine, both involve workers staying in local communities. An influx of workers has the potential to affect the capacity of hotels and temporary accommodations, grocery stores and service centres, healthcare services, and fire and emergency services. Increased marine traffic in the nearshore and land-fast ice zone has the potential to increase the cumulative effect on traditional travel routes and access to harvesting locations.

Transboundary effects from routine oil and gas activities on human environment VSECs are not anticipated, other than inter-provincial/territorial migration of workers, and transboundary economic effects (e.g., purchase of goods and services outside of Nunavut.

Accidents and malfunctions (i.e. oil spill) could interfere directly with commercial fishing, traditional harvest, marine based tourism, traditional use and practices, and consumption of traditional foods, depending on the spatial extent and timing of a spill relative to these activities. Depending on its location and magnitude, an accidental spill could result in actual or perceived effects to the availability or quality of the marine environment, and result in loss of access to areas and species that may be used for both traditional and non-traditional harvesting activities.

EFFECTS OF THE ENVIRONMENT ON OIL AND GAS ACTIVITIES

Potential effects of the environment on offshore oil and gas activities in the Area of Focus are associated with risks of natural hazards and influences of nature. Potential effects of the environment on the scenarios would typically be addressed through design and operational procedures developed in consideration of expected normal and extreme environmental conditions. Potential effects of the environment on the scenario are considered in the infrastructure decisions and the lifecycle assessment including the design, construction, and operation and maintenance of equipment to be used in the scenario activities. As technology is advancing rapidly, it is expected that the equipment will be designed, constructed, and operated to respond to reasonably projected environmental forces that may occur in the

Arctic and specifically in the Area of Focus. Current designs and future advances would help to maintain safety, integrity, and reliability in consideration of existing environmental changes.

*C*ONCLUSION

The exercise of assessing potential effects of oil and gas activities on the physical, biological, and human environment in the Area of Focus is complicated by the regions susceptibility to effects of climate change and the rapidly evolving socio-economic conditions in Nunavut. The goal of the SEA is to inform the government on whether oil and gas activity might proceed, and under which conditions. While a strategic environmental assessment can be used as planning tool for communities and decision makers, its use must be balanced with the understanding that its contribution is qualitative in nature and is based on assumptions, current best practices, and approaches that may or may not be aligned with how, or if, proposed oil and gas activities might proceed in the region.

If oil and gas activities were not to proceed in the Area of Focus, there would be no effects on the physical, biological, or human environment resulting from oil and gas activities. However, other development activities (e.g. shipping, mining, tourism) and pressure on the environment from human use is expected to increase in the future; as a result, the environment is likely to face the same types of potential effects as those described for routine oil and gas activities. Oil spills could also occur as a result of vessel collisions, and accidental discharges from vessel or barges. In addition, climate change will continue to affect habitat and biological and human populations in the region.

Data and information gaps associated with many of the VECs and VSECs identified through the SEA scoping process are a key reason for attributing low confidence to the predictions of effects that are discussed. With shifting dynamics in the Arctic environment resulting from climate change and increasing pressure to explore opportunities for development and economic opportunities, the need to fill gaps in knowledge in the Area of Focus has become a critical element in effective planning and policy making for the region. Many of the information gaps identified through the process of completing this literature review exercise are associated with understanding the current status of populations and how they may respond to a shifting environment.

Table ES-1 Table of Concordance

Final Scope List for the NIRB's Strategic Environmental Assessment in Baffin Bay and Davis Strait (NIRB 2018)		**Environmental Setting and Review of Potential Effects of Oil and Gas Activities (Nunami Stantec 2018)**	***Strategic Environmental Assessment in Baffin Bay and Davis Strait: Oil and Gas Life Cycle Activities and Hypothetical Scenarios* (Nunami Stantec Ltd. 2018)**	**Final Report (NIRB 2018)**
Appendix A: Background Information				
Purpose of the Assessment		Section 1.0	N/A	NIRB to Complete
SEA Phases		N/A	N/A	NIRB to Complete
Area of Focus		Section 2.1	N/A	NIRB to Complete
Objectives	1. Background Information	Section 3.0, Section 4.0, Section 5.0	Section 2.0, Section 3.0, Section 6.0	NIRB to Complete
	2. Describe potential challenges, obstacles, and other factors relevant to possible oil and gas development	N/A	Section 6.0	NIRB to Complete
	3. Describe possible oil and gas development scenarios	Section 2.3.3.1	Section 4.0, Section 5.0, Section 9.0	NIRB to Complete
	4. Assess the potential impacts and benefits	Section 7.0	N/A	NIRB to Complete
	5. Identify knowledge and data gaps, including areas of concern	Section 8.0, Appendix B	N/A	NIRB to Complete
	6. Develop Final SEA Report with recommendations	N/A	N/A	NIRB to Complete
Collection and Use of Information		N/A	N/A	NIRB to Complete
SEA Management		N/A	N/A	NIRB to Complete
Appendix C: Draft Scope List				
Past Oil and Gas Activities		N/A	Section 2.0	NIRB to Complete
Activities and Components		Section 2.3.3.1	Section 4.0 and Section 5.0	NIRB to Complete
Spatial and Temporal Boundaries		Section 2.1	Section 1.0 and Section 7.0	NIRB to Complete
Components to be Considered		Table ES-2	N/A	NIRB to Complete
Subjects of Note	Energy security and diversification	N/A	N/A	NIRB to Complete
	Naturally occurring oil seeps, including location and extent	Section 3.7.2.2	Section 2.0	NIRB to Complete
Assessment of Effects of Offshore Oil and Gas Scenarios/Activities		Table ES-2	N/A	NIRB to Complete
Assessment of Effects of the Environment on Potential Offshore Oil and Gas Scenarios/Activities		Section 7.4	N/A	NIRB to Complete
Assessment of Cumulative Effects		Section 7.1.2, Section 7.2.2, Section 7.3.2	N/A	NIRB to Complete
Assessment of Transboundary Effects		Section 7.1.3, Section 7.2.3, Section 7.3.3	N/A	NIRB to Complete
Any Other Relevant Matters	Technical Innovations	N/A	Section 6.0	NIRB to Complete
	Discussion of similar resource development projects in other jurisdictions	N/A	Section 8.0	NIRB to Complete

Table ES-2 Table of Concordance: Appendix C, Components to be Considered

Final Scope List for the NIRB's Strategic Environmental Assessment in Baffin Bay and Davis Strait (NIRB 2018) **Appendix C: Draft Scope List Components to be Considered**	**Environmental Setting and Review of Potential Effects of Oil and Gas Activities (Nunami Stantec 2018)**							***Strategic Environmental Assessment in Baffin Bay and Davis Strait: Oil and Gas Life Cycle Activities and Hypothetical Scenarios* (Nunami Stantec Ltd. 2018)**	**Final Report (NIRB 2018)**
VEC/VSEC	**VEC/VSEC**	**Environmental Setting**	**Assessment of Offshore Oil and Gas Scenarios / Activities**	**Assessment of Cumulative Effects**	**Assessment of Transboundary Effects**	**Assessment of Effects of Accidents and Malfunctions**	**Mitigation Measures and Planning Considerations**		
Physical Environment									
1. Climate and meteorology (weather and storm conditions) 2. Oceanography (including wind, waves, tides, currents, sea level, storm surge, and upwelling) 3. Sea ice and iceberg conditions	Climate and Meteorology	Section 3.1	NE	NE	NE	NE	Section 7.1.5, Appendix B	N/A	NIRB to Complete
	Oceanography	Section 3.4	Section 7.1.1	Section 7.1.2	Section 7.1.3	Section 7.1.4.1	Section 7.1.5, Appendix B	N/A	NIRB to Complete
	Bathymetry	Section 3.3	NE	NE	NE	NE	Section 7.1.5, Appendix B	N/A	NIRB to Complete
	Sea Ice and Iceberg Conditions	Section 3.5	Section 7.1.1	NE	NE	Section 7.1.4.3	Section 7.1.5, Appendix B	N/A	NIRB to Complete
4. Air quality	Air Quality and Greenhouse Gases	Section 3.2	Section 7.1.1	NE	Section 7.1.3	NE	Section 7.1.5, Appendix B	N/A	NIRB to Complete
5. Acoustic environment (atmospheric and under water noise)	Acoustic Environment	Section 3.6	Section 7.1.1	Section 7.1.2	NE	NE	Section 7.1.5, Appendix B	Section 4.1	NIRB to Complete
6. Geology (coastal and submarine)	Geology	Section 3.7	NE	NE	NE	NE	Section 7.1.5, Appendix B	Section 2.0	NIRB to Complete
7. Coastal landforms 8. Marine sediment	Coastal Landforms	Section 3.8	NE	NE	NE	NE	Section 7.1.5, Appendix B	N/A	NIRB to Complete
	Marine Sediment	Section 3.9	Section 7.1.1	NE	NE	Section 7.1.4.2	Section 7.1.5, Appendix B	N/A	NIRB to Complete
Biological Environment									
9. Coast and shoreline environment (including coastal and marine plants)	Coast and Shoreline	Section 4.2	NE	NE	NE	Section 7.2.4.	Section 7.2.5, Appendix B	N/A	NIRB to Complete
10. Plankton 11. Benthic flora and fauna (including soft corals and seaweed) 12. Fish and fish habitat (including water quality) 13. Waterbirds (seabirds, waterfowl, and shorebirds) 14. Marine mammals	Plankton	Section 4.3	Section 7.2.1	Section 7.2.2	NE	Section 7.2.4.	Section 7.2.5, Appendix B	N/A	NIRB to Complete
	Benthic Flora and fauna	Section 4.4	Section 7.2.1	Section 7.2.2	NE	Section 7.2.4.	Section 7.2.5, Appendix B	N/A	NIRB to Complete
	Fish and Fish Habitat	Section 4.5	Section 7.2.1	Section 7.2.2	Section 7.2.3	Section 7.2.4.	Section 7.2.5, Appendix B	N/A	NIRB to Complete
	Waterbirds	Section 4.6	Section 7.2.1	Section 7.2.2	Section 7.2.3	Section 7.2.4.	Section 7.2.5, Appendix B	N/A	NIRB to Complete
	Marine Mammals	Section 4.7	Section 7.2.1	Section 7.2.2	Section 7.2.3	Section 7.2.4.	Section 7.2.5, Appendix B	N/A	NIRB to Complete
15. Species at Risk	Species at Risk[1]	Section 4.1	**	**	**	**	**	N/A	NIRB to Complete
16. Special and Sensitive Areas	Special and Sensitive Areas	Section 4.8	Section 7.2.1	Section 7.2.2	NE	Section 7.2.4.7	Section 7.2.5, Appendix B	N/A	NIRB to Complete
17. Areas of Concerns/Importance	Areas of Concern or Importance	Section 4.9	Section 7.2.1	Section 7.2.2	NE	Section 7.2.4.7	Section 7.2.5, Appendix B	N/A	NIRB to Complete
Human Environment									
18. Potentially interested communities	Potentially interested communities[2]	Section 5.1	N/A	N/A	N/A	N/A	N/A	N/A	NIRB to Complete

[1] ** Potential environmental effects on species at risk (see Section 4.1) are not addressed separately (or individually), but are discussed under marine fish and fish habitat, waterbird, and marine mammal VECs.
[2] VSECs are assessed for the Qikiqtani region, with a focus on the potentially interested communities

Table ES-2 Table of Concordance: Appendix C, Components to be Considered

Final Scope List for the NIRB's Strategic Environmental Assessment in Baffin Bay and Davis Strait (NIRB 2018) Appendix C: Draft Scope List Components to be Considered	Environmental Setting and Review of Potential Effects of Oil and Gas Activities (Nunami Stantec 2018)							***Strategic Environmental Assessment in Baffin Bay and Davis Strait: Oil and Gas Life Cycle Activities and Hypothetical Scenarios* (Nunami Stantec Ltd. 2018)**	**Final Report (NIRB 2018)**
VEC/VSEC	**VEC/VSEC**	**Environmental Setting**	**Assessment of Offshore Oil and Gas Scenarios / Activities**	**Assessment of Cumulative Effects**	**Assessment of Transboundary Effects**	**Assessment of Effects of Accidents and Malfunctions**	**Mitigation Measures and Planning Considerations**		
19. Economic development and opportunities	Economic Development and Opportunities	Section 5.2	Section 7.3.1	Section 7.3.2	NE	Section 7.3.4	Section 7.3.5	N/A	NIRB to Complete
20. Employment	Employment	Section 5.3	Section 7.3.1	Section 7.3.2	NE	Section 7.3.4	Section 7.3.5	N/A	NIRB to Complete
21. Contracting and business development	Contracting and Business Development	Section 5.4	Section 7.3.1	Section 7.3.2	NE	Section 7.3.4	Section 7.3.5	N/A	NIRB to Complete
22. Education and training	Education and Training	Section 5.5	Section 7.3.1	Section 7.3.2	NE	Section 7.3.4	Section 7.3.5	N/A	NIRB to Complete
23. Population demographics		Section 5.1.1	Section 7.3.1	Section 7.3.2	NE	Section 7.3.4	Section 7.3.5	N/A	NIRB to Complete
24. Wellbeing and health of coastal communities	Health and Wellbeing	Section 5.6	Section 7.3.1	Section 7.3.2	NE	Section 7.3.4	Section 7.3.5	N/A	NIRB to Complete
25. Community infrastructure and services	Community Infrastructure and Services	Section 5.7	Section 7.3.1	Section 7.3.2	NE	Section 7.3.4	Section 7.3.5	N/A	NIRB to Complete
26. Traditional activity & knowledge and community knowledge including:	Traditional Use and Practices	Section 5.8	Section 7.3.1	Section 7.3.2	NE	Section 7.3.4	Section 7.3.5	N/A	NIRB to Complete
• Land use	Traditional Harvest	Section 5.9	Section 7.3.1	Section 7.3.2	NE	Section 7.3.4	Section 7.3.5	N/A	NIRB to Complete
• Food security • Cultural activities	Traditional Foods	Section 5.10	Section 7.3.1	Section 7.3.2	NE	Section 7.3.4	Section 7.3.5	N/A	NIRB to Complete
27. Non-traditional, recreation, and tourism activities	Non-Traditional Use	Section 5.12	Section 7.3.1	Section 7.3.2	NE	Section 7.3.4	Section 7.3.5	N/A	NIRB to Complete
28. Cultural and commercial harvesting (including fisheries)	Commercial Harvest	Section 5.13	Section 7.3.1	Section 7.3.2	NE	Section 7.3.4	Section 7.3.5	N/A	NIRB to Complete
29. Marine commercial traffic (including cruise tourism and re-supply vessels)	Marine Transportation	Section 5.14	Section 7.3.1	Section 7.3.2	NE	Section 7.3.4	Section 7.3.5	N/A	NIRB to Complete
30. Other reasonably foreseeable future activities[3]	N/A	Section 2.3.6			NE			N/A	NIRB to Complete
31. Heritage resources	Heritage resources	Section 5.11	Section 7.3.1	Section 7.3.2	NE	Section 7.3.4	Section 7.3.5	N/A	NIRB to Complete
Other Considerations									
32. Climate change	Climate Change	Section 6	N/A	N/A	N/A	N/A	N/A	N/A	NIRB to Complete
33. Accidents and Malfunctions	N/A	N/A	N/A	N/A	N/A	Section 7.1.4, Section 7.2.4, Section 7.3.4	Appendix B	Section 10.0	NIRB to Complete
34. Jurisdiction and responsible authorities	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Section 3.0	NIRB to Complete

NOTES:
NE: indicates that initial screening of effects on that VEC has determined that the VEC or VSEC is not expected to interact with oil and gas activities, or if potential effects can be reduced or eliminated using standard mitigative approaches or planning considerations. This notation is also used to indicate that the assessment of effects determined that no cumulative effects, transboundary effects, or effects from accidents and malfunctions would occur.
N/A: indicates that the topic is not applicable and/or discussed

[3] Reasonably foreseeable future activities are identified in Table 2.2 to provide context for the assessment of cumulative effects on VECs and VSECs

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Abbreviations

μg/m³	micrograms per cubic metre
2D	two dimensional
3D	three dimensional
AFA	Arctic Fishery Alliance LP
AMO	Atlantic Multidecadal Oscillation
BF	Baffin Fisheries
BIC	Baffin Island Current
CAAQS	Canadian Ambient Air Quality Objectives
CAC	common air contaminant
CANGRD	Canadian Gridded Temperature and Precipitation Anomalies
CCME	Canadian Council of Ministers of the Environment
CEA Agency	Canadian Environmental Assessment Agency
CH_4	methane
CIS	Canadian Ice Service
CO	carbon monoxide
CO_2	carbon dioxide
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CPI	consumer price index
CPRA	*Canadian Petroleum Resources Act*
CWS	Canada Wide Standards
dB	decibel
dBA	A-weighted decibels
DFO	Fisheries and Oceans Canada
EBSA	Ecologically and Biologically Significant Areas
ECCC	Environment and Climate Change Canada
EC-WG	Eastern Canada-West Greenland
EEM	Environmental Effects Monitoring
EMOBM	enhanced mineral oil-based mud
EPP	environmental protection plan
FLNG	floating liquid natural gas
FPSO	floating production, storage, and offloading
GDP	gross domestic product
GHG	greenhouse gas
Gt	Gigatonnes
GWP	global warming potentials
hPa	hecto pascals

Hz .... hertz
IBA .... important bird area
IIBA .... Inuit Impact Benefits Agreement
INAC .... Indigenous and Northern Affairs Canada
IPCC .... Intergovernmental Panel on Climate Change
IPY .... International Polar Year
IQ .... Inuit Qaujimaningit
IUCN .... International Union for the Conservation of Nature
kHz .... kilohertz
LNG .... liquified natural gas
MARPOL .... International Convention for the Prevention of Pollution from Ships
MBS .... Migratory Bird Sanctuary
MOS .... model output statistics
MPA .... Marine Protected Area
MW .... megawatt
MWO .... Marine Wildlife Observer
N_2O .... nitrous oxide
NAAQO .... National Ambient Air Quality Objectives
NAFO .... Northwest Atlantic Fisheries Organization
NAO .... North Atlantic Oscillation
NAPS .... National Air Pollution Surveillance
NCRI .... Nunavut Coastal Resource Inventory
NEAS .... Nunavut Eastern Arctic Shipping
NEB .... National Energy Board
NIRB .... Nunavut Impact Review Board
NMCA .... National Marine Conservation Area
NOAA .... National Oceanic and Atmospheric Administration
NO_X .... nitrogen oxides
NSA .... Nunavut Settlement Area
NSIDC .... National Sea Ice Data Center
NSSI .... Nunavut Sealink and Supply Inc.
NWA .... National Wildlife Area
NWA-EA .... The Northwest Atlantic/Eastern Arctic
NWMB .... Nunavut Wildlife Management Board
O_3 .... ozone
OA .... operations authorization
OBM .... oil-based mud
PAH .... polycyclic aromatic hydrocarbons
PM .... particulate matter

PM_{10} .... particulate matter less than 10 micrometres in diameter
$PM_{2.5}$ .... particulate matter less than 2.5 microns
PSA .... particle size analysis
QC .... Qikiqtaaluk Corporation
QIA .... Qikiqtani Inuit Association
QSO .... Qikiqtani School Operations
RCP .... Representative Concentration Pathway
ROV .... remote operated vehicle
SAIC .... Science Applications International Corporation
SARA .... *Species at Risk Act*
SBM .... synthetic-based mud
SEA .... Strategic Environmental Assessment
SEL .... sound exposure level
SLP .... sea level pressure
SO_2 .... sulphur dioxide
SPL .... sound pressure level
SPLpeak .... peak sound pressure level
SPLrms .... root mean square sound pressure level
SST .... surface sea temperature
SWH .... significant wave height
t .... tonne
TAC .... total allowable catch
TD .... total depth
TK .... traditional knowledge
TSS .... total suspended solids
USD .... US Dollars
VC .... valued component
VEC .... valued ecosystem component
VOC .... volatile organic compounds
VSEC .... valued socio-economic component
WBM .... water based mud
WGC .... Western Greenland Current
WMP .... waste management plan
μPa .... micropascal

1 INTRODUCTION AND BACKGROUND

On February 9, 2017, the Nunavut Impact Review Board (NIRB) received a referral from Indigenous and Northern Affairs Canada (INAC) to initiate the process of completing a Strategic Environmental Assessment for the Baffin Bay and Davis Strait region (the SEA) (Nunavut Impact Review Board 2018). The objective of the SEA is to develop an improved understanding of potential types of oil and gas related activities that could be proposed within the Canadian waters of Baffin Bay and Davis Strait outside of the Nunavut Settlement Area (NSA) along with their associated adverse effects, benefits, and management strategies (Nunavut Impact Review Board 2018). The Final SEA Report can be used as a tool that can support regional planning strategies and inform future project specific environmental and decision-making processes. he Final SEA will be prepared by the NIRB and submitted to the Minister of Crown-Indigenous Relations and Northern Affairs in March 2019.

An effective SEA considers the scope and nature of potential environmental effects, mitigation and planning considerations that can reduce or eliminate potential effects, and the scope and nature of predicted residual effects that could remain after implementation of mitigation and planning measures (Government of Canada 2010). Public and Stakeholder concerns are a key consideration in the completion of a SEA (Government of Canada 2010).

To support the NIRB in the preparation of a Final SEA report, Nunami Stantec was retained to prepare a literature review of the current state of knowledge of the physical, biological and human environments of Baffin Bay and Davis Strait, as well as the associated potential effects that oil and gas activities could have on specific valued ecosystem components (VECs) and valued socio-economic components (VSECs) in the region. The content of this report has been prepared to align with the Final Scope List (Nunavut Impact Review Board 2018). The Final Scope List was developed through a comprehensive public process to frame the scope for the SEA in Baffin Bay and Davis Strait.

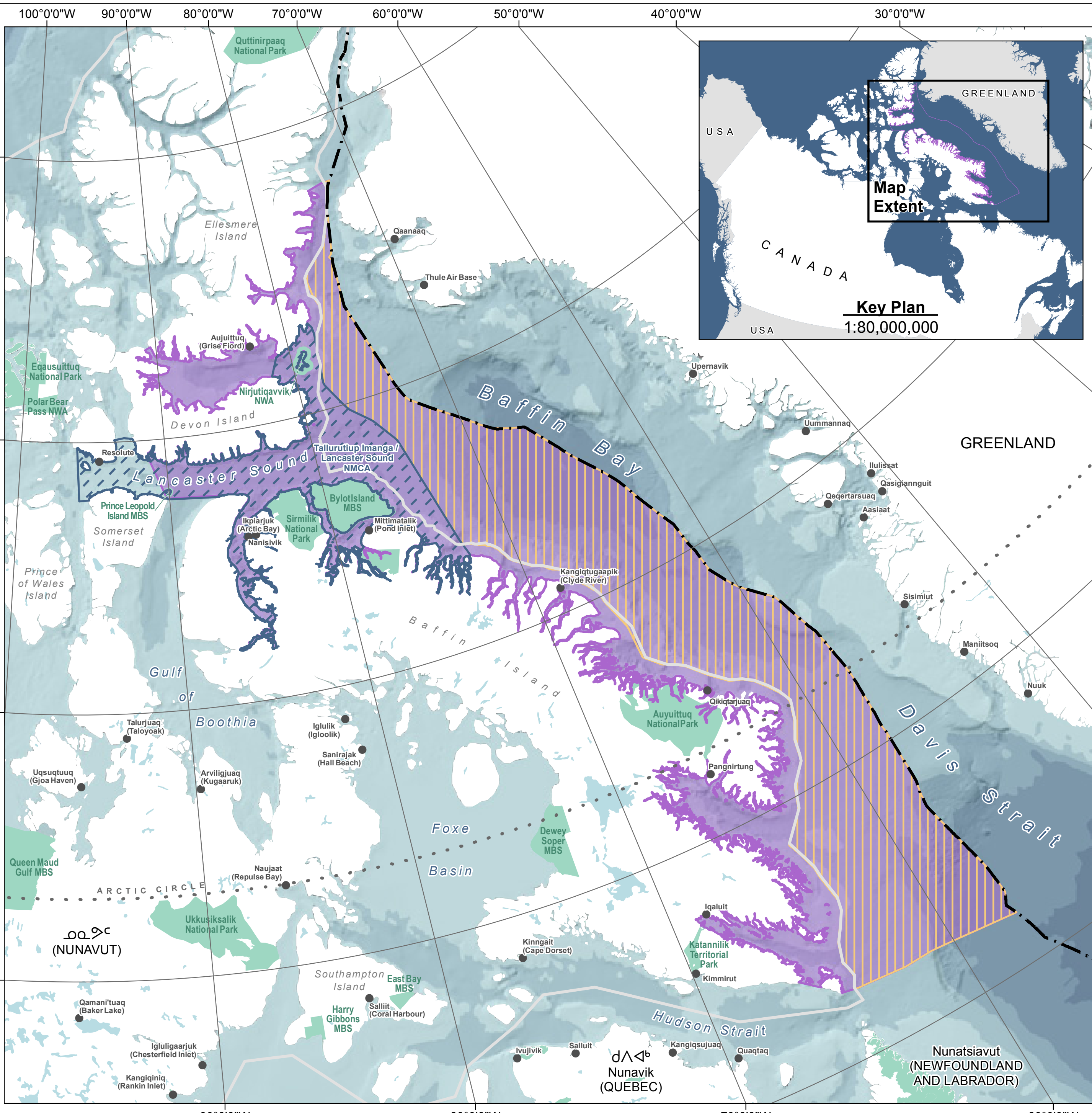
2 STRATEGIC ENVIRONMENTAL ASSESSMENT—CONTEXT AND APPROACH

2.1 Spatial and Temporal Boundaries

The SEA considers possible types of oil and gas related development activities that might be proposed in the future within the Canadian waters of Baffin Bay and Davis Strait outside of the NSA. It also considers the associated adverse effects, benefits, and management strategies that could occur as a result of these activities, including cumulative effects. The Area of Focus established for the SEA is illustrated in Figure 2.1. It includes offshore[4] areas in Baffin Bay and Davis Strait, Lancaster Sound, Jones Sound, Smith Sound, and the southern part of Nares Strait. This broader Area of Focus is used when describing the environmental setting for the region (Sections 3, 4, and 5) and the discussion of potential effects of oil and gas activities (Section 7). The hypothetical scenarios of oil and gas activity described in Section 2.3.3.1 include a description of potential oil and gas exploration and development activities that could occur in the Baffin Bay and Davis Strait region of Canada's eastern arctic offshore outside of the NSA. The area within which offshore oil and gas activities could occur is shown on Figure 2.1 as "Development Scenarios". The hypothetical development scenarios (see Section 2.3.3.1) does not exclude the potential for coastal based infrastructure and activities and components to be established in support of offshore oil and gas development activities and components.

The temporal boundaries of the SEA extend through the typical life cycle of oil and gas exploration and development activities and is assumed to be 15–20 years for exploration and 30–60 years for field development and production. Given the rapid advancement in offshore technology in the oil and gas sector, as well as the environmental changes associated with climate change, and ongoing and expected future research and observation of the physical, biological and human environments in the region, the information presented in the SEA should be updated periodically to reflect any updated information that becomes available.

[4] The term offshore refers to marine waters seaward from the shoreline, and typically beyond the continental shelf.



Base Features

- Community[1]
- Limit of Exclusive Economic Zone[4]
- Nunavut Settlement Area[3]
- Tallurutiup Imanga / Lancaster Sound NMCA[2]
- Protected Area or National Park[4]

Bathymetry Depth[5] (m)

< 200, 200 - 1000, 1000 - 2000, 2000 - 3000, > 3000

Project Features

- Area of Focus[2]
- Development Scenarios[2]

1:12,000,000

0 50 100 200 300 400 Kilometres

References:
[1]Atlas of Canada Base Maps, 2017
[2]NIRB, 2017
[3]Nunavut Planning Commission, 2010
[4]National Framework Canada, 2017
[5]Natural Earth, 2016

Nunavut Impact Review Board Strategic Environmental Assessment

Figure 2.1 Spatial Boundaries of the Strategic Environmental Assessment

NUNAMI STANTEC LIMITED

N.I.R.B.

Prepared By: Nunami Stantec Limited
Projection: Canada Lambert Conformal Conic, North American 1983
Date: Apr 13, 2018
Project Number: 12322100
Produced By: L. Trudell
Verified By: J. Beckett
Revision: 01

Filepath: S:\1232\projects\123221001\figures\report\SEA\fig_123221001_NIRB_SEA_02.1_Spatial_Boundaries_of_the_Strategic_Environmental_Assessment.mxd

2.2 Inuit Qaujimaningit

2.2.1 Definitions

The NIRB's final scope for the SEA in Baffin Bay and Davis Strait states that "the SEA will incorporate available scientific information, Inuit Qaujimajatuqangit and Inuit Qaujimaningit[5] and other types of traditional knowledge (TK), and public feedback. An essential component of the SEA is to reflect Inuit concerns and traditional use of the associated marine areas."[6] The NIRB further explains that "Inuit Qaujimaningit shared with the Board by the public and Inuit organizations will be considered essential to shaping and influencing the SEA process and will be given equal weight as western scientific information." (Nunavut Impact Review Board 2018)

The NIRB's final scope for the SEA in Baffin Bay and Davis Strait states that "Inuit Qaujimajatuqangit refers to traditional values, beliefs, and principles while Inuit Qaujimaningit [IQ] encompasses Inuit TK (and variations thereof), as well as Inuit epistemology as it relates to Inuit Societal Values and Inuit Knowledge (both contemporary and traditional)" (Nunavut Impact Review Board 2018). This report will use the term IQ, to refer to "Inuit Traditional Knowledge, as well as Inuit epistemology, without reference to temporality" (Nunavut Impact Review Board n.d.).

2.2.2 Information Collection

A literature review was conducted to collect IQ and scientific information relevant to the Area of Focus and NIRB's scope of factors and issues to be considered in the SEA (Nunavut Impact Review Board 2018). The sources reviewed for the collection of IQ included publicly available traditional land use study reports (e.g., The Inuit Land Use and Occupancy Project and The Nunavut Atlas), websites highlighting IQ (e.g., Draft Nunavut Land Use Plan), government research reports where IQ was the main source of information (e.g., Nunavut Wildlife Management Board [NWMB] 1998. *A Study of Inuit Knowledge of the Southeast Baffin Beluga*), and scientific studies where IQ figured prominently as a source of information (e.g., Priest and Usher 2004; Nunavut Department of Environment 2005). Information collected from the IQ literature review was considered and used concurrently with information collected from the scientific literature review.

Where the use of shapefiles for mapped information on land use, occupation, or resources was available from a publicly available source, permission to use that information in the SEA was sought. As of March 27, 2018, permission to use the shapefiles from The Nunavut Atlas, Nunavut Land Use Plan Community Priorities and Values, Nunavut Climate Change, and Pikialasorsuaq Commission—Pikialasorsuaq pillugu Isumalioqatigiissitat websites had not been received.

[5] Inuit Qaujimajatuqangit refers to traditional values, beliefs, and principles while Inuit Qaujimaningit encompasses Inuit traditional knowledge (and variations thereof) as well as Inuit epistemology as it relates to Inuit Societal Values and Inuit Knowledge (both contemporary and traditional).
[6] Nunavut Impact Review Board (NIRB). 2018. Final Scope for the NIRB's Strategic Environmental Assessment in Baffin Bay and Davis Strait. NIRB File No.: 17SN034. 25 Pp.

2.2.3 Reporting

It is acknowledged that the written format and language used for drafting this report represent traditional means of communicating in western science. Despite the medium for reporting, efforts have been made to give information from IQ and western science equal weight. In western science reporting, in-text citations are required to acknowledge sources of information; this report uses in-text citations for both scientific information and IQ.

IQ related to the valued ecosystem components named in the NIRB scope for the SEA was reviewed alongside scientific literature related to the same. Both sources contributed to reporting in the Physical, Biological, and Human Environment sections, as well as the Potential Effects, Mitigation and Planning Considerations section. IQ figures prominently as a source in the Traditional Use and Practices, Traditional Harvest, and Traditional Foods reporting within the Human Environment section.

The knowledge bases of IQ and western science are the result of different historical and cultural legacies (Arnakak 2005; Iaccarino 2003; Kuptana and Napayok-Short 2016; Mazzocchi 2006).Throughout the report, it will be evident where information from IQ and western science have complementary conclusions. In cases where IQ and western science reach different conclusions on the same issue, information from each will be presented, but not reconciled in favour of one knowledge base or another. Reconciliation of differing conclusions will require further engagement with Inuit and scientists beyond the scope of the SEA.

In identifying potential effects on Inuit traditional use and practices, traditional harvest, and traditional food, this assessment uses a conservative approach that recognizes that a lack of publicly available IQ for a specific species, area or activity does not necessarily represent a lack of current use of that species, area or activity, especially as the SEA specific IQ has not yet been obtained. The assessment assumes that species identified through IQ that are present within the Area of Focus, could be hunted, trapped, fished or gathered by Inuit groups.

Assumptions on traditional use are also supported by western scientific information on other biophysical elements. For example, the assessments of benthic flora and fauna, fish and fish habitat, waterbirds, and marine mammals can help inform an assessment of traditional use and practices, traditional harvesting activities, and traditional foods. The assessments of the physical environment and climate change can provide information regarding changes in the environment that may affect conditions under which traditional use and practices and traditional harvest can occur. However, the results of these biophysical assessments may not fully align with IQ on traditional use and practices, traditional harvest and traditional foods assessment. Furthermore, mitigation measures for biophysical effects also may not mitigate potential effects on traditional use and practices, traditional harvest, and traditional foods.

2.3 Strategic Environmental Assessment—Methodology

A Strategic Environmental Assessment provides an opportunity to engage in an open and transparent process with local communities, stakeholders and regulatory authorities to address regional scale issues associated with the analysis of effects of human activities on the environment. The SEA for Baffin Bay and Davis Strait is focused on understanding potential effects, benefits and management strategies associated with future oil and gas activities but will also consider the potential cumulative impacts that could arise in combination with other human activities in the region. It also addresses potential transboundary effects that could occur in neighboring jurisdictions.

2.3.1 Identification of Valued Components

Since April 2017, the NIRB has collected available information and input from communities, stakeholders and the general public to identify VECs and VSECs that represent broad indicators of ecosystem health and regional environmental change. These components take into account the temporal and spatial boundaries established for the SEA, and draw from relevant information from scientific sources, IQ, traditional, and community knowledge. *The Final Scope List for the NIRB's Strategic Environmental Assessment in Baffin Bay and Davis Strait* (Nunavut Impact Review Board 2018) identifies the specific components to be considered (VECs and VSECs). Each of the valued components is considered in the discussion of environmental setting (Sections 3, 4, and 5), and the discussion of potential effects (Section 7).

2.3.2 Environmental Setting

A fulsome description of environmental setting provides a baseline understanding of the VECs and VSECs in the region. Baseline information was collected through review of available literature and IQ and did not draw from any field-based research or modelling exercises completed specifically for the SEA. Literature was sourced through internet search (e.g. google, online databases, government sources) and hard copy literature (e.g. books, reports, etc.).

2.3.3 Potential Effects from Routine Activities

The review of potential effects of routine oil and gas activities on the selected VECs and VSECs is based on a description of routine activities that are likely to be associated with oil and gas development in an arctic environment, as well as the identification of hypothetical *scenarios* that illustrate what a typical oil and gas development life cycle might look like in the Area of Focus. Routine activities associated with offshore oil and gas development are described in *Strategic Environmental Assessment in Baffin Bay and Davis Strait: Oil and Gas Life Cycle Activities and Hypothetical Scenarios* (Nunami Stantec Ltd. 2018). Potential accidents and malfunctions are also described. The report was prepared by Nunami Stantec to support the NIRB in the completion of the SEA and provide context for the review of potential effects of oil and gas activities on the VECs and VSECs.

Four hypothetical scenarios are described below, one for each of the typical phases of offshore oil and gas activities; specifically: exploration, appraisal, production, and decommissioning activities. Each scenario describes the circumstances and assumptions associated with a reasonable prediction of how oil and gas exploration and development could proceed in the region. Potential accidents and malfunctions are also discussed.

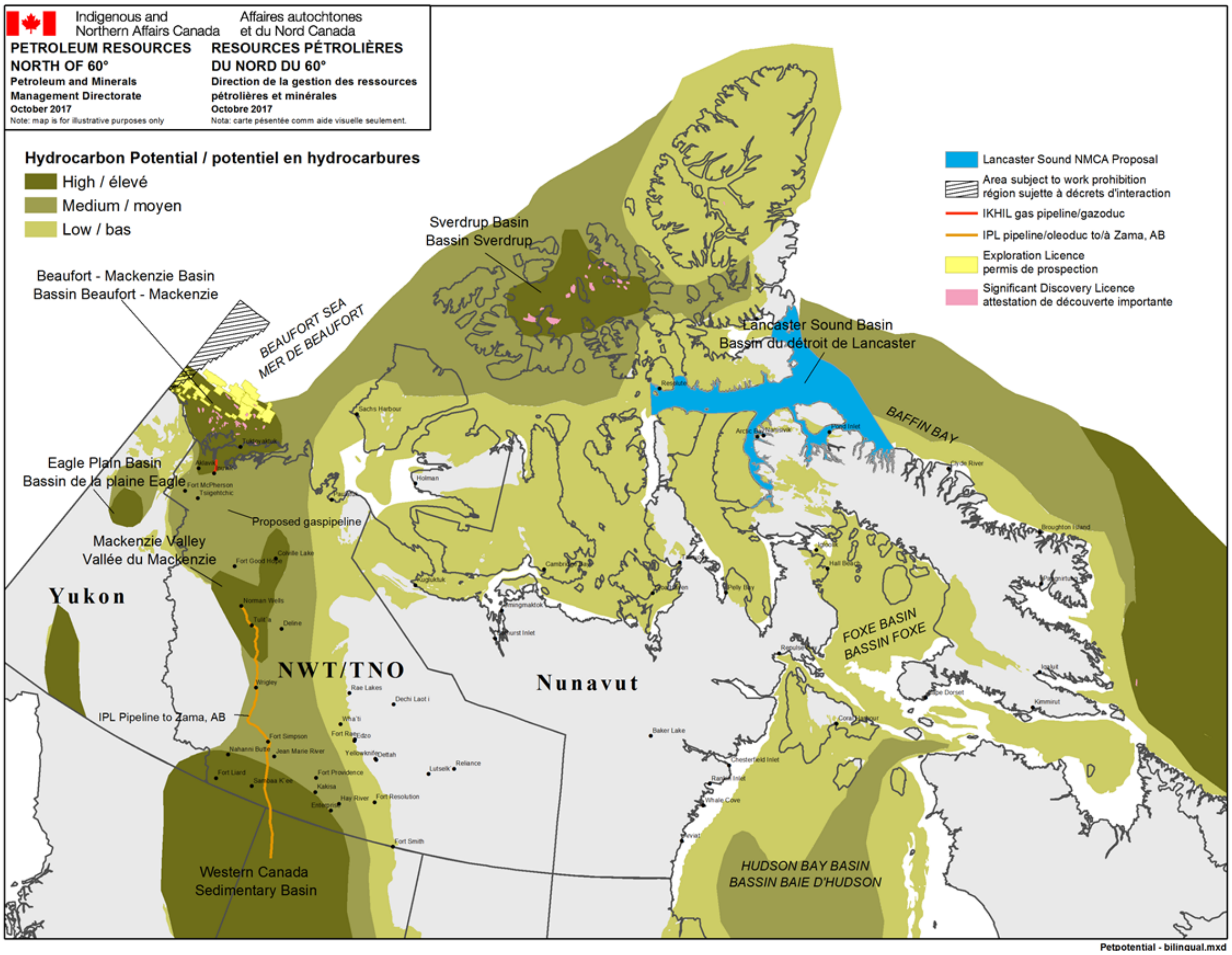
2.3.3.1 Hypothetical Scenarios

The hypothetical scenarios consider approximate timelines, activities, financial feasibility, domestic policy and regulations, and climate to provide a baseline understanding of what the potential impacts and effects pathways could be if oil and gas exploration and/or development were to proceed in the Area of Focus. The scenarios are not associated with a specific location within the Area of Focus but are intended to cover the full complement of oil and gas exploration and development activities that could occur in the Baffin Bay and Davis Strait region of Canada's eastern arctic offshore outside of the NSA. Although the sedimentary basin underlying the region is predominantly unexplored to date, the data that does exist suggests that the highest geological potential lies within southern Davis Bay (Figure 2.2). For the purposes of the hypothetical scenarios, it is assumed that oil and gas exploration and development would most likely be focused in southern Davis Bay. However; the activities and infrastructure described within the hypothetical scenarios and the associated potential effects would be similar throughout the Area of Focus. It is important to note that the scenarios are intended to illustrate potential approaches to oil and gas development in the Arctic. While the intent is to make them realistic, they are not a proposal for a real project, nor are they a representation of government initiatives or a specific industrial interest. They are intended only as a basis for evaluating associated potential effects. A central premise of this approach is that as substantial changes in technology occur or substantial new information becomes available, the scenarios and the SEA should be adjusted.

There is variation in the way in which oil and gas exploration and development is carried out. For example, oil and gas exploration programs can vary depending on type of equipment, nature of survey, depth of drilling target etc. The scenarios are intended to be broadly representative of what might occur.

If an oil and gas project was considered, a detailed project description would need to be developed to support the screening and assessment of environmental and socio-economic effects, and the preparation of required regulatory documents.

For additional details on the activities, timelines and regulatory requirements associated with the scenarios, refer to *Strategic Environmental Assessment in Baffin Bay and Davis Strait: Oil and Gas Life Cycle Activities and Hypothetical Scenarios* (Nunami Stantec Ltd. 2018).



Source: Petroleum and Minerals Management Directorate, Indigenous and Northern Affairs Canada

Figure 2.2 Hydrocarbon Potential Priority Areas in the Canadian Arctic

SCENARIO A: EXPLORATION WITH OFFSHORE SEISMIC SURVEYS

Initial interest in oil and gas resources in a region is generally based on an understanding of geological and hydrocarbon potential. Given that data on hydrocarbon potential in the Area of Focus is limited, additional seismic surveys would be required to determine the potential and composition of the recoverable hydrocarbons in the region, before any further oil and gas exploration would proceed. This data would likely be collected by first completing two dimensional (2D) offshore seismic surveys. The surveys would likely cover a large area with survey lines spaced several kilometres apart and be conducted during the open water season. Surveys could take one to three years to complete. The results of these surveys would provide a general understanding of the regional geological structure.

If results from the 2D seismic survey indicate potential hydrocarbon potential, and industry expresses interest in pursuing exploration of resources in the region, they would then solicit the federal government to put out a call for bids on specific lease areas. Once a company secures an exploration license, they would then conduct a three dimensional (3D) offshore seismic survey within that lease area to provide additional data on known geological targets. Survey lines would be spaced 200–400 m apart. The 3D offshore seismic survey would be conducted during the open water season, and typically would be completed within one season.

POTENTIAL CAPITAL EXPENDITURES

The cost to complete both a 2D survey and a 3D survey could range from $7 million USD[7] to $18.5 million USD[8]. Completion of a seismic survey requires a fully trained and experienced vessel crew and a fully trained and experienced seismic crew. The contracted vessels come with the full crew complement and very little onshore support is required. Local employment opportunities might include 6–10 seasonal positions as Marine Wildlife Observers (MWOs) on board seismic vessels to implement and monitor mitigation commitments. There also could be indirect employment opportunities associated with supplies and services from local sources.

EQUIPMENT AND INFRASTRUCTURE

- Seismic vessel (single air source array and single streamer for 2D survey and up to 2 air source arrays and 6–24 streamers for 3D survey)
- 1–2 support vessels (ice capable)

Requirements for onshore support would be limited (e.g. base for crew transfer, helicopter support) and would likely be provided from Nuuk (Greenland) or Newfoundland and Labrador where appropriate infrastructure is already in place. Crew transfer via helicopter could be based from the Iqaluit airport or any of the other communities in the region if it is feasible and in closer proximity to the location of the seismic survey.

POTENTIAL ACCIDENTS AND MALFUNCTIONS

Potential accidents and malfunctions that could be associated with offshore seismic surveys include:

- Fire and explosions
- Loss of life (falling off the vessel)
- Downed aircraft (helicopter)
- Vessel collisions
- Major weather and sea ice conditions

[7] Assumes completion of 2D and 3D seismic programs within two open water seasons with lower cost seismic vessel
[8] Assumes completion of 2D and 3D seismic surveys completed within four open water seasons with higher cost seismic vessel

- Vessel strike with marine mammals
- Batch spills (e.g., fuel spills from vessels)

Accidents and malfunctions during seismic surveys are uncommon given the slow speeds that seismic vessels must travel (4–5 knots), and international safety standards that the vessels adhere to (described in Section 10). Additionally, the Area of Focus is not heavily used commercially (e.g., commercial fishing vessels and gear, tourism, commercial shipping), which further reduces the likelihood for interactions that could lead to accidents or malfunctions.

SCENARIO B: EXPLORATION DRILLING

If the 3D seismic survey identifies promising hydrocarbon potential within the lease area, and the lease holder decides that it is economically feasible to continue exploration, the next step is to drill into the reservoir to a certain distance below the seabed (referred to as the total depth [TD]) to confirm the presence and type of hydrocarbon and the vertical extent of the reservoir. Delineation drilling would be conducted to determine the horizontal extent of the field. Based on timelines to drill wells in offshore Newfoundland, it is assumed that the time to drill a well would be 35–65 days. This scenario assumes that exploration drilling would be conducted year-round for a total of one year. The program would require an ice management program, a drilling waste management program, and an air emissions management program to comply with standard industry best practices, mitigations and commitments and regulatory conditions. Icebreakers and other support vessels would be required for ice management and logistics support.

Prior to drilling the well, geotechnical and geohazard surveys would be completed to provide detailed information on the area immediately surrounding the well location. Methods to complete these surveys include:

- High-resolution multi-channel seismic data
- Side-scan sonar
- High-resolution sub-bottom profiles
- Seabed photography, magnetometer data and sediment grab samples

During drilling, formation evaluation would be conducted frequently to measure the formation properties, including the porosity and permeability of the rock and the reservoir fluid properties if oil or gas is encountered. Methods to complete formation evaluation include:

- Periodic well logging
- Vertical seismic profiling after drilling is completed
- Well testing using down hole wireline tools

For this scenario, it is assumed that flow testing would not be required.

At the end of each drilling season, drilling activities would be suspended and the well secured until the next drilling season begins. Once a well has reached its target depth and all testing has been completed, it would be plugged and abandoned in accordance with National Energy Board (NEB) regulations.

The drilling platform will support drilling facilities, wellheads and support services (including accommodations), utilities, flare boom and a helideck. The wellhead production will be tied back to the floating production, storage and offloading (FPSO) vessel via existing subsea Infrastructure.

Potential Capital Expenditures

The cost to complete the exploration drilling program associated with this scenario could range from $100 million USD to $150 million USD. Local employment opportunities might include 10–20 full-time positions as MWOs and environmental monitors on board the drilling rig and support vessel to implement and monitor mitigation commitments. With appropriate advance training, additional employment opportunities could be available for residents of Nunavut. There also would be indirect employment opportunities associated with supplies and services from local sources.

Equipment and Infrastructure

- Arctic class drilling platform (drillship or semi-submersible)
- 1–2 icebreaker support vessels
- 2–3 supply vessels (ice strengthened)
- 1–5 fuel tankers (ice strengthened)
- 1–2 wareships (ice strengthened) for offshore storage
- Onshore storage facilities in coastal communities for emergency equipment such as oil spill response equipment and other emergency equipment

Onshore support likely would be provided from Nuuk (Greenland) or Newfoundland and Labrador, where appropriate infrastructure is already in place. It is assumed that purpose built onshore infrastructure would not be required. Crew transfer via helicopter could be based from the Iqaluit airport. Limited transits between Iqaluit and the drill site could occur, assuming that a deep-water port is available. With the exception of storage facilities for emergency response equipment, this scenario assumes that any onshore infrastructure and services required on Baffin Island to support a drilling program would be located in Iqaluit.

Potential Accidents and Malfunctions

Potential accidents and malfunctions associated with exploration drilling include:

- Fire and explosions
- Loss of life (falling off the vessel)
- Downed aircraft (helicopter)

- Terrorist threats
- Drilling rig loss of integrity
- Vessel collisions
- Major weather and sea ice conditions
- Vessel strike with marine mammals
- Batch spills
- Subsea blowout

SCENARIO C: FIELD DEVELOPMENT AND PRODUCTION DRILLING

If a business decision is made to proceed with developing an oil or gas field, the operator would complete a field development plan and proceed with development drilling. To allow for year-round drilling, storage capacity and a means to routinely move the product to market would be required. Although there are several production system options, this scenario assumes that the system would be similar to what has recently been used in Norway and Greenland (see Sections 8.1 and 8.6). The drilling program would be designed to limit or avoid landfall through the use of subsea development tied into FPSO vessels for oil production or floating liquefied natural gas (FLNG) vessels. The drilling platform would support drilling facilities, wellheads and support services (including accommodations), utilities, flare boom and a helideck. Production would take place through a subsea system of oil or gas producing wells, water injection wells and gas injection wells. Power to operate the equipment located on the platform would be needed and could be generated from the operation of equipment such as three dual-fueled turbine generators (two operational, one spare).

The FPSO or FLNG vessels would be designed with large storage capacity and allow for the safe loading of oil or gas on to shuttle tankers for transport to an export destination. The number of tankers and their frequency of transit would depend on production rates, storage capacity on the offshore or onshore facility, vessel capacity and destination locations. A typical large offshore oil production field could require 200,000 deadweight tonnage tankers loading every few days, with similar frequency of liquified natural gas (LNG) tankers for a natural gas facility offshore or onshore.

Ice management and logistics support from icebreakers and other support vessels would be required. The program would also require an ice management program, a drilling waste management program, and an air emissions management program to comply with standard industry best practices, mitigations and commitments and regulatory conditions.

This scenario assumes a 40-year production life. When the production rate becomes uneconomical, the production facilities would be decommissioned. Facilities would be dismantled, removed and reclaimed, and the wells put into a permanent safe state.

Potential Capital Expenditures

Capital costs associated with the field development scenario could be approximately $14 billion USD.

Offshore field development and production could employ skilled and unskilled workers including engineers, welders, electricians, cooks, support staff, health and safety specialist, environmental specialists, helicopter pilots, technicians, geologists, and healthcare staff. Local employment opportunities would likely include full-time positions as environmental monitors on board the drilling rig and support vessels to implement and monitor mitigation commitments. However, additional opportunities for employment of Nunavut residents and business for Nunavut companies also are likely, due to the longer lead time for production activities. This could include a number of initiatives to train Nunavut residents to work on the production platform in some capacity, or on the supply vessels that support the platform. Other opportunities may include, but are not limited to, onshore support (e.g., supply base operations), aviation support, provision of supplies, offshore medical services, consulting, legal support, human resources and administration staff, logistics and customs brokers, catering, etc. Given the long lead time for production activities, development of procurement strategies by local businesses, training and apprentice programs, and support for local capacity building would help provide additional employment opportunities within Nunavut. The long lead time and duration of production activities makes it feasible and justifiable for local residents and businesses to invest in relevant training and business development initiatives.

Equipment and Infrastructure

- Arctic class drilling platform (FPSO)
- 1–2 icebreaker support vessels
- 2–3 supply vessels (ice strengthened)
- 1–5 fuel tankers (ice strengthened)
- 1–2 wareships (ice strengthened) for offshore storage
- Onshore storage facilities in coastal communities for emergency equipment such as oil spill response equipment and other emergency equipment

The support infrastructure for development and production is similar to that described in Scenario B, and would consist of a permanent fleet of supply and support vessels, icebreakers as required, and aviation support. A supply and helicopter base could be located in Iqaluit. With the exception of storage facilities for emergency response equipment, this scenario assumes that any onshore infrastructure and services required on Baffin Island to support a drilling program would be located in Iqaluit.

POTENTIAL ACCIDENTS AND MALFUNCTIONS

Potential accidents and malfunctions associated with exploration drilling include:

- Fire and explosions
- Loss of life (falling off the vessel)
- Downed aircraft (helicopter)
- Terrorist threats
- Drilling rig loss of integrity
- Vessel collisions
- Major weather and sea ice conditions
- Vessel strike with marine mammals
- Batch spills
- Subsea blowout

SCENARIO D: NO OFFSHORE OIL AND GAS ACTIVITY

If through planning, consultation and regulatory decision-making processes, the Area of Focus is deemed to not be an appropriate region for oil and gas activities, then hydrocarbon resources would remain undeveloped and activities associated with the exploration and development of these resources would not occur.

POTENTIAL CAPITAL EXPENDITURES

None

EQUIPMENT AND INFRASTRUCTURE

None

POTENTIAL ACCIDENTS AND MALFUNCTIONS

None

2.3.3.2 Impacts and Effects

The activities associated with each of the scenarios described above have the potential to interact with VECs and VSECs through various pathways. Where an interaction occurs, an impact from an activity could result in an effect on a component of the environment. For example, in the case of Scenario A, an offshore seismic exploration program would be completed; the seismic survey is the **activity**[9]. This activity would interact with various components of the environment by producing underwater noise (e.g., the **impact**[10]). Underwater noise associated with seismic surveys could result in change in behaviour (e.g., the **effect**[11]) for VECs like marine mammals and fish. Oil and gas exploration and development activities and the potential impacts associated with each of those activities, are summarized in Table 2.1. A brief description of the potential impacts is provided following the table.

Potential effects are initially screened to determine if there could be an interaction with a VEC or VSEC that could result in potential residual effects. If a VEC or VSEC is not expected to interact with oil and gas activities, or if potential effects can be reduced or eliminated using standard mitigative approaches or planning considerations (i.e., existing regulations, temporal or geographic avoidance, industry best practice or policy) then it is assumed that effects on the VEC or VSEC would not occur (or be minimal), and it is not included in the discussion of potential effects. This initial screening is based on professional judgement and information collected from the review of available literature on potential impacts and effects of oil and gas activities.

[9] The term *activity* refers to the various procedures and components undertaken to complete aspects of the oil and gas life cycle.
[10] The term *impact* is used to describe the influence that an activity has on the environment.
[11] The term *effect* is used to describe the consequence of an impact on a specific receptor in the environment.

Table 2.1 Oil and Gas Activities and Potential Impacts

Scenario	Activities	Potential Impacts									
		Air Emissions	**Noise**	**Routine Discharge (e.g., treated waste)**	**Drill and Mud Cuttings**	**Ice Disturbance**	**Habitat Alteration**	**Employment and Expenditures**	**Exclusion Zones**	**Direct Interference**	**Indirect Interference**
Scenario A: Exploration with Offshore Seismic Survey	Offshore Seismic Survey (2-D and 3-D)	✓	✓	✓		✓	✓	✓	✓	✓	✓
Scenario B: Exploration Drilling	Vertical Seismic Profiling	✓	✓	✓		✓	✓	✓	✓	✓	✓
	Well site, geotechnical and geohazard surveys		✓	✓	✓	✓	✓	✓	✓	✓	✓
	Drilling Program (platforms, well control, formation evaluation, waste management)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Drilling Support (icebreakers, supply vessels, fuel supply vessels, wareships, helicopters, shore-based facilities and services)	✓	✓	✓		✓	✓	✓	✓	✓	✓
	Well Site suspension and abandonment						✓		✓		
Scenario C: Field Development and Production	Drilling and flow testing (delineation wells, development wells, flow testing)	✓	✓	✓	✓		✓	✓	✓	✓	✓
	Reservoir monitoring (4D seismic survey)	✓	✓	✓				✓	✓	✓	✓
	Subsea installations		✓		✓		✓	✓	✓		
	Offshore platform (assumes floating production, storage and offloading structure)			✓		✓	✓	✓		✓	✓
	Drilling Support (icebreakers, supply vessels, fuel supply vessels, wareships, helicopters, shore-based facilities and services)	✓	✓	✓		✓	✓	✓		✓	✓
	Transportation (marine and onshore)	✓	✓	✓		✓	✓	✓		✓	✓
	Production operations (operation and waste systems)			✓			✓	✓			
	Onshore infrastructure[1]							✓			
	Well Site suspension and abandonment										
Scenario D: No offshore oil and gas activity	No oil and gas activities associated with Scenario D										

NOTE:
A check mark indicates that there is a pathway for an impact to result in potential effects on a VEC or VSEC. The application of planning and mitigation strategies can be applied to reduce potential effects.
[1] Hypothetical scenario assumes that existing infrastructure in Iqaluit will be used (e.g., deep-water port, airport, etc.)

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If potential residual effects are identified for a VEC or VSEC, those effects are discussed in the context of the associated impacts. A summary of potential effects is based on review of available literature and IQ. Following the discussion of potential effects, a prediction summary of potential residual effects associated with the hypothetical scenarios is based on a qualitative characterization of magnitude, geographic extent, frequency and duration. The following definitions are used in the characterization of effects:

- **Magnitude:** The amount of change relative to existing conditions
  - Negligible—no measurable change expected
  - Low—a measurable change could occur
  - Moderate—measurable change but less than high
  - High—a large measurable change that could threaten sustainability
- **Geographic Extent:** The geographic area in which an environmental effect occurs
  - Local—residual effect is restricted to the footprint of the activity.
  - Regional—residual effect extends outside of the footprint of the activity (e.g., within the Area of Focus and/or NSA)
  - Transboundary—residual effect extends outside of Federal waters associated with the Area of Focus into neighboring jurisdictions (i.e. Greenland, NSA)
- **Frequency:** Identifies when the residual effect occurs and how often during the activity
  - Single event
  - Multiple irregular event (no set schedule)
  - Multiple regular event
  - Continuous—residual effect occurs continuously
- **Duration**: The period of time required until the receptor (VEC or VSEC) returns to its existing condition, or the effect can no longer be measured or otherwise perceived
  - Short-term—residual effect restricted to one aspect of an activity
  - Medium-term—residual effect extends through the timeframe of the activity
  - Long-term—residual effect extends beyond the timeframe of the activity
  - Permanent—unlikely to recover to existing conditions

The assessment of potential effects also includes an indication of confidence in the prediction of effects. The terms *low*, *medium*, and *high* are used to indicate relative confidence based on professional judgement about factors including the amount of information available, it’s applicability to the region, and how dated the information may be.

AIR EMISSIONS

Air emissions from both exploration drilling and production operations contributes to localized changes in air quality in the immediate vicinity of the activities. The main sources of emissions are:

- Burning diesel fuel for electric power generation that creates carbon dioxide and nitrous compounds
- Methane and aliphatic volatile organic compounds (VOC) that are vented to the atmosphere from processes and fugitive emissions
- Flaring (as discussed under formation evaluation) and well testing that contribute to carbon dioxide, and small quantities of carbon monoxide, sulfurous and nitrous oxides and particulate matter
- Offshore loading of oil at loading buoys

For equipment like flares, turbines and generators required for specific project specifications, the operator will review manufacturers' emission factors to determine the best high-performance and efficient equipment to purchase during the design phase. Once installed and operational, the operator is required to report the annual quantities of greenhouse gas emissions to the regulator as per the Canada Offshore Waste Treatment Guidelines (National Energy Board et al. 2010), while continuously assessing opportunities for reduction.

NOISE

Ambient noise can be produced from aircraft and vessels used to support seismic programs and drilling operations, or from the drilling platform itself.

Underwater noise is produced by vessels used to support all phases of oil and gas exploration and development. Seismic vessels tow air source arrays suspended behind the survey vessel on floatation devices to maintain a specified operating depth. Air source arrays currently in use will output sound source levels less than 260 decibels (dB) at 1 m (Gisiner 2016; International Association of Geophysical Contractors 2002). This sound level decreases with increasing distance from the source. The source emits a sound that lasts approximately 0.1 seconds and is repeated every 10–15 seconds. Sound propagation[12] through the water is influenced by bathymetry, seabed sediment characteristics, temperature, depth and salinity (Farcas et al. 2016).

ROUTINE DISCHARGE

The *Canada Oil and Gas Drilling and Production Regulations* (2009) (Government of Canada 2009) establish the requirement for a proponent to develop an environmental protection plan (EPP) to address all "discharge streams". The NEB *Filing Requirements for Offshore Drilling in the Canadian Arctic* (National Energy Board 2015) outline the information to be included in the EPP or a separate Waste Management Plan (WMP) pertinent to waste management in the Arctic offshore. The *Canadian Offshore Chemical Selection Guidelines for Drilling and Production Activities on Frontier Lands* (National Energy

[12] The transmission of sound through a medium (e.g. the water column) and associated characteristics (e.g. speed, intensity and transmission loss).

Board et al. 2009) and the *Canadian Offshore Waste Treatment Guidelines* (National Energy Board et al. 2010) supplement the EPP guidelines (Canada - Newfoundland and Labrador Offshore Petroleum Board et al. 2011) by providing a framework for chemical selection, and an aid to operators in the management of waste material and the discharge of chemicals in offshore areas. The NEB's stated goal for these guidelines is to reduce the potential for environmental effects from waste management in offshore drilling and production operations.

Routine discharges from maritime operations could include domestic wastewater (greywater), sewage (blackwater), wash down and drainage from decks and exposed structures, cooling water, ballast water and bilge water. All vessels in a drilling program would be subject to international maritime law, including the International Convention for the Prevention of Pollution from Ships (MARPOL) 73/78 *International Convention for the Prevention of Pollution from Ships* and the provisions of the *Arctic Shipping Pollution Prevention Regulations,* the *Arctic Waters Pollution Prevention Regulations* and the *International Code for Ships Operating in Polar Waters (Polar Code)*. All discharges must be approved as part of a program-specific WMP.

Water runoff into the sea, from the above-the-waterline structures of drilling platforms, cannot be avoided. Clean decks are necessary to prevent draining water from mixing with oil stains, chemical stains, granular or finer material, or other residue on the surface of the deck. Bilge water and any collected drainage water is normally processed through onboard oil-water separators and tested for oil concentration before release. Discharge of oily mixtures is prohibited in Canadian Arctic waters.

Greywater is discharged directly to the sea, as treatment of greywater is not required under MARPOL 73/78. Sewage and domestic wastes are normally processed through onboard treatment plants before being discharged as treated blackwater and macerated food waste.

Cooling water[13] is generally part of a closed loop system. Seawater pumped on board for this purpose cannot be contaminated or mixed with water from other sources before it is returned to the sea during normal operations.

Ballast water discharges are governed by a Ballast Water Management Plan, which includes approved onboard treatment systems. Ballast water treatment systems and discharges would be expected to comply with applicable international and federal guidance specific to Canadian waters.

Drill and Mud Cuttings

Drilling wastes, in the form of residual drilling fluids and cuttings, comprise the principal wastes generated during offshore well drilling. In Canada, other than residual base fluid retained on cuttings, no synthetic-based mud (SBM) or enhanced mineral oil-based mud (EMOBM) fluid, or any whole mud containing these constituents, should be discharged to the sea, and under no circumstances should oil base fluid or whole mud containing oil base fluid be discharged.

[13] Sea water that is pumped from the sea and passed through heat exchangers to remove heat from processes on the installation before being returned to the sea.

To minimize the quantity of oil discharged into the marine environment, the NEB recommends operators use water-based mud (WBM) or low polyaromatic hydrocarbon content, non-toxic and biodegradable SBM. The use of oil-based mud (OBM) is approved only in exceptional circumstances, when the use of WBM or SBM is not technically feasible.

The cuttings associated with SBM can be discharged to sea only after injection is shown not to be technically or economically feasible. Before discharge, cuttings must be treated with best available technology to reduce oil concentrations on wet solids. Operators may discharge untreated WBM and associated cuttings to the sea; however, all offshore discharges are subject to approval by the NEB. Prior to authorizing offshore waste discharges, the NEB will consider stakeholder concerns, potential environmental effects, waste volumes, and levels of contaminants in the waste.

The *Offshore Chemical Selection Guidelines for Drilling and Production Activities on Frontier Land* (National Energy Board et al. 2009) and the *Offshore Waste Treatment Guidelines* (National Energy Board et al. 2010) provide approaches to identify less toxic drilling mud additives and production chemicals, and reduce potential environmental effects of drilling mud / cuttings and produced water discharges. These guidelines are similar to that of the *Oslo and Paris Convention for the Protection of the Marine Environment of the North-East Atlantic* (OSPAR Commission 2007)

Sea Ice Disturbance

Disturbance to sea ice is primarily caused by icebreaker vessels fragmenting and changing sea ice characteristics as they move through the water. Icebreakers generally support exploration and production drilling programs in arctic environments and may be used in ice management programs to protect the drilling platform or as supply vessels moving between the drilling platform and the onshore port.

Habitat Alteration

Habitat for biological VECs can be altered by icebreakers or by the physical presence of a drilling platform. Icebreakers generally support exploration and production drilling programs and may be used in ice management programs to protect the drilling platform or as supply vessels moving between the drilling platform and an onshore port. Artificial lighting associated with the drilling platform can alter habitat for waterbirds, resulting in sensory disturbance and disorientation. Lighting and shading from the platform can alter habitat for fish resulting in sensory disturbance. The placement of the well head and discharge of drill and mud cuttings can result in increased total suspended solids (TSS) and changes in sediment composition on the seabed immediately surrounding the wellhead.

Employment and Expenditures

Activities associated with oil and gas exploration and production will contribute directly and indirectly to local employment, and an increase in expenditures on goods and services from local businesses. Prior to any activity, a company is required to prepare a Benefits Plan for approval by the INAC Minister, well in advance of the anticipated start date of a proposed work or activity. The Benefits Plan identifies the means for employment of Canadians and for providing Canadian companies with a full and fair opportunity to participate in the supply of goods and services for oil and gas work. The plan is specifically intended to provide northern residents, northern businesses and Indigenous peoples the opportunity to participate in and directly benefit from oil and gas work in their region (to the extent possible).

In addition to a Benefit Plan under the CPRA, as per Article 26 in the *Agreement between the Inuit of the Nunavut Settlement Area and Her Majesty the Queen in right of Canada* (Nunavut Agreement), an operator is required to enter into an Inuit Impact and Benefits Agreement (IIBA) with an Inuit representative organization on its proposed project if it involves development or exploitation of resources located partially or wholly on Inuit Owned Land (IOL). The formal contract is legally binding as per the rules of contracts and describes how Inuit community[ies] that could be affected by the project can benefit, along with the recognition of negative implications and how any such impacts can be avoided or reduced. As the possible development scenarios in the SEA Area of Focus are located in Canadian offshore waters and not on IOL, an Inuit Impact and Benefits Agreement would not be required for those activities.

EXCLUSION ZONES

Some activities associated with exploration drilling and production require the use of exclusion zones to reduce the likelihood of unsafe interaction with equipment and protect the safety of personnel in the case of an accident or emergency associated with oil and gas activities. Exclusion zones may be in place around seismic ships to mitigate for interaction between fishing vessels (with gear and/or nets) and seismic vessels (with towed sound source arrays and streamers). Exclusion zones may also be placed around drilling vessels and platforms, LNG terminals or vessels, or onshore facilities that could pose some hazard (e.g., chemical storage). Within these exclusion zones, no unauthorized vehicles, vessels or other activities, including commercial fishing, are typically permitted.

DIRECT INTERFERENCE

Activities associated with oil and gas exploration and drilling can directly interfere with other human activities in the Area of Focus including commercial fishing, traditional harvest, spiritual practices, and recreational activities.

INDIRECT INTERFERENCE

Indirect interference could occur when oil and gas activities have a direct effect on one aspect of the environment that, in turn, affects land and marine use in the Area of Focus. This impact would be relevant when direct effects on a component of the physical or biological environment results in potential changes to traditional harvesting, cultural and spiritual practices, and recreational activities.

2.3.4 Potential Effects of Climate Change on Predicted Project Effects

As noted in Section 2.1, the overall life cycle for an oil or gas development, if it were to proceed, could span a period of 45–80 years or more. Regulatory approvals, planning and execution for each phase could range from 2–5 years for seismic exploration, 4–8 years for exploration drilling, 40 years or more for production, and 2–5 years for decommissioning.

As changes to climate are occurring at a rapid rate in the Arctic (see Section 6), the assessment of effects for the SEA includes a qualitative assessment of how climate change could alter the prediction of potential effects. This involved consideration of how climate change might affect the timing, extent and types of project activities and, in turn, modify the effects characterization on the VEC or VSEC. For example, reductions in sea ice thickness and extent are creating a longer and more extensive open water season, which would allow for a temporal and spatial increase in human activities. Over time, this could modify the duration and geographic extent of the predicted effects on different VECs. The discussion of how climate change may alter the prediction of potential effects is based on professional knowledge about oil and gas operations, the ecology of individual VECs, and a thorough understanding of the effects of climate change on the Arctic socio-ecological system.

2.3.5 Mitigation Measures and Planning Considerations

For each of the VECs and VSECs considered in the review of potential effects, mitigation measures and planning considerations that may reduce or eliminate potential adverse effects are identified and described. These measures are inclusive of standard mitigations that are regulated by law, guidelines developed by regulatory authorities and industry to address specific aspects of oil and gas activities, and additional or enhanced levels of mitigation or planning that specifically address issues and concerns raised by local communities and stakeholder or apply to the unique environment in the region. Mitigation and planning considerations are summarized in Appendix B.

2.3.6 Cumulative Effects

The assessment of cumulative effects addresses how potential effects from one project or activity may interact cumulatively with residual effects from other projects and activities conducted or expected to be conducted in or adjacent to the SEA Area of Focus. A review and discussion of cumulative effects at the broader regional scale offers an opportunity to understand the implications of development outside the constraints of a project level environmental impact assessment (Canadian Council of Ministers of the Environment 2009). A list of past, present, and reasonably foreseeable activities to be considered in the discussion of cumulative effects and their potential to interact cumulatively with the hypothetical oil and gas scenarios is presented in Table 2.2. Potential cumulative effects are identified and discussed in the context of relevant VECs and VSECs for each of the Physical, Biological, and Human Environments. Cumulative effects mechanisms are described based on the review of potential effects from oil and gas activities and other human activities in the region. Effects of climate change and changes in oceanographic conditions are addressed through consideration of how these changes might influence the baseline condition and the future condition of a VEC or VSEC (see Section 7).

Table 2.2 Past, Present, and Reasonably Foreseeable Activities

Other Projects and Physical Activities with Potential for Cumulative Environmental Effects	Potential Cumulative Environmental Effects				
	Scenario A: Seismic Exploration	Scenario B: Exploration Drilling	Scenario C: Field Development and Production Drilling	Scenario D: No Offshore Oil and Gas Activity	Other Non-oil and gas activities in the Area of Focus
Past and Present Physical Activities and Resource Use					
Mining—Baffinland Mary River Mine (marine transportation)	✓	✓	✓		✓
Commercial Shipping	✓	✓	✓		✓
Commercial Fishing	✓	✓	✓		✓
Tourism (cruise ships)	✓	✓	✓		✓
Research (Military, Academic)	✓	✓	✓		✓
Traditional Use and Practices, Traditional Harvest, Traditional Foods	✓	✓	✓		✓
Oil and Gas—Greenland	✓	✓	✓		✓
Oil and Gas—Atlantic Canada	✓	✓	✓		✓
Future Physical Activities					
Mining—(marine transportation)	✓	✓	✓		✓
Deepwater Port (Iqaluit)	✓	✓	✓		✓
Commercial Shipping	✓	✓	✓		✓
Commercial Fishing	✓	✓	✓		✓
Tourism (cruise ships)	✓	✓	✓		✓
Research (Military, Academic)	✓	✓	✓		✓
Traditional Use and Practices, Traditional Harvest, Traditional Foods	✓	✓	✓		✓
Oil and Gas—Greenland	✓	✓	✓		✓
Oil and Gas—Atlantic Canada	✓	✓	✓		✓
Oil and Gas – Baffin Bay and Davis Strait (Scenario A, B, and C)	✓	✓	✓		✓

NOTES:
✓ = those “other projects and physical activities” whose residual effects are likely to interact cumulatively with residual environmental effects associated with oil and gas activities in the Area of Focus.

2.3.7 Transboundary Effects

Under the *Canadian Environmental Assessment Act*, transboundary effects are defined as environmental effects which occur across provincial or international boundaries, or boundaries between federal and non-federal lands (Knight Piésold Consulting 2012). Transboundary effects may occur when residual effects extend outside of federal waters within the Area of Focus, or when a VEC or VSEC is affected by activities in one jurisdiction and then moves to other jurisdictions (i.e., seasonal migration) where the initial effects are compounded (i.e., by additional impacts) or result in effects on other VECs and/or VSECs in the other jurisdiction. Examples of transboundary effects may include a fuel spill at sea within Canadian federal waters which is then carried over into Greenland waters via currents and exposes VECs in that jurisdiction to potential effects.

For each of the VECs and VSECs where transboundary effects could occur, effects mechanisms are described based on the review of potential effects from oil and gas activities. Additional planning and mitigation measures that address potential transboundary effects are described.

2.3.8 Potential Effects of Accidents and Malfunctions

With mitigation and planning, accidents and malfunctions are unlikely. However, the potential consequences of these events can be large and, as a result, concerns from communities and regulatory agencies are often focused on potential effects of accidents and malfunctions on the environment. Contingency planning is required to reduce or avoid impacts on workers, public safety and the environment, and bring an incident under control as quickly and effectively as possible. Operators would be expected to have contingency plans in place for all potential accidents, such as:

- Fire and explosions
- Loss of life
- Medical evacuations
- Downed aircraft
- Vessel collisions
- Vessel strike with marine mammals
- Terrorist threats
- Drilling platform loss of integrity
- Vessel collisions and collisions with wildlife
- Major weather and sea ice conditions
- Batch spills (e.g., fuel spills from vessels)
- Uncontrolled hydrocarbon release (subsea blowout)

Companies are required to undertake a risk evaluation on all of their activities from design through to completion of operations, with intent to prevent a non-routine event from occurring, and to be prepared to respond if one occurs. In the operations authorization (OA) application, the NEB requires the operator to describe the risk assessment methodology and management processes used to identify threats and hazards, and to identify response measures should an unexpected incident occur.

In the case of offshore oil and gas, oil and fuel spills are generally the primary concern. To address accidents and malfunctions, the SEA focuses on a discussion of potential effects from spills. Potential effects of accidents and malfunctions on the physical, biological and human valued components (VCs) are discussed based on a desktop review of available literature on the effects of oil and gas spills. Additionally, an accidental vessel collision with marine mammals is considered.

Focused attention is given to those VCs that would be most vulnerable to effects or hold special ecological or cultural value as identified by IQ or TK (e.g., harvested species, special and protected areas).

2.3.9 Information Gaps and Recommendations

In addition to mitigation measures and planning considerations, the identification of knowledge and data gaps is an important step in developing policy and programs for managing sustainable development. These gaps can be considered when recommending follow-up measures and programs to monitor potential effects. A summary of information gaps and recommendations for each of the physical, biological and human environments is provided in Section 8.

3 ENVIRONMENTAL SETTING—PHYSICAL ENVIRONMENT

The following sections provide an overview of the VECs selected for the physical environment of the Area of Focus: climate and meteorology, air quality and greenhouse gases (GHG), bathymetry, oceanography, sea ice and iceberg conditions, acoustic environment, geology, coastal landforms, and marine sediment.

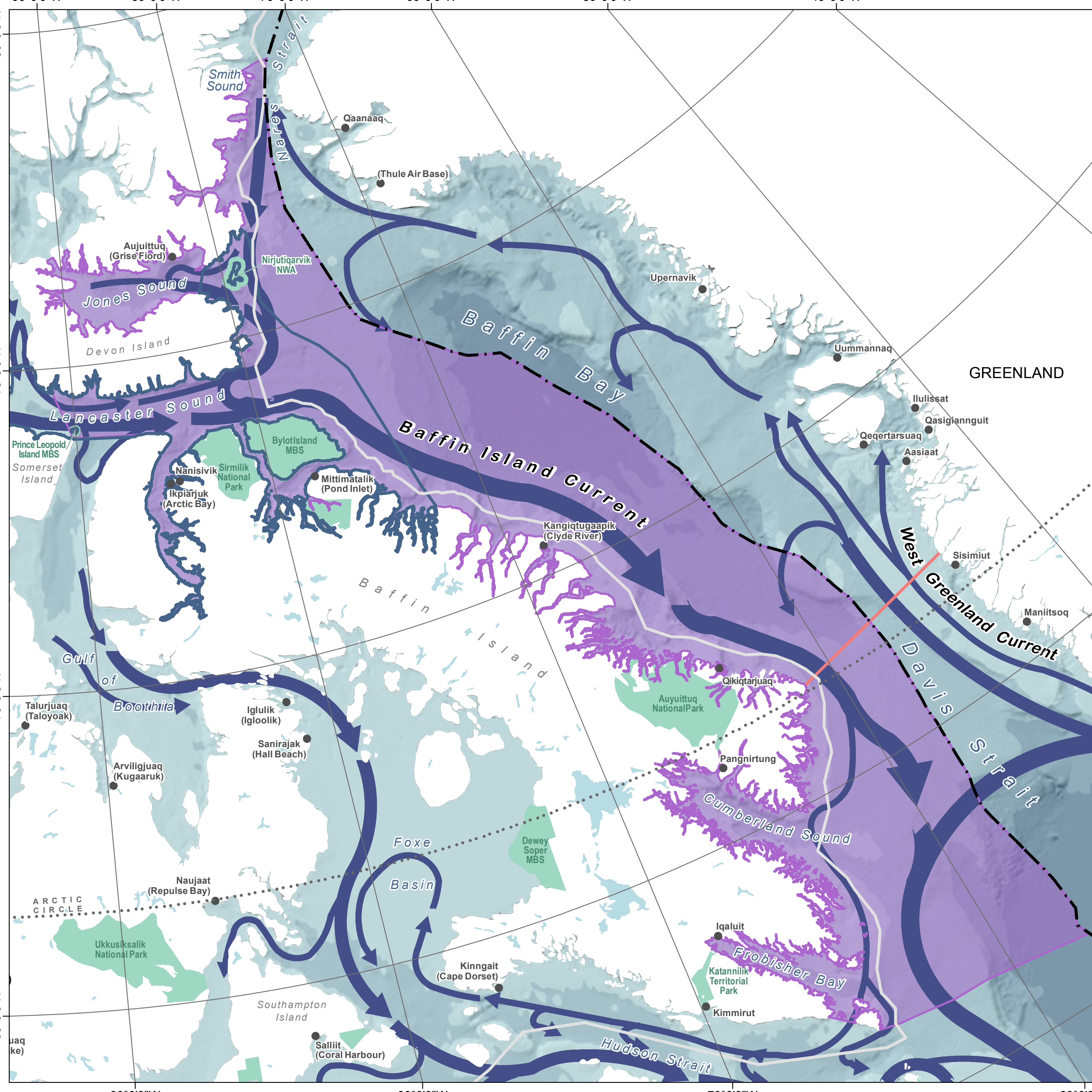
The environmental features and processes presented in the following sections are relevant to understanding and assessing potential environmental disturbances, associated environmental changes, and effects pathways that may result from development activities (e.g., shipping, oil and gas exploration) in the Area of Focus. These potential effects are assessed and described in Section 7.1. Effects of climate change on components of the physical environment are described in Section 6.

3.1 Climate and Meteorology

The Baffin Bay and Davis Strait area is north of the Arctic Circle which means it is far enough north so that it is not influenced by the typical westerly flow that occurs in areas further to the south. As such, it is generally north of the typical storm track. Meteorological conditions in the area are influenced by air masses over Greenland and North America (Tang et al. 2004a).

There are two atmospheric patterns that tend to influence the weather conditions in the area: the North Atlantic Oscillation (NAO) and the Atlantic Multidecadal Oscillation (AMO). The NAO results from the difference in atmospheric pressure between the Subtropical (Azores) High-pressure area and the Subpolar Low-pressure area (NOAA 2018b). The AMO is a result of ongoing large-scale multidecadal fluctuations in sea surface temperature in the North Atlantic Ocean. Cool and warm phases can last for 20 to 40 years with differences in temperatures of approximately 0.6°C between extremes (NOAA 2005). In addition to these patterns, ocean currents in the Atlantic Ocean also influence the local meteorology and climate. These differences in pressures, temperatures and ocean currents are the primary drivers of the meteorological conditions experienced in the Baffin Bay and Davis Strait area.

Currents within Baffin Bay and Davis Strait are shown in Figure 3.1. The figure shows the general circulation and bathymetry in Baffin Bay and Davis Strait (reproduced with permission from Curry et al. 2011). The red lines indicate the location of the mooring array in Barrow Strait described in Peterson and Pettipas (2013), and the mooring array across Davis Strait described in Curry et al. (2011).



Base Features

- Community[1]
- Limit of Exclusive Economic Zone[4]
- Nunavut Settlement Area[3]
- Tallurutiup Imanga / Lancaster Sound NMCA[2]
- Protected Area or National Park[4]

Bathymetry[5] Depth (m)

< 200 | 200 - 1000 | 1000 - 2000 | 2000 - 3000 | > 3000

Project Features

- Area of Focus[2]
- Generalized Currents [6]
- Mooring Array

1:10,000,000

0 50 100 200 300

Kilometres

Nunavut Impact Review Board Strategic Environmental Assessment

Figure 3.1 Generalized Currents in Baffin Bay and Davis Strait

NUNAMI STANTEC LIMITED

N.I.R.B. NUNAVUMI AVATILIKIYIN KATIMAYIIN

Prepared By: Nunami Stantec Limited
Projection: Canada Lambert Conformal Conic, North American 1983
Date: Apr 13, 2018
Project Number: 12322100
Produced By: L. Trudell
Verified By: J. Beckett
Revision: 01

References:
[1]Atlas of Canada Base Maps, 2017
[2]NIRB, 2017
[3]Nunavut Planning Commission, 2010
[4]National Framework Canada,2017
[5]Natural Earth, 2016
[6]Curry et al., 2011

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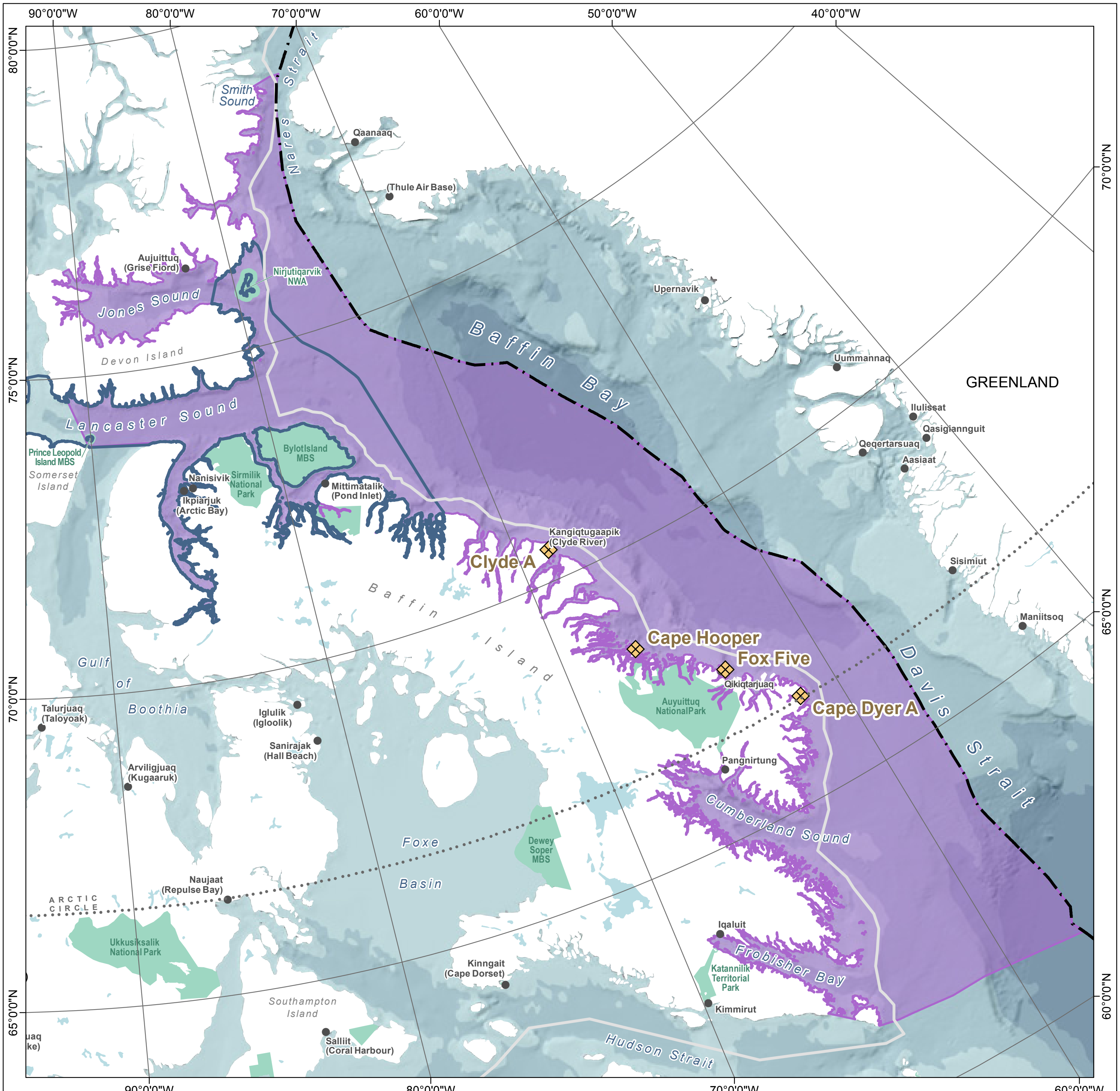
A brief summary of meteorological parameters in the region are provided to characterize the existing climate and meteorological conditions within the area of focus. The following surface meteorological stations have sufficient data availability and were considered for the study:

- Clyde River, Nunavut
- Qikiqtarjuaq, Nunavut
- Cape Hooper
- Cape Dyer

The four stations are located along the east coast of Baffin Island. A map showing the locations of the stations is provided in Figure 3.2. The Clyde River station is the main focus of the study given its central location to Baffin Bay and Davis Strait. Meteorological parameters from the other stations are also included, as required, to supplement data from the Clyde River Station, and give a more complete picture of the climate and meteorology within the area of focus. It is noted that climate normals are only available for the 1971–2000 period for the Cape Hooper and Cape Dyer stations. Climate normals are not available for the Qikiqtarjuaq station.

A summary of the climate normals for the period of 1981-2010 for the Clyde River station is provided in Table 3.1. Climate normal summaries are taken from Environment and Climate Change Canada (ECCC) Canadian Climate Normals (ECCC 2018c).



Base Features

- Community[1]
- Limit of Exclusive Economic Zone[4]
- Nunavut Settlement Area[3]
- Tallurutiup Imanga / Lancaster Sound NMCA[2]
- Protected Area or National Park[4]

Bathymetry[5] Depth (m)

< 200 | 200 - 1000 | 1000 - 2000 | 2000 - 3000 | > 3000

Project Features

- Area of Focus[2]
- Canadian Weather Station[6]

1:10,000,000

0 50 100 200 300

Kilometres

Nunavut Impact Review Board Strategic Environmental Assessment

Figure 3.1 Meterological Station Locations

Prepared By: Nunami Stantec Limited
Projection: Canada Lambert Conformal Conic, North American 1983
Date: Apr 13, 2018
Project Number: 12322100
Produced By: L. Trudell
Verified By: J. Beckett
Revision: 01

References:
[1]Atlas of Canada Base Maps, 2017
[2]NIRB, 2017
[3]Nunavut Planning Commission, 2010
[4]National Framework Canada,2017
[5]Natural Earth, 2016
[6]Environment Canada, 2018

Filepath: S:\1232\projects\123221001\figures\report\SEA\fig_123221001_NIRB_SEA_03.2_Meteorological_Station_Locations.mxd

Table 3.1 Climate Normals 1981–2010—Clyde River, Nunavut

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Temperature													
Daily Mean (°C)	-29.1	-29.9	-27.2	-19.1	-8.2	1	5	4.3	0.5	-7	-17.2	-24.1	-12.6
Daily Maximum (°C)	-25.2	-25.7	-22.6	-14.1	-4.2	3.9	8.8	7.3	2.8	-3.8	-13.4	-20.1	-8.9
Daily Minimum (°C)	-33.0	-33.8	-31.7	-24.0	-12.2	-1.8	1.2	1.1	-1.9	-10.1	-20.8	-27.9	-16.2
Extreme Daily Maximum (°C)	3.3	3.3	-1	11.7	8.9	17.8	22.2	20	14.6	10.3	6.7	2.8	--
Date (yyyy/dd)	1977/10	1946/28	2000/30	1975/29	1951/25	1975/30	1969/29	1969/02	1988/02	1984/15	1948/01	1976/23	--
Extreme Daily Minimum (°C)	-50.2	-50.1	-47.8	-41.1	-31.1	-17.2	-6.8	-5.6	-16.1	-28.7	-39.5	-45	--
Date (yyyy/dd)	1987/17	1990/08	1991/04	1948/01	1974/01	1972/04	1989/16	1958/30	1961/30	1986/31	1986/25	1994/16	--
Precipitation													
Rainfall (mm)	0	0	0	0	0.5	5.6	14.5	32.2	10.2	0.3	0	0	63.3
Snowfall (cm)	10.6	8.7	8.4	12.7	16.5	12.5	6.6	5.2	27.7	40.4	28.2	17.2	194.7
Precipitation (mm)	8.8	6.3	7.4	15.6	17.7	16.5	22.3	31.4	33	37.7	22.9	13.5	233
Extreme Daily Precipitation (mm)	23.1	14	11.5	41	23.7	23.7	32.5	37.3	36.8	26.9	37	19.3	--
Date (yyyy/dd)	1963/08	2002/18	2002/01	1977/07	1977/01	1982/04	1952/07	1960/20	1952/05	1971/27	1982/26	1975/01	--
Other													
Daytime Relative Humidity (%)	65.1	63.6	63.6	71.2	81.1	83.5	78.5	80.1	80.8	81.6	74.8	67.5	74.3
Radiation Extreme Global - RF1 (MJ/m2)	0.3	3.7	11.9	22.4	30.7	32.3	30.5	22	13.9	6.5	0.7	0	-
Date (yyyy/dd)	1993/31	1992/29	1988/30	1989/30	1993/31	1989/19	1991/11	1989/05	1989/03	1990/01	1988/02	1990/02	-

Table 3.1 Climate Normals 1981–2010—Clyde River, Nunavut

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean Wind Speed (km/h)	15	14	12.6	12.9	13.1	13	12.6	13.2	14	17.4	17.9	15.7	14.3
Most Frequent Wind Direction	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW
Extreme Wind Gust Speed (km/h)	119	106	117	89	85	81	91	98	94	119	122	113	--
Extreme Wind Gust Direction	NW	NW	NW	NW	NW	S	NW	SW	NW	NW	NW	NW	--
Date (yyyy/dd)	1980/07	1981/13	1988/14	1984/19	1984/08	1987/05	1983/18	1991/19	1981/02	1988/07	1985/10	1986/19	--
SOURCE: Environment and Climate Change Canada 2018													

3.1.1 Air Temperature

Air temperatures in the region typically range between lows near -35°C in the winter and highs near 10°C in the summer. For example, as shown in Table 3.1, the lowest average daily minimum temperature at Clyde River is -33.8°C, occurring in February and the highest average daily temperature is 8.8°C, occurring in July. Extreme temperatures at Clyde River range between -50.2°C in January and 22.2°C in July.

The average daily mean, maximum and minimum temperatures observed at Clyde River, Cape Hooper and Cape Dyer are shown in Figure 3.3. Temperatures are based on the climate normals from the 1981–2010 and 1971–2000 30-year periods (ECCC 2018c).

Nauyarluk (2001, as cited in Nunavut Tunngavik 2001) reported that 2001 was an abnormally cold year, attributing it to a change in the Earth's tilt, and stating: "The snow on the seashore was covered with a layer of ice, prior to the ice forming on the sea-ice. There was water along the seashore where the sea-ice met land," (Nauyarluk 2001, as cited in Nunavut Tunngavik 2001).

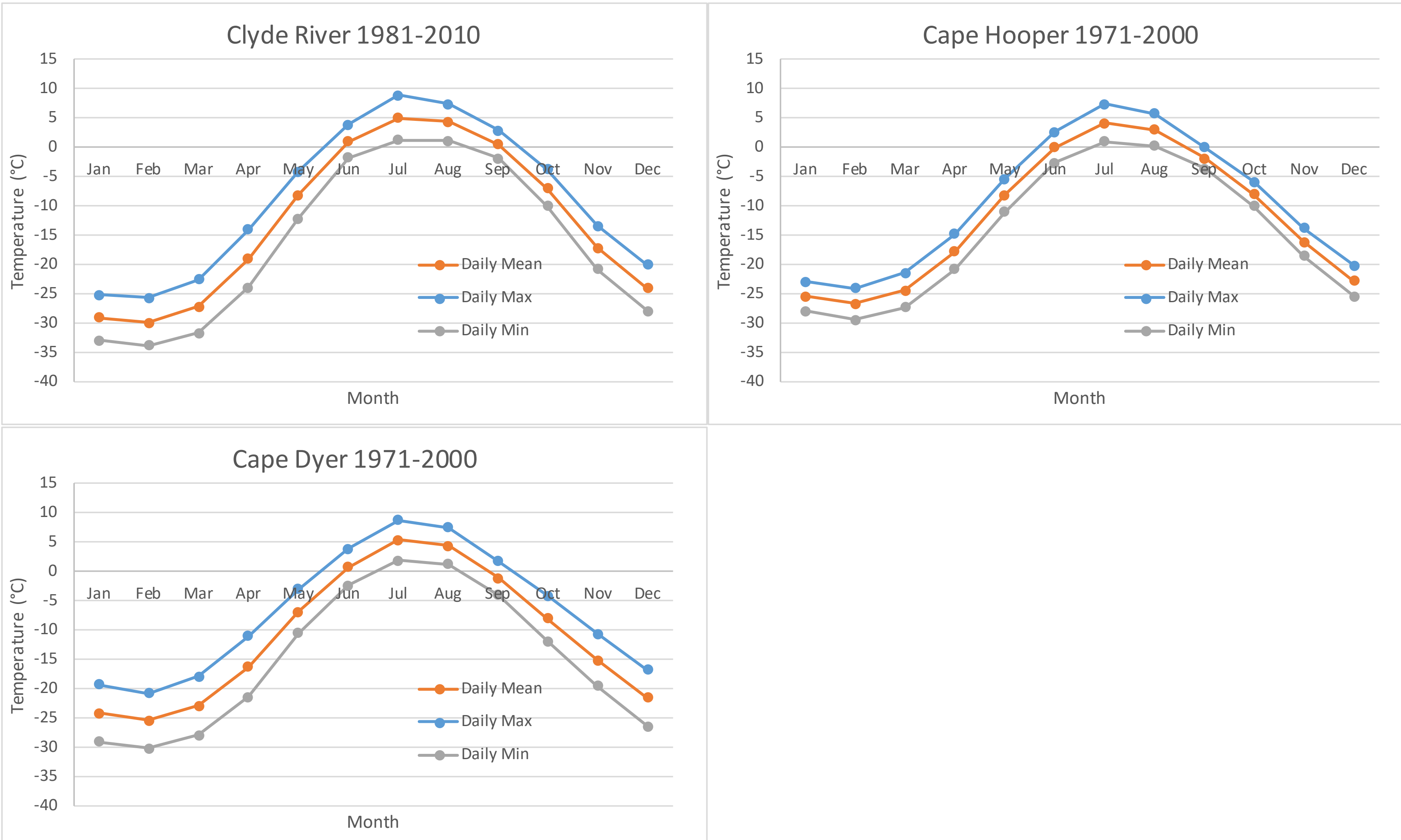


Figure 3.3 Climate Normals—Monthly Temperatures

3.1.2 Winds

The surface winds in the region generally prevail from the northerly, northwesterly and westerly directions. The highest wind speeds occur most frequently during the winter months from the north and northwest.

"Due to the mountains, we have two prevailing winds funneled into the community of Pond Inlet. One prevailing wind is from the High Arctic, funneled through Navy Board Inlet. The other is funneled from the weather patterns of Baffin Bay, via Clyde River and through Pond Inlet" (Kilukishuk 2001, as cited in Nunavut Tunnagavik 2001).

Inuit from Pangnirtung have observed changes in the wind, stating: "the wind seems to spring out of nowhere and when the clouds start to change, it is immediate and the wind springs up right away, even during the spring," (Uniuqsaagaq, I. 2002, as cited in Nunavut Department of Environment 2005). Inuit from Pangnirtung and Iqaluit have noted that the wind has become more unpredictable recently, shifting direction more often, and coming from unexpected directions, and potentially resulting in faster temperature changes (Manniapik 2002, as cited in Nunavut Department of Environment 2005; Uniuqsaaga, 2002, as cited in Nunavut Department of Environment 2005; Boas 2002, as cited in Nunavut Department of Environment 2005; Joamie 2002, as cited in Nunavut Department of Environment 2005; Koomarjuk 2002, as cited in Nunavut Department of Environment 2005; Mike 2002 as cited in Nunavut Department of Environment 2005).

Inuit from Grise Fiord have observed changes in wind patterns, including more wind in recent years, and note that "…the wind was always cold, even during the summer, it now blows with a warmth in the summer and even the spring" (Pijamini 2001, as cited in Nunavut Tunnagavik 2001; Nunavut Department of Environment n.d.) This shift in winds has been attributed to changes in the earth's angle;

> I have lived in the North all of my life. I initially grew up in Pangnirtung, where I then moved to Grise Fiord in 1962. The Inuit who have been there since the 1950s are aware of these changes in the placement and angle of the sun, especially the dark season. It used to be completely dark during the dark season, when there was no moonlight or starlight available. Nowadays, even during this period, there is now a band of light during noon. This never used to happen before. The winds have shifted as well, probably due to this tilt. (Pijamini 2001, as cited in Nunavut Tunnagavik 2001)

Similar changes in the strength, direction and predictability of wind have also been reported by Inuit from Arctic Bay (Shooyook 2004, as cited in Ford et al. 2008).

Annual and seasonal wind rose plots for the period of 2013 to 2017 are provided in Figure 3.4 and Figure 3.5 for Clyde River and in Figure 3.6 and Figure 3.7 for Qikiqtarjuaq (NOAA 2018a).

At Clyde River, winds prevail from the northwest quadrant throughout the year. The highest wind speeds occur most frequently from the northwest during the winter months. The lowest wind speeds occur most frequently from the north and southeasterly directions during the summer months. Average monthly wind speeds range between 12 and 18 km/hr. The highest extreme wind gust of 122 km/hr from the northwesterly direction occurred in November 1985 at Clyde River (ECCC 2018c).

At Qikiqtarjuaq, winds prevail from north and south-southwesterly directions. The highest wind speeds occur most frequently from the north and northwesterly directions during autumn and winter months. The lowest winds occur most frequently from the north and northeasterly directions during the spring and summer months.

Inuit of Arctic Bay, Iqaluit, and Pangnirtung have also observed changes in the direction, strength and frequency of the wind (Ford et al. 2008). The observations vary between communities, and even within communities illustrating the unpredictable nature of current wind patterns. Inuit living in Iqaluit and Pangnirtung have observed an overall shift in the dominant direction of the wind (Nunavut Department of Environment 2005). Arctic Bay Inuit note that the winds are strongest during the summer months and that change in wind direction can be sudden (Ford et al. 2008). Inuit of Iqaluit indicate that winds shift more now than in the past, with more frequent winds in the winter, and spring (Nunavut Department of Environment 2005). Some residents of Iqaluit and Pangnirtung note that winds are strongest in the fall, while others from these communities note that overall winds have weakened (Nunavut Department of Environment 2005).

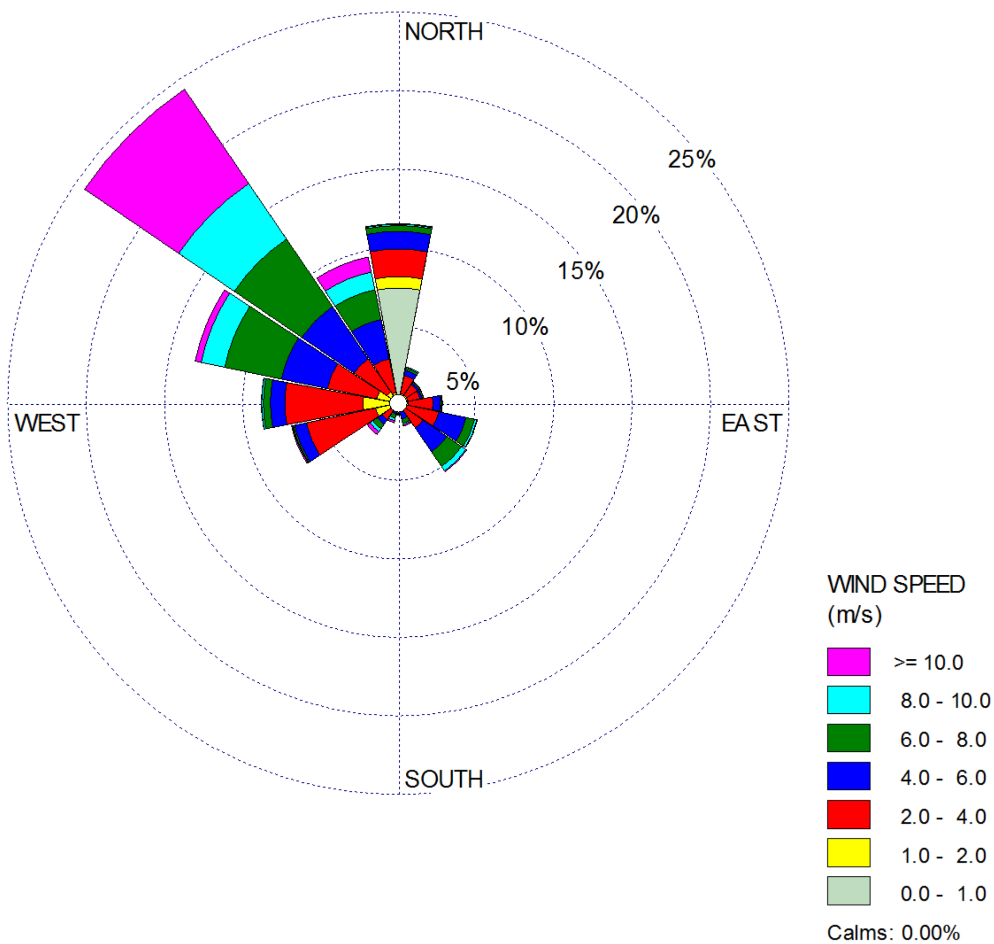


Figure 3.4 Annual Wind Rose Plot—Clyde River—2013–2017

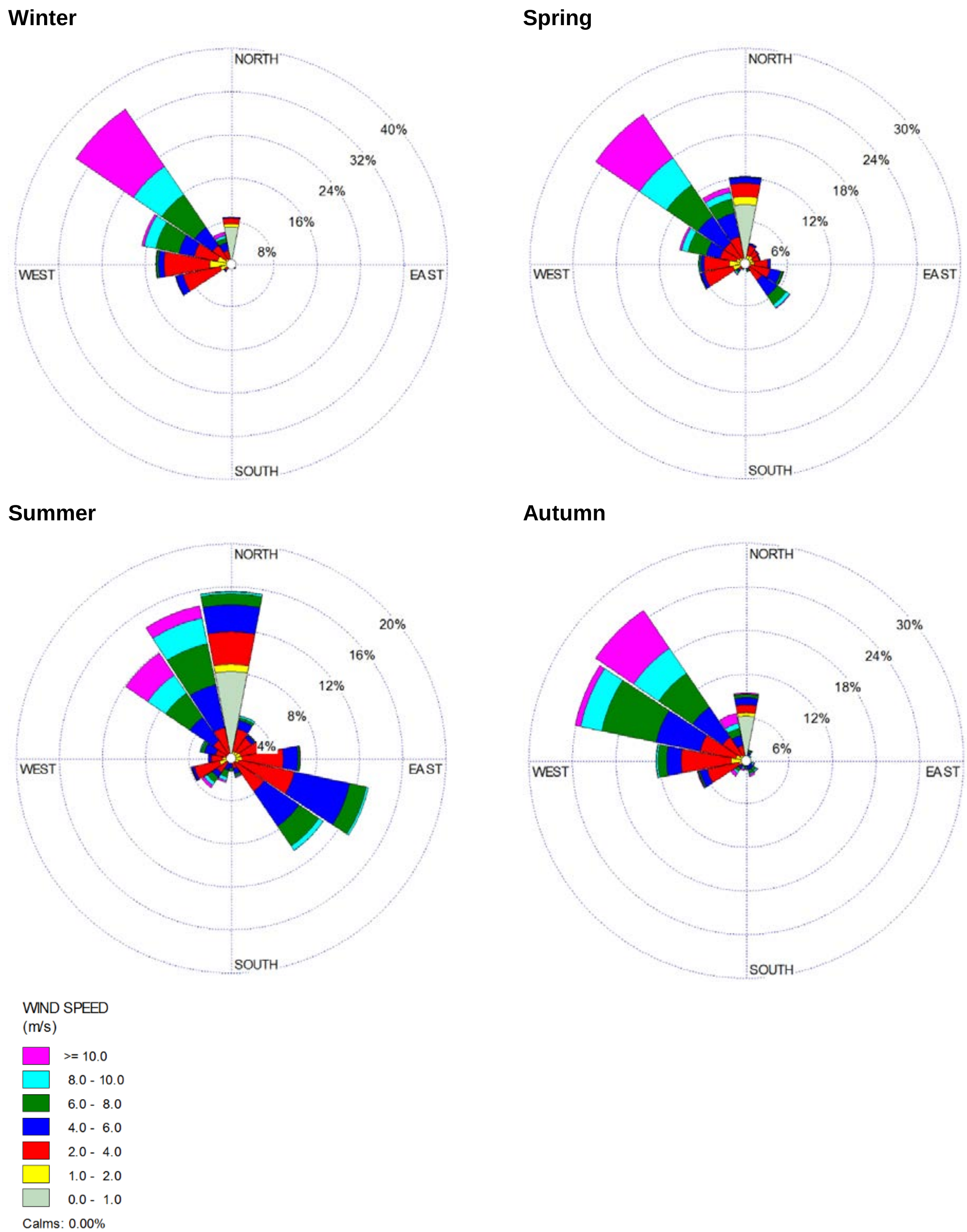


Figure 3.5 Seasonal Wind Rose Plots—Clyde River—2013–2017

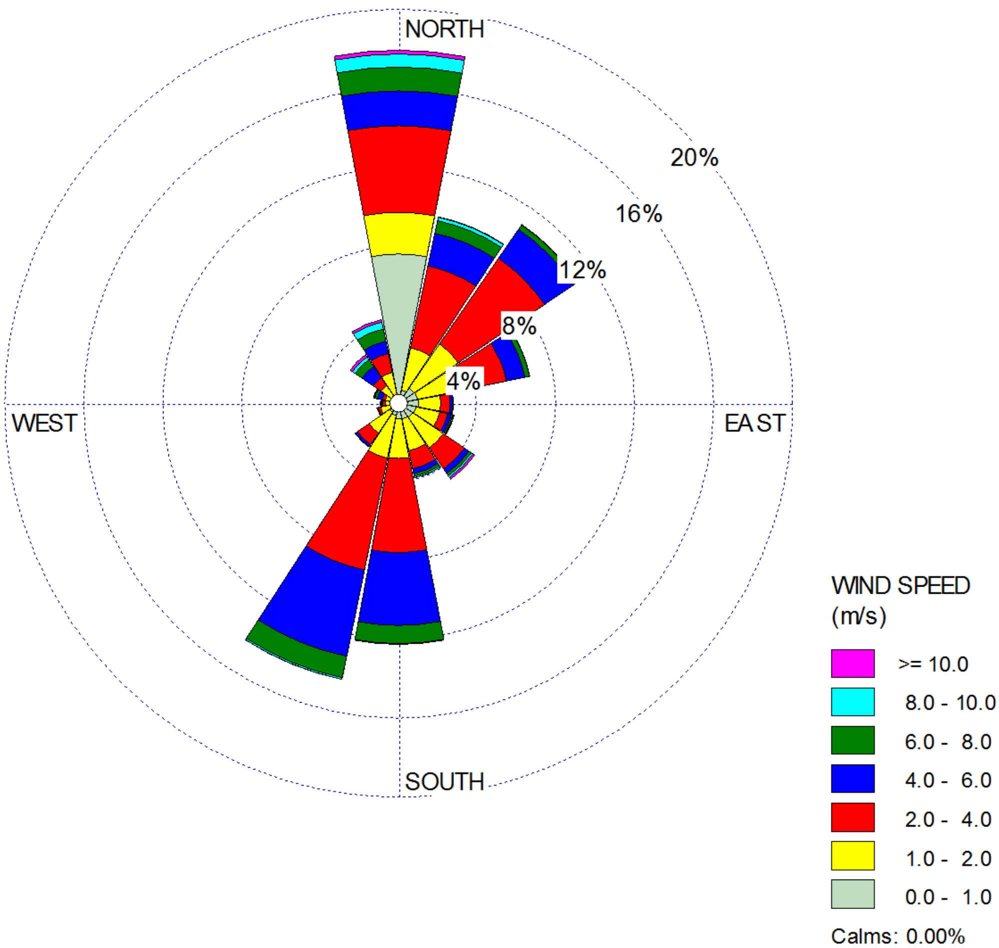


Figure 3.6 Annual Wind Rose Plot—Qikiqtarjuaq—2013–2017

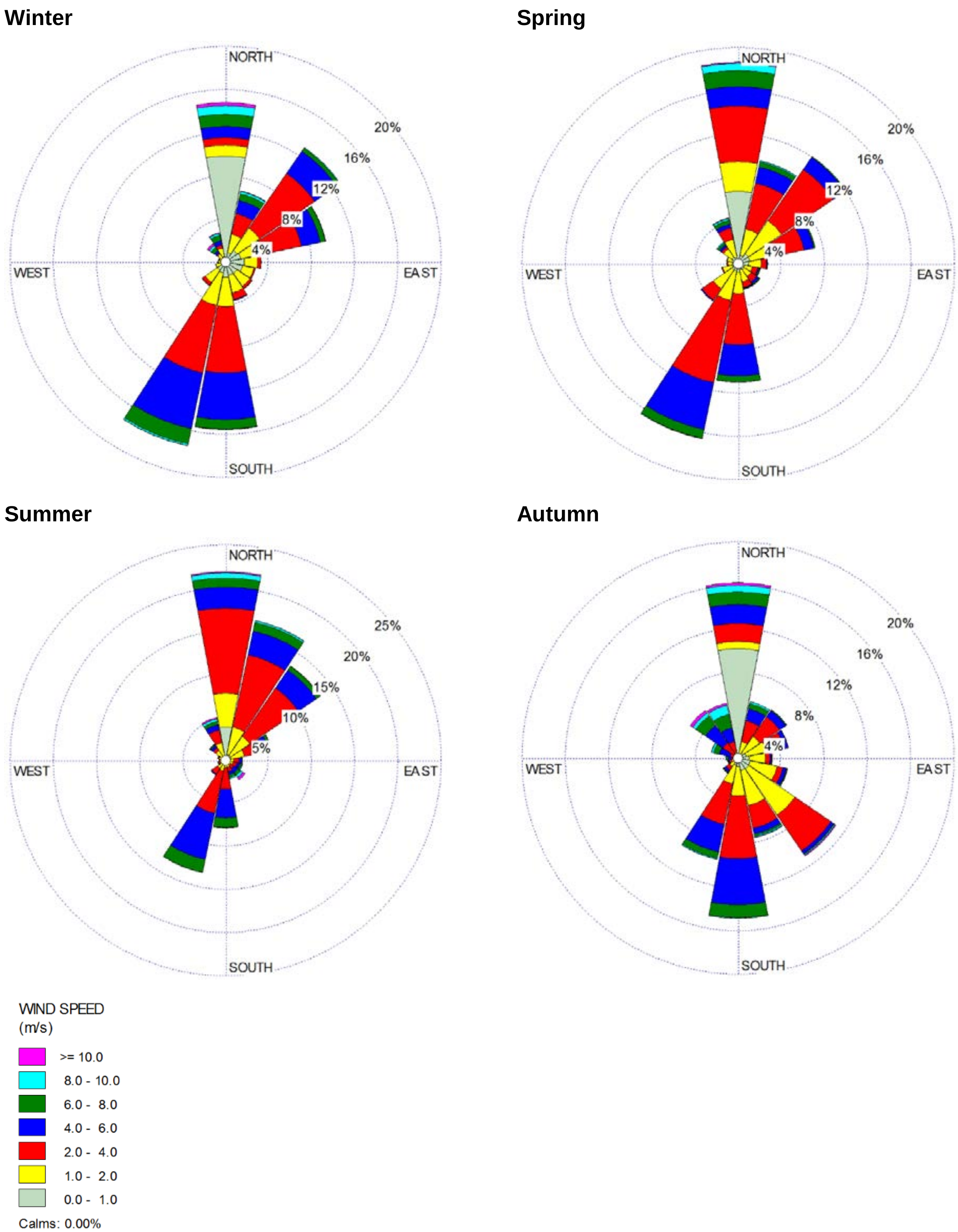


Figure 3.7 Seasonal Wind Rose Plots—Qikiqtarjuaq—2013–2017

3.1.3 Precipitation

The average annual precipitation at Clyde River is 233 mm, for the 30-year climate normals period of 1971 to 2000 (total annual liquid precipitation equivalent is not available for the 1981–2010 climate normals period). The annual average total rainfall over the 1981–2010 period is 63.3 mm and the annual average total snowfall for the same period is 194.7 cm (ECCC 2018c).

At other meteorological stations in the area (Cape Dyer and Cape Hooper), annual precipitation ranges from 281.7 mm (at Cape Hooper) to 602.5 mm (at Cape Dyer), based on climate normals from 1971 to 2000. At Cape Hooper the annual total snowfall and rainfall is 223.9 cm and 57.8 mm. At Cape Dyer the annual total snowfall and rainfall is 566.2 cm and 98.4 mm (ECCC 2018c).

The monthly precipitation is shown in Figure 3.8 for each of the three stations in the area of focus with climate normals available.

Precipitation amounts are generally higher at the stations further to the south, within the Area of Focus.

During the NCRI for Qikiqtarjuaq, interviewees reported that there is less snow fall in winters than there was previously (Nunavut Department of Environment 2010; Nunavut Department of Environment 2005). Inuit from Iqaluit and Pangnirtung have observed less snowfall and less accumulation of snow on land and the sea ice (Nunavut Department of Environment 2005).

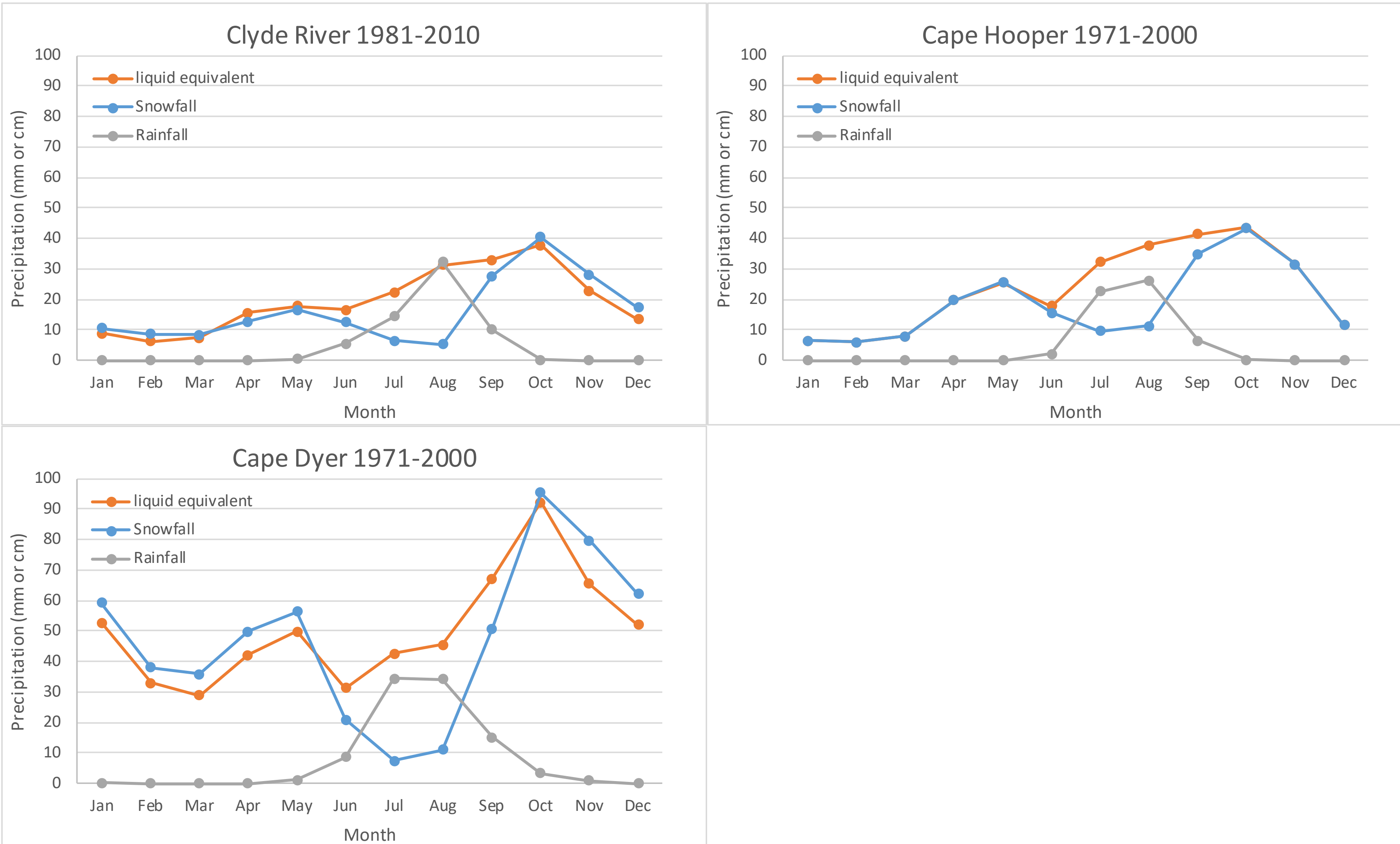


Figure 3.8 Climate Normals—Monthly Precipitation

3.1.4 Visibility

Periods of reduced visibility can occur in the region as a result of fog or blowing snow during storms. Climate normals for visibility are only available at the Cape Dyer meteorological station. For the 1971–2000 period, the average total hours per year with visibility reduced below 1 km is 512.7 or less than 6% of the time, on average at Cape Dyer. The most hours with visibilities less than 1 km occur in May at 60.8 hours per month, whereas the least hours with reduced visibility occur in April at 28.6 hours per month. There are 1,269.1 hours with visibilities reduced from 1 to 9 km per year, on average and 6,984.2 hours with visibilities greater than 9 km per year, on average (ECCC 2018c).

Hours with reduced visibility are shown graphically by month in Figure 3.9.

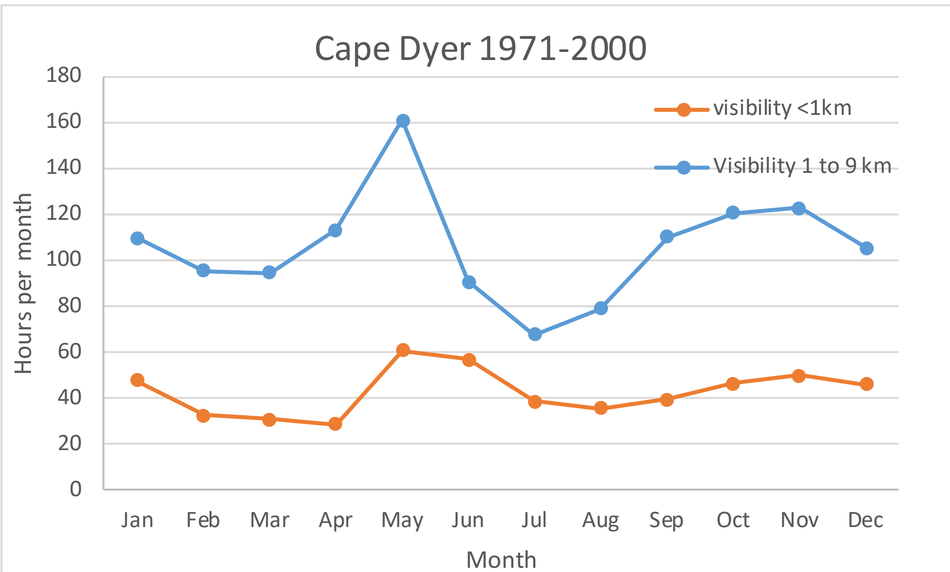


Figure 3.9 Climate Normals—Monthly Hours with Reduced Visibility

3.1.5 Icing

Icing conditions in the Baffin Bay area often occur due to freezing fog and freezing sea spray. Freezing rain in Baffin Bay is thought to be infrequent (Valeur et al. 1996). Sea spray is typically more of a concern than freezing fog, as ice accumulation is often more substantive from sea spray. Icing conditions occur most frequently from October to December when air temperatures typically range between freezing (0°C) and -15°C. When air temperatures fall below -15°C, icing becomes less of an issue as the airborne water droplets freeze prior to contact with surfaces (Valeur et al. 1996).

3.1.6 Extreme Events

Extreme events including storms, winds, waves, and tsunamis in the Area of Focus are summarized in this section.

3.1.6.1 Storms and Winds

In northern Canada, storms generally move into the region rather than forming in place (Atkinson et al. 2016). The most prominent storm track in the Area of Focus is from the southeast Labrador Sea northward to Baffin Island (Atkinson et al. 2016). As noted above, the Baffin Bay and Davis Strait area is far enough north that it is not significantly influenced by the typical westerly flow that occurs in areas further to the south (Tang et al. 2004b). As such, it is generally north of the main storm track. However, extratropical systems do track over and dissipate in the Canadian Archipelago on occasion (Roberts et al. 2008). Typically, storms occur most frequently in the eastern Canadian Arctic in October and November, on average. Some storms on Baffin Island are wind events and some are precipitation events that produce snow, freezing rain, or rain (Atkinson et al. 2016; Hanesiak et al. 2010; Roberts et al. 2008). Storm winds can drive wave and swell responses that propagate into and fracture sea ice (Asplin et al. 2012; Atkinson et al. 2016). This enhances ice decay and introduces additional heat and moisture into the atmosphere (Atkinson et al. 2016). The large expanses of open water now found in the Arctic Ocean and marginal seas can provide the thermal gradients necessary to drive powerful storms of large areal extent (Atkinson et al. 2016).

Areas with shallow inner-shelf bathymetry create conditions favourable for the development of storm surges (Atkinson et al. 2016). This, when combined with large expanses of low relief areas, can result in flooding (Atkinson et al. 2016).

Where the Area of Focus covers both coastal and offshore areas, it should be noted that the fiord-head deltas present on Baffin Island have the potential to be exposed to combined river and marine flooding (Atkinson et al. 2016).

Cyclone activity is closely related to storms. A cyclone is a general term used by forecasters to describe weather systems that are characterized by a rotating and seemingly organized system, in an area of pressure (atmospheric) that is lower than the areas outside the system. Reference is made to tropical cyclones, extra tropical cyclones, tornadoes, or hurricanes, depending on the wind speed. They often start forming over tropical or sub-tropical waters and can move hundreds of kilometres from the origin. They rotate counterclockwise in the Northern Hemisphere.

A review of Arctic cyclone activity over the period 1948–2002 indicated the following (Zhang et al. 2004):

- Arctic cyclone activity increased in the second half of the 20^{th} century
- Number and intensity of cyclones entering the Arctic from mid-latitudes has increased
- Using the sea level pressure (SLP) at the center of cyclone events as an indicator, Baffin Bay has a higher cyclone count in winter than in summer

- The long term mean value of the SLP of cyclone centers in Baffin Bay ranges from 996–1,002 hecto-Pascals (hPa)[14] in winter, and 1,000–1,007 hPa in summer (atmospheric pressure during an absence of storms is typically 1,013 hPa)
- Lower values of cyclone SLP reflect deeper cyclones, with stronger winds
- More storms come in to the Arctic in the winter from mid-latitudes, and those from the North Atlantic are stronger than those generated locally

A summary note suggests that the storms in the Arctic are expected to be fewer and stronger in winter, and more numerous but weaker in summer (Zhang et al. 2004).

High winds occur relatively often within the Area of Focus. For example, wind speeds at Clyde River greater than 36 km/hr occur about 7% of the time, on average (based on the 2013 to 2017 five-year period, as shown above in Figure 3.4). The highest extreme wind gusts observed at Clyde River are in excess of wind speeds associated with Category 1 hurricanes, at speeds up to 122 km/hr (Category 1 hurricane wind speeds range between 119 to 153 km/hr, based on the Saffir-Simpson Hurricane Wind Scale) (NOAA 2018b).

3.1.6.2 Waves and Tsunamis

Waves on the surface of waterbodies, such as oceans and lakes, are generated by local winds and remote storms. Surface wind waves are categorized into two main classes: wind-sea or wind-forced waves; and swells. Wind-forced waves typically travel at speeds slower than the surface wind speed. Swells travel faster than the surface wind speeds. The significant wave height (SWH) is defined as the average height of the highest one-third of wave heights and is the main metric in wave studies.

Observations on waves in the Area of Focus are taken largely from the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (Rhein et al. 2013), with the exception of some IQ indicating that larger waves, resulting in increased shoreline erosion, were observed around Grise Fiord (Nunavut Department of Environment n.d.).

Observations have been made from four sources: from ships on a voluntary basis, wave modeling, measurements on buoys, and satellite recordings.

- Ship measurements from 1950–2002 suggest trends in SWH of 14 cm/decade
- Wave modeling (using hindcasts) suggest an increase in the SWH over much of the North Atlantic, above 45°N, up to 20 cm/decade
- Buoy data provided very few useful and valid data for the Northern Hemisphere
- Satellite observation data to date for waves has been poorly sampled and is limited for the Northern Hemisphere, although the values for the South seem to be valid

[14] hPa is a measurement of barometric pressure. hPa stands for hecto (x100) Pascals.

In summary, and as stated in the IPCC Report, there is medium confidence based on ship observations and wave modeling that mean SWH has increased since the 1950s over much of the North Atlantic north of 45°N, with typical winter season trends of up to 20 cm per decade (Rhein et al. 2013).

In Baffin Bay, waves are relatively small most of the time. When larger waves occur, it is often infrequent and typically of short duration. This is due to the frequent presence of sea ice and infrequent, short-duration storms in the area (Valeur et al. 1996).

Related to waves, there are few known historical tectonic tsunamis in the arctic regions of North America. However, local tsunamis can occur in the region as a result of landslides and ice from calving glaciers (Ruffman and Murty 2006). Records of these tsunami like waves date back to the beginnings of exploration off Greenland and in Baffin Bay (Ruffman and Murty 2006).

More recently, a tsunami was reported in Greenland in June of 2017 that was the result of a 4.0 magnitude earthquake. The resulting tsunami killed four people and caused significant damage. The wave crested as high as 91 m (300 ft) (National Geographic 2017).

Based on the information reviewed, the potential exists for tsunamis and large waves to occur in the region, as in any coastal location, but the risk is likely to be relatively low in the Baffin Bay and Davis Strait area.

3.1.7 Weather Forecasting

Weather forecasting is defined as the application of science and technology to predict the conditions of the atmosphere regarding temperature, precipitation (e.g., rain, snow, freezing rain) for specific locations for a period of hours to 14 days. Weather forecasts are made by measuring the weather elements such as temperature, pressure, humidity, wind speed, and wind direction, for as many locations as possible, and using this information, combined with historical records, to understand the state and behavior of the atmosphere, and predict what the conditions will be in the future.

Current weather forecasts are now better than those in the past because of better monitoring and communication technologies, as well as a denser network of weather monitoring stations. Still, the weather phenomenon is an uncertain process, and accurate prediction at all times is elusive, especially as the time horizon extends out past seven days. In the early days, the basis of weather forecasts was based on the concept of persistence—the continuing trend in weather elements from one day to the next (Neiburger et al. 1973). The basis of modern forecasts is a computer-intensive, gridded estimation of pressure changes in the atmosphere that determine the trajectory of weather disturbances ranging from weak depressions (in pressure) to large storms including hurricanes.

In areas where the surface weather monitoring network is sparse (as is the case for the Area of Focus), forecasts are often tailored by using statistical relationships between the computer forecast and the actual conditions.

3.2 Air Quality and Greenhouse Gases

There are many factors affecting the natural and human environment in the Arctic. Air pollution is one such driver of change that affects climate change, ecosystems and health, but there are substantial uncertainties when it comes to quantifying these effects.

While progress has been made in recent years to increase the understanding of air pollution in the Arctic, the sensitivity of the Arctic climate to emissions of pollutants is not well characterized. Long term surface observations provide the main source of information on seasonal cycles and long-term trends in Arctic pollutants.

Ground level ozone, aerosol particles including black carbon and sulphates, as well as polycyclic aromatic hydrocarbons (PAHs) can be transported to the Arctic region from emission sources far outside the Arctic, for example, from locations at mid-latitudes such as Europe, Asia and North America. Black carbon is of particular interest due to its ability to absorb light and significantly reduce the surface albedo in the Arctic, particularly during the summer (Arnold et al. 2016). Emissions can also come from activities within the arctic, such as shipping, power production, and other industrial activities.

The main sources of emissions include resource extraction (mining, oil and gas), flaring of excess gas, marine shipping (e.g., supply and cruise ships), diesel electric generating stations serving off grid communities, and domestic combustion (e.g., vehicles, furnaces, fires) (ECCC 2017d).

These pollutants can affect the atmospheric radiation balance and contribute to Arctic climate warming (Arnold et al. 2016). Since the Arctic atmosphere is a cold stable air mass, with suppressed mixing of pollutants, there is an important vertical component that influences what contributes most to the near surface atmosphere (i.e., the troposphere) in the Arctic.

The fate of airborne pollutants is largely determined by transfer from the atmosphere to the surface and is thus influenced by the stratified vertical structure of the Arctic troposphere. Therefore, understanding vertical transport in the Arctic is one of the key uncertainties in evaluating the impacts of extra-Arctic pollutants on the Arctic (Arnold et al. 2016).

A summary of the quantities of air contaminants released to the atmosphere in Nunavut is provided in Table 3.2.

Table 3.2 Air Contaminants and GHG Emissions—Nunavut 2015

Emissions (tonnes per year)									
Air contaminants, 2015						Greenhouse gases (GHGs), 2015			
TSP	$PM_{2.5}$	NO_2	SO_2	CO	THC	CO_2	CH_4	N_2O	CO_2e
10,400	-	12,600	2,560	2,040	700	581,000	360	51	626,000[a]

NOTE:
[a] Some hydroflurocarbons are not shown but are included in the total value.

SOURCE: (ECCC 2017c, 2017d)

For context, the GHG emissions from Canada are 722,000,000 tonnes CO_2e per year for the year 2015 (ECCC 2017c). Table 3.3 compares Nunavut's emissions of selected criteria air contaminants to the national totals.

Table 3.3 2015 Emissions Totals for Selected Criteria Air Contaminants, Nunavut and Canada

Criteria Air Contaminant	Total Nunavut Emissions, 2015 (kilotonnes, kt)[1]	Percent of National Emissions	Total 2015 National Emissions (kilotonnes, kt)[1]
PM	10.4	0.05%	22,881
VOCs	0.70	0.04%	1,859
NO_X	12.6	0.67%	1,894
CO	2.04	0.04%	5,595
SO_2	2.56	0.24%	1,054
NOTES: [1] Environment Canada (2017b) CO = carbon monoxide; VOCs = volatile organic compounds; NOx = nitrogen oxides; PM = total particulate matter; SO_2 = sulphur dioxide			

Small local thermal power generating stations and marine vessel traffic (supply vessels and cruise ships) in the area are the largest sources of emissions in the region (ECCC 2017b). The NO_x from sources in Nunavut makes up the largest percentage of total national emissions at 0.7%, with the majority of the NO_x being produced by marine vessel traffic.

Ambient air quality is monitored by federal, provincial and territorial agencies across Canada. This activity is the National Air Pollution Surveillance (NAPS) program. The program was initially set up in 1969, and is done cooperatively among the provinces, territories and some municipal governments. There are approximately 286 sites in communities located in every province and territory (ECCC 2018).

Ambient Air Quality is only measured in a few locations in Nunavut. A summary of the 2016 data measured at the Iqaluit station is provided in Table 3.4. The concentrations of VOCs are not measured in Nunavut and likely to be nominal on average, due to the small number of sources in the region.

Table 3.4 Summary of Measured Concentrations ($\mu g/m^3$)—Iqaluit—2016

Value	Average Period	Maximum	Percentiles			Minimum	Nunavut Ambient Air Quality Standards ($\mu g/m^3$)
			98th	95th	90th		
NO_X	1-hour	248	75.7	36.3	26.9	3.58	400
	24-hour	65.7	51.2	28.6	23.9	5.83	200
$PM_{2.5}$	24-hour	23.0	11.0	8.00	6.00	0	30
Ozone	8-hour	84.4	76.6	72.6	68.7	9.82	124
SOURCE: (ECCC 2017a)							

As is shown in Table 3.4, measured concentrations in 2016 for NO_x, $PM_{2.5}$, and ozone are well below the Nunavut Ambient Air Quality Standards. This suggests that air quality is generally good most of the time.

Given the relatively low emissions of $PM_{2.5}$ from within Nunavut (915 tonnes [t] in 2015), it is likely that $PM_{2.5}$ concentrations are mainly due to transboundary effects from secondary formation and long-range transport of direct releases from other areas outside of the Arctic (e.g., Asia, North America, Europe) (Arnold et al. 2016). Ambient ozone concentrations are also likely due to long range transport from other areas outside the arctic, as there likely would not be much ozone formation due to local emissions.

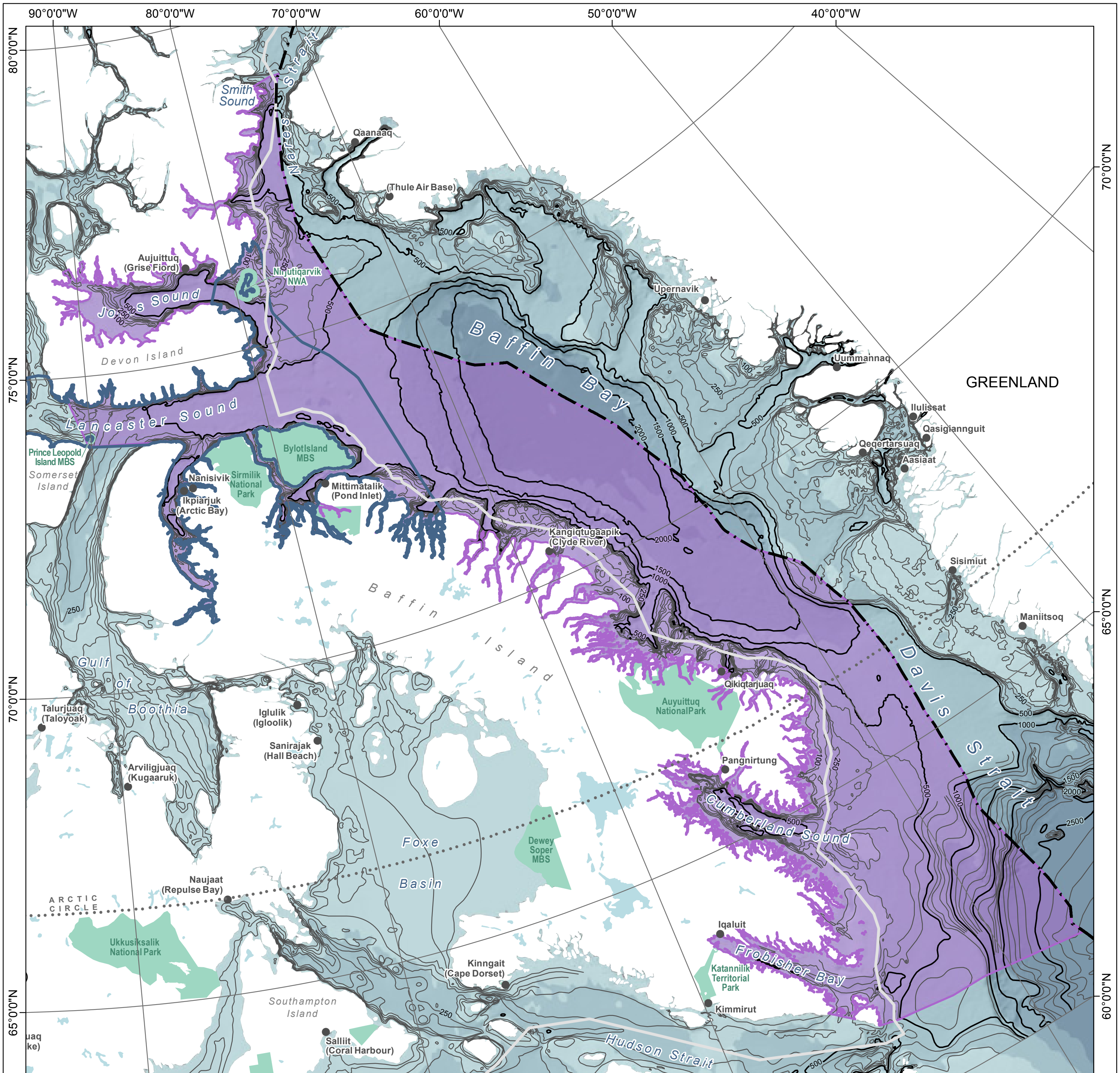
3.3 Bathymetry

Baffin Bay is a semi-enclosed oblong basin approximately 1,400 km long and 550 km wide (Tang et al. 2004b). There is a large abyssal plain in the central region of Baffin Bay with depths in excess of 2,300 m (Tang et al. 2004b). Baffin Bay connects the Arctic and Atlantic Oceans, and is bordered by Greenland to the east, Baffin Island to the west, the Canadian Arctic Archipelago to the north, and Davis Strait to the south (Hamilton and Wu 2013). On the Greenland side of Baffin Bay, there is a wide shelf extending approximately 150 km, while on the Baffin Island side there is a much narrower shelf extending approximately 35 km (Gibb 2015). Figure 3.10 shows the generalized bathymetry of the region.

The bathymetry of Baffin Bay is unique among the Arctic seas due to the presence of shallow sills to the north and south, which restrict water movement and create a relatively isolated body of cold, deep, polar water (Boertmann and Mosbech 2011). Baffin Bay connects to both the Arctic and Atlantic Oceans across these sills, and while these sills restrict deep water flow, they still permit cold Arctic surface waters to enter Baffin Bay from the north via Lancaster Sound (55 km wide, 125 m deep), Jones Sound (30 km wide, 190 m deep), and Nares Strait (40 km wide, 220 m deep) (Gibb 2015). These sills also permit intermediate waters from the Atlantic Ocean to enter from the south through Davis Strait (Gibb 2015).

Like Baffin Bay, Davis Strait is also a semi-enclosed basin that separates western Greenland and Baffin Island (Merkel et al.). Davis Strait is over 300 km wide and up to 1,000 m deep (Hamilton and Wu 2013). However, unlike Baffin Bay, Davis Strait is widely open to the rest of the Northwest Atlantic Ocean without obvious bathymetric barriers such as shallow sills (Jørgensen et al. 2005b). Arctic waters entering Baffin Bay to the north through Lancaster Sound, Jones Sound, and Nares Strait flow south through Davis Strait to enter the Northwest Atlantic Ocean (Niemi et al. 2017).

The main sedimentary basins in the Area of Focus are the Baffin Basin and Lancaster Sound basins. Other sedimentary basins in the Area of Focus include the North Water Basin, Carey Basin, Glacier Basin, Jones Sound Basin, Lady Ann Basin, North Bylot Trough, Eclipse Trough, and Scott Inlet Basin. Submarine fans in the Area of Focus include the Baffin Fan and the Lancaster Sound Trough-Mouth Fan (Harrison et al. 2011; Li et al. 2011).



Base Features

- Community[1]
- Limit of Exclusive Economic Zone[4]
- Nunavut Settlement Area[3]
- Tallurutiup Imanga / Lancaster Sound NMCA[2]
- Protected Area or National Park[4]

Bathymetry[5] Depth (m)

< 200 | 200 - 1000 | 1000 - 2000 | 2000 - 3000 | > 3000

Project Features

- Area of Focus[2]

Bathymetry[6]

- Major Bathymetric Contour
- Minor Bathymetric Contour

1:10,000,000

0 50 100 200 300

Kilometres

References:
[1]Atlas of Canada Base Maps, 2017
[2]NIRB, 2017
[3]Nunavut Planning Commission, 2010
[4]National Framework Canada,2017
[5]Natural Earth, 2016
[6]Geological Survey of Canada, 2003

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Figure 3.10 Generalized Bathymetry of Baffin Bay and Davis Strait

Prepared By: Nunami Stantec Limited
Projection: Canada Lambert Conformal Conic, North American 1983
Date: Apr 13, 2018
Project Number: 12322100
Produced By: L. Trudell
Verified By: J. Beckett
Revision: 01

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3.4 Oceanography

3.4.1 Currents

The Baffin Bay and Davis Strait region is influenced by the West Greenland Current that carries Arctic water northwards along the west coast of Greenland, and by the Baffin Island Current that brings cold and fresh water down the east coast of Baffin Bay along the coast of Baffin Island (see Figure 3.1 in Section 3.1) (Niemi et al. 2017). While the Baffin Island Current and Western Greenland Current are the main currents in the Area of Focus, other currents are present, and these are described below.

3.4.1.1 Baffin Island Current

The cold and fresh Arctic water entering Baffin Bay through Lancaster Sound, Jones Sound, and Nares Strait form the broad, surface-intensified Baffin Island Current (Hamilton and Wu 2013; participant from Qikiqtarjuaq as cited in Dowsley 2005). This fresh water entering Baffin Bay is somewhat confined to the margins of the bay as part of a cyclonic circulation pattern (Hamilton and Wu 2013). The Baffin Island Current flows southward along the coast of Baffin Island and into the western half of Davis Strait; eventually feeding into the Labrador Current (Hamilton and Wu 2013).

Dunlap and Tang (2006) modelled the mean circulation in summer and found that the main factor influencing the Baffin Island Current was inflow from Lancaster Sound, Jones Sound, and Nares Strait. Changes in the freshwater flux entering Baffin Bay through these northern channels can influence the Baffin Island Current and have the potential to affect the Northwest Atlantic ecosystem and fisheries by altering the physical properties of productive east coast banks and slope areas (Hamilton and Wu 2013).

3.4.1.2 West Greenland Current

Along the west Greenland shelf and slope, the West Greenland Current transports cold and fresh Arctic water northward as a continuation of the Eastern Greenland Current, and relatively warm and salty water from the Irminger Sea further offshore (Hamilton and Wu 2013). The majority of the water originating in the Irminger Sea is circulated cyclonically around the northern Labrador Sea, and is constrained by the bathymetry of Davis Strait (Hamilton and Wu 2013). However, a portion of this water from the Irminger Sea continues to flow northward along the slope into Baffin Bay as a continuation of the West Greenland Current (Bourke et al. 1989).

Wang et al. (2012) modelled circulation at the 500 m depth level to determine seasonal variations in the circulation pattern of the region. The modelling indicated that, in summer, the deeper core of the West Greenland Current that contains warmer and saltier Irminger Sea water reaches the southern end of Davis Strait before the majority turns southwest toward the Labrador Sea. In winter, the modelling indicated that the northern limit of the core of the West Greenland Current is further south than in summer and confirmed the observations of Tang et al. (2004b) that no strong winter current is present in eastern Davis Strait.

Modelling also showed that an increase in the Baffin Island Current corresponds to an increase in the flow of the West Greenland Current in the opposite direction, so when the Baffin Island Current accelerates because of strong northerly winds, the West Greenland Current accelerates correspondingly (Dumont et al. 2010). Nunavummiut Elders and hunters note that currents are now stronger, and tides are more pronounced than in the past (Nunavut Tunngavik Inc. 2005).

3.4.1.3 Other Currents

In addition to the Baffin Island Current and West Greenland Current, other currents in the Area of Focus contribute to circulation patterns observed in the region.

The North Water Polynya, described in more detail in Section 3.4.6, is a nexus for ocean currents flowing northwards up the east side of Davis Strait, and those flowing eastwards (Lancaster and Jones Sounds) and southwards (Nares Strait) from the Arctic through the Canadian Arctic Archipelago (Foster et al. 2015). These various currents transport and mix water derived from Atlantic, Arctic, and Pacific Oceans, as well as water from multiple rivers and sea ice melt (Alkire et al. 2011; Foster et al. 2015). Modelled circulation patterns for the North Water Polynya show a southward current crossing the entire area that is associated with the Baffin Island Current, and a northward current entering the area at the southeast corner and turning south at various locations, representing the West Greenland Current (Dumont et al. 2010).

The complex geometry of the Canadian Arctic Archipelago includes many small channels that can give rise to large tidal currents at small scales (Hannah et al. 2009). Tidal currents can contribute to the vertical transport of heat and nutrients through the generation of internal tides (Hannah et al. 2009). Tidal currents can also produce sufficient turbulence to cause the vertical mixing capable of forming and maintaining a polynya (Nunavut Department of Environment n.d.). Slow-moving tidal currents that encounter a shallow and/or narrow strait area can move warmer, deeper water to the surface, preventing the formation of ice (Nunavut Department of Environment n.d.).

In Lancaster Sound, during the spring, there is a westward current along the northside of the Sound, and an eastward flow along the south side of the Sound (Archambault et al. 2010; Collin and Dunbar 1964).

Along with the fresh water input through Lancaster Sound, Jones Sound, and Nares Strait associated with the Baffin Island Current (described above), Hamilton and Wu (2013) observed fresh water, originating from the East Greenland Coastal Current, along the Greenland coast.

3.4.2 Sea Water Temperature and Salinity

There are multiple layers of water present in Baffin Bay and each of these represent different temperatures and salinities (Hamilton and Wu 2013; Jorgensen et al. 2005).

Hamilton and Wu (2013) sampled along a north-south transect down the centre of Baffin Bay and Davis Strait that spanned from the north end of Baffin Bay south to the northern edge of the Labrador Sea. Over the deeper part of the transect, the temperature structure showed three distinct layers. There was a cold surface layer (less than 200 m depth), a warmer intermediate layer (200–1,000 m depth), and a deep layer (greater than 1,000 m depth) that had a temperature in between that of the surface and intermediate layer. Characteristic temperatures for these three layers reported by Hamilton and Wu (2013) were, from surface to bottom, -1ºC, 1ºC, and 0ºC respectively. Jorgensen et al. (2005) has previously reported bottom temperatures of 3–5ºC at depths of 400–1,500 m in Davis Strait.

In the study by Hamilton and Wu (2013), the horizontal and vertical distribution of salinity revealed the same pattern as that observed with temperature in the upper surface layer (i.e., lower salinity was correlated closely with lower temperature) (Hamilton and Wu 2013). However, below the upper surface layer, there was no clear difference in salinity below 200 m, and it was not possible to differentiate between an intermediate and deep layer (Hamilton and Wu 2013). Hamilton and Wu (2013) also determined that salinity in the central part of Baffin Bay is higher than that of coastal waters.

The temperature and salinity in the Area of Focus have limited seasonal variability, except in the upper 300 m of eastern Davis Strait, northern Baffin Bay, and the mouth of Lancaster Sound (Tang et al. 2004b). Tang et al. (2004b) show a temperature minimum at approximately 100 m in the Area of Focus, suggesting that winter convection does not penetrate deeper than this depth. Higher salt content has been noted in the waters around Clyde River (Palituq S. as cited in Nunavut Environment 2017).

The water in the northwest region of Baffin Bay is 4°C cooler than in the southeast region as a result of the circulation patterns described by Hamilton and Wu (2013) (see Section 3.4.1). In general, the salt water has been reported to be warmer in recent years (Ivalu 2001 as cited in Nunavut Tunngavik 2001; Pijamini 2001 as cited in Nunavut Tunngavik 2001)

3.4.3 Tides

The tides in Baffin Bay are semi-diurnal, with a tidal range of 3.0 m in the southern part of the bay (Tait et al. 1986). These tides become mixed semi-diurnal, with a tidal range of 2.8 m in the northern part of the bay at the entrance to Lancaster Sound (Tait et al. 1986). The tides in the northern part of the bay are approximately six hours out of phase with those in the southern part of the bay (Tait et al. 1986). There is an amphidromic point (point of zero tidal amplitude) near Clyde River where the tidal range is 1.4 m (Tait et al. 1986).

The tide enters the eastern end of Lancaster Sound from Baffin Bay and moves westward through the sound (Tait et al. 1986). The tides in Lancaster Sound are semi-diurnal and a tidal range of 2.8 m remains constant throughout the sound but decreases moving westward through Barrow Strait (Tait et al. 1986).

The tides in Jones Sound are semi-diurnal and move into the Sound from Baffin Bay to the east (Tait et al. 1986). The tidal ranges in Jones Sound vary with a range of 2.7 m in the eastern end of the Sound that increases to 3.8 m moving westward, before decreasing to 2.9 m at the western end of the Sound at the entrance to Cardigan Strait (Tait et al. 1986). The tidal range continues to decrease as it moves through Cardigan Strait and into Norwegian Bay (Tait et al. 1986).

The tidal range in Frobisher Bay, on southeast Baffin Island, reaches up to 11 m in height at the head of the bay (Nunavut Parks 2008d).

Historical environmental variations, including changes in tides, have been recorded by the Inuit of Nunavut. "According to the traditional knowledge of our ancestors, we have to keep in mind that they are the benchmarks for the change to our environment that is occurring in Nunavut. They were collected over millennia and should be used by the government in looking at the changes to the climate" (Qarpik 2001 as cited in Nunavut Tunngavik 2001). Recently, currents have been noted to be stronger and tides more pronounced (Nunavut Tunngavik 2005). In Iqaluit and Pangnirtung, high tides are reported to be higher, and low tide further from the shoreline. Neap tide is stronger than usual, with areas that were bare before, now underwater. Tidal areas dry out completely, where in the past they did not (Qarpik 2001 as cited in Nunavut Tunngavik 2001; Nunavut Department of Environment 2005). Tidal pools are getting warm, and neap tides are stronger than they were in the past (Nunavut Department of Environment 2005).

3.4.4 Upwelling and Polynyas

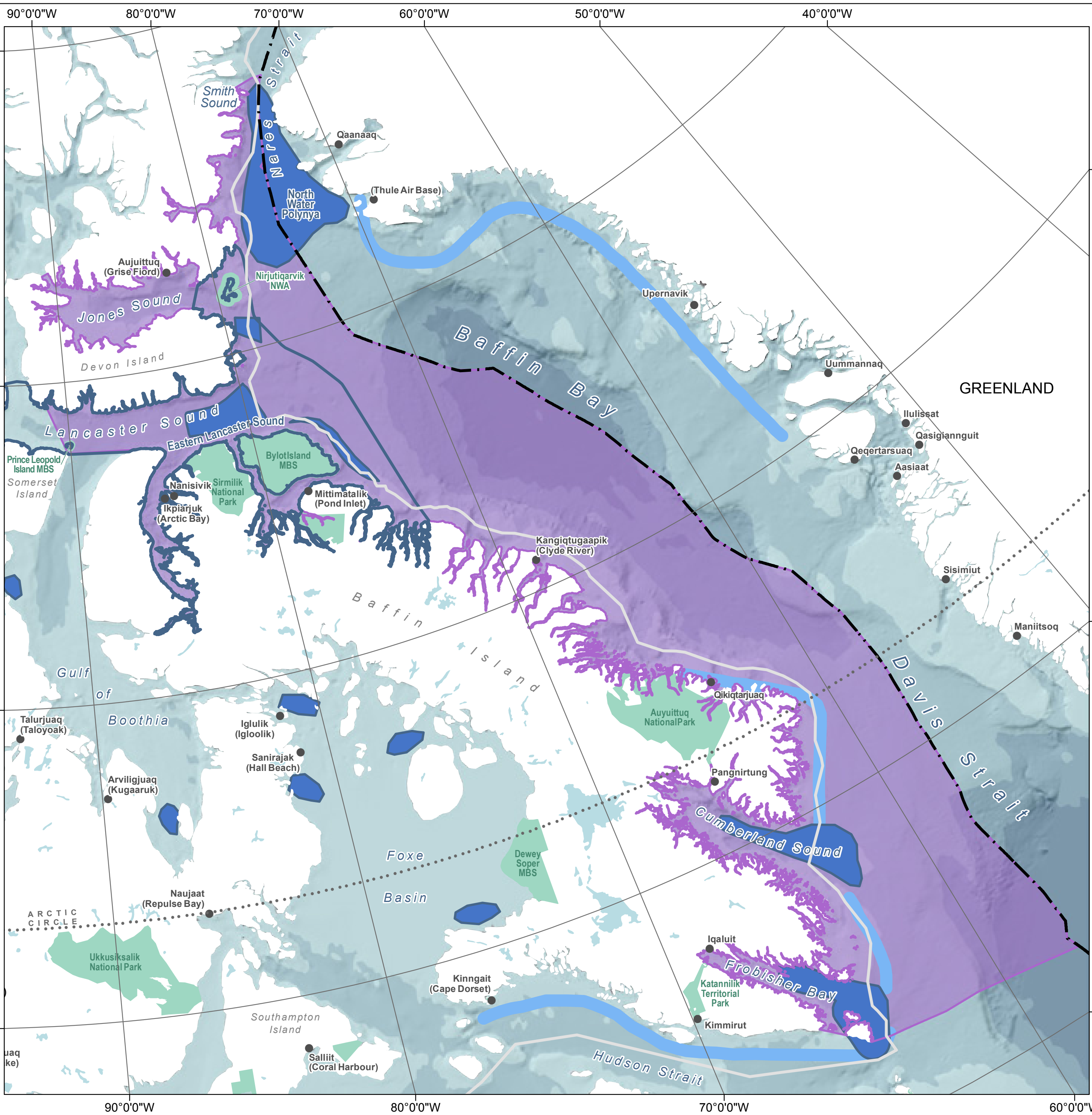
Within the Area of Focus, localized upwelling events in shallow coastal areas are associated with the formation and maintenance of polynyas (Dumont et al. 2010). A polynya is a geographically fixed region of open water or low average sea-ice thickness that is isolated within thicker pack ice (Hannah et al. 2009). In general, polynyas in the Arctic are created at the periphery of central basins and near the coasts where favourable conditions for formation and maintenance occur (Dumont et al. 2010). Shallow coastal areas are the most favourable sites for the formation of polynyas because these are areas of localized upwelling, and convective and tidal mixing (Dumont et al. 2010).

The presence of open water in winter can be a chance occurrence that is short-lived in nature, and such occurrences are largely unpredictable and of limited usefulness to animals and humans (Nunavut Department of Environment n.d.). However, recurrent open water sites are the physical manifestation of one or several predictable physical processes that result in spatial and temporal reliability (Nunavut Department of Environment n.d.). The formation of recurring open water sites in ice-covered seas, including polynyas and shore-fast leads, reflect local geography, ice conditions, and water movements such as upwelling and tidal mixing (Nunavut Department of Environment n.d.).

Polynyas that reliably occur each year are believed to be ecologically significant; there is a positive correlation between recurrent open water sites and the abundance of marine organisms such as whales, seals, and marine birds (Hannah et al. 2009; Stirling 1980b). Further, the availability of food from increased primary production in phytoplankton, ice algae, and marine plants is a major contributing factor in the abundance of marine organisms observed at recurrent open water sites (Nunavut Department of Environment n.d.).

There are known polynyas in the Area of Focus as identified by Stirling (1980b), Barber and Massom (2007), and the Grise Fiord Nunavut Coastal Resource Inventory (Nunavut Department of Environment n.d.) Polynyas known to occur in the Area of Focus are shown in Figure 3.11[15] and the nature of these are summarized in Table 3.5.

[15] More recent data on polynyas is available and was requested, but as of the time of completion of this report, the request had not been fulfilled.



Base Features

- Community[1]
- Limit of Exclusive Economic Zone[4]
- Nunavut Settlement Area[3]
- Tallurutiup Imanga / Lancaster Sound NMCA[2]
- Protected Area or National Park[4]

Bathymetry[5] Depth (m)

< 200 | 200 - 1000 | 1000 - 2000 | 2000 - 3000 | > 3000

Project Features

- Area of Focus[2]
- Polynyas[6]
- Major Shorelead Polynyas[7]

1:10,000,000

0 50 100 200 300

Kilometres

References:
[1]Atlas of Canada Base Maps, 2017
[2]NIRB, 2017
[3]Nunavut Planning Commission, 2010
[4]National Framework Canada,2017
[5]Natural Earth, 2016
[6]Mallory, M.L. and A.J. Fontaine. 2004
[7]Hannah et al., 2009

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Figure 3.11 Known Polynyas

NUNAMI STANTEC LIMITED

N.I.R.B.

Prepared By: Nunami Stantec Limited
Projection: Canada Lambert Conformal Conic, North American 1983
Date: Apr 13, 2018
Project Number: 12322100
Produced By: L. Trudell
Verified By: J. Beckett
Revision: 01

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Table 3.5 Polynyas in the Area of Focus

Polynya	Description
Flagler Bay	Small concentration of polynyas located at the far northern tip of the Area of Focus in Kane Basin
North Water	Large concentration of polynyas located in the northern section of the Area of Focus in Smith Sound and in northern Baffin Bay
Hell Gate-Cardigan Strait	Small concentration of polynyas located at the western end of Jones Sound
Lady Ann Strait	Small concentration of polynyas located at the mouth (eastern end) of Jones Sound)
Coburg Island	Small concentration of polynyas located in northern Baffin Bay near the entrance to Jones Sound
Bylot Island	Large concentration of polynyas in northwest Baffin Bay located at entrance to Lancaster Sound
Lancaster Sound	Small concentration of polynyas located at the northern part of Lancaster Sound along the south coast of Devon Island
Cumberland Sound	Large concentration of polynyas located in western Davis Strait in Cumberland Sound
Frobisher Bay	Large concentration of polynyas located in southwestern Davis Strait in Frobisher Bay
SOURCE: (Nunavut Department of Environment n.d.)	

The International North Water Polynya Study was a large multidisciplinary project between 1997 and 1999 that showed many indications that upwelling occurs in the North Water Polynya, or Pikialasorsuaq, including the persistence of strong northerly winds during the spring phytoplankton bloom (Odate et al. 2002; Tremblay et al. 2002). The two types of upwelling observed in the North Water Polynya are associated with the two types of physical boundaries, the coast and the landfast ice (Dumont et al. 2010). The first type, coastal upwelling, occurs along Ellesmere Island and the west coast of Greenland during periods of northerly and southerly winds (Dumont et al. 2010). The second type is the upwelling generated at a landfast ice edge (Dumont et al. 2010).

Modelled circulation patterns in the North Water Polynya showed that wind conditions typical of late spring are likely to produce strong upwelling events along the coast of Greenland (Dumont et al. 2010). These models showed that the area of upwelling can be extended by the presence of an ice bridge and other landfast ice edges over deeper waters, where nutrients and possibly heat can be brought near the surface (Dumont et al. 2010). The model also showed there can by cyclonic eddying at the landfast ice edge (Dumont et al. 2010).

The density profile of Smith Sound has an east to west gradient, with denser water in the eastern part of the Sound (Bâcle et al. 2002; Melling et al. 2001), and simultaneous and recurrent downwelling. Eastern upwelling events during the ice-free season favour the buildup of this density structure in Jones Sound (Dumont et al. 2010).

Further, tidal currents can contribute to the vertical transport of heat and nutrients through the generation of internal tides (Hannah et al. 2009).

IQ has indicated that sea currents are becoming stronger annually and, as a result, polynyas are present in unusual places and ice is becoming thinner (Qaunaq 2001 as cited in Nunavut Tunngavik 2001; Pijamini 2001, as cited in Nunavut Tunngavik 2001).

In addition to the polynyas described in Table 3.5, there are also major shorelead polynyas in the Area of Focus (also shown on Figure 3.11). One such shorelead polynya is known to occur along the coast of Greenland in Baffin Bay, which stretches from approximately Saunders Øer Island in the north and Disko Island to the south (see Figure 3.11). Another follows the coast of Baffin Island in Davis Strait and through Hudson Strait, beginning near Qikiqtuarjuaq and ending near Cape Dorset (see Figure 3.11).

Smaller polynyas are also found at several sites along the west coast of Greenland (Boertmann and Mosbech 2011). There is also a shear zone, with open cracks and leads, between the land-fast ice and the drift ice on the west coast of Greenland (Boertmann and Mosbech 2011). The formation of new polynyas has been observed in recent years (Pijamini 2001 as cited in Nunavut Tunngavik 2001; Qarpik 2001 as cited in Nunavut Tunngavik 2001; Novaqilik 2002, as cited in Nunavut Environment 2005).

While Davis Strait is much shallower than Baffin Bay, both areas are characterized by open water periods in the summer months from July to October (Nunami Stantec Ltd. 2010). In the winter months, from November to June, pack ice dominates the area, with the exception of polynyas that typically remain ice free for most of the year (Nunami Stantec Ltd. 2010).

Hannah et al. (2009) used a tidal model to map the strength of tidal currents, tidal mixing, and the vertical movement associated with tidal currents that drive water upslope and downslope. Tidal hot spots corresponded with the location of several recurring polynyas, which suggests the importance of tidal currents and mixing in the dynamics of recurring polynyas (Hannah et al. 2009).

3.4.4.1 North Water Polynya-Pikialasorsuaq

The North Water polynya, or Pikialasorsuaq, is a recurrent polynya located in northern Baffin Bay at the entrance of Smith Sound in the Nares Strait, and between Ellesmere Island and Greenland (Pikialasorsuaq Commission 2017) (see Figure 3.11). There is an ice arch present in Kane Basin that prevents the inflow of ice from the north. As a result, ice is moved away from the ice arch and the coast of Greenland, which creates a region of thin ice and open water (Tang et al. 2004b). Due to climate change, discussed in detail in Section 7, the northern ice bridge in Kane Basin, Nares Strait, and Smith Sound has become less reliable in recent years, and the polynya has become less predictable and more poorly-defined (Pikialasorsuaq Commission 2017).

On average, the North Water polynya covers an area of 20,000 km², but this area can increase up to 80,000 km² at its peak in July (Pikialasorsuaq Commission 2017). The North Water polynya receives only light ice cover, distinguishing it from the rest of Baffin Bay, which is ice covered for most of the year, with the exception of the other polynyas described in Table 3.5 and shown in Figure 3.11.

The Inuit have recognized the North Water as a critical resource and habitat for key marine mammals, fish, and seabirds upon which communities depend (Nunavut Department of Environment 2010; Pikialasorsuaq Commission 2017). Due to its biological diversity, the polynya has been an important hunting ground, providing Inuit with food and resources for making clothes and tools, and thus, deemed invaluable for cultural and spiritual well-being (Pikialasorsuaq Commission 2017). “We think about the need for conserving the wildlife in Pikialasorsuaq for the next generations. We wish to protect the animals in Pikialasorsuaq like polar bears, walruses, narwhals and belugas, seals, birds and many other from too much disturbance from large ship traffic and oil explorations in the area” (Aronsen 2013 as cited in The Association of Fishers and Hunters of Greenland 2013).

The North Water polynya is a nexus for various currents in Area of Focus (see Section 3.4.1) and is therefore a critical downstream area for monitoring the distribution of future oil pollution in the Canadian Arctic (Foster et al. 2015). Although some of the functioning and characteristics of the North Water polynya are reasonably well understood, its future remains uncertain due to the potential cumulative effects of climate change and increased human activities in the Arctic (Pikialasorsuaq Commission 2017). For example, travel across the polynya by the Inuit is becoming increasingly dangerous, and not always possible (Pikialasorsuaq Commission 2017).

3.4.5 Trends, Extreme Events, and Seasonal Variations

The physical and chemical properties of Baffin Bay and Davis Strait are susceptible to localized and indirect impacts of climate change and other environmental stressors (Niemi et al. 2017). Oceanographic changes such as warming temperatures, ocean acidification, and changing nutrient regimes have been observed within the Baffin Bay and Davis Strait area (Niemi et al. 2017), with the potential for substantial impacts on ecosystem biodiversity, productivity, and species distribution (Bergeron and Tremblay 2014; Hamilton and Wu 2013; Niemi et al. 2017; Yamamoto-Kawai et al. 2013).

As mentioned in Section 3.4.2, within the Area of Focus there is little seasonal variation in temperature and salinity, except in the upper 300 m of eastern Davis Strait, northern Baffin Bay, and the mouth of Lancaster Sound (Tang et al. 2004b). However, there is strong inter-annual variation in both temperature and salinity (Hamilton and Wu 2013).

In terms of currents, seasonal variation in Baffin Bay is complex, but a general trend has emerged that currents in the summer and fall tend to be stronger than those in the winter and spring at all depths (Tang et al. 2004b). The largest seasonal variation in currents in the Area of Focus occurs at the mouth of Lancaster Sound and on the Baffin Island slope (Tang et al. 2004b).

Increases in the freshwater input from the Greenland ice sheet and Canadian glaciers can impact the salinity in Baffin Bay and Davis Strait coastal currents (Hamilton and Wu 2013). Hamilton and Wu (2013) have predicted a salinity increase of 0.4 psu by the year 2050. As an extension of the Baffin Island Current, the upper water of the Labrador Current will also be affected by this freshening, with possible impacts on the Labrador coasts and Grand Banks ecosystems. However, the long-term effects of this growing fresh water input on stratification and thermohaline circulation is not known (Hamilton and Wu 2013). Trends in variability in the fresh water and heat input into the western North Atlantic Ocean via

Baffin Bay and Davis Strait is of particular interest, because of the potential effect this input may have on global ocean circulation (Hamilton and Wu 2013).

Along with changes to fresh water input, changing sea ice conditions and changing weather also can influence oceanographic conditions in Baffin Bay and Davis Strait (Hamilton and Wu 2013). The variability of currents in the Area of Focus can cause contrasting ice conditions on the eastern and western sides of Davis Strait (Mathieson et al. 2010).

3.5 Sea Ice and Iceberg Conditions

Sea ice conditions in Baffin Bay range from near complete coverage from December to April to nearly ice free in the late summer (August-September). Ice starts to clear in spring, beginning in the southeastern and Northern Water regions. Sea ice formation starts to increase in early fall when freezing temperatures return (Tang et al. 2004). Icebergs are generated from glacial ice from the Canadian Archipelago and the Greenland Ice Sheet. The main source is the west cost of Greenland near Disko Bay.

A number of studies have been done to characterize the climate and meteorology of the Arctic Ocean and Baffin Bay (Duarte et al. 2012; Hamilton and Wu 2013; Peterson and Pettipas 2013; Tang et al. 2004b). Inuit from Arctic Bay, Iqaluit and Pangnirtung have identified changes in sea ice beyond normal year to year variability (Shooyook I 2004, as cited in Ford et all 2008; Nunavut Department of Environment 2005). Satellite data and meteorological information are being collected on an on-going basis to help understand the biophysical environment and how it may change in future. The activities are carried out by the Canadian Ice Service (CIS) and United States National Sea Ice Data Center (NSIDC), as well as other organizations such as the Danish Meteorological Institute.

The changes being observed are more coordinated now and point to a warming trend (air temperature, and sub-surface sea temperature) and thinning of the sea ice in the Arctic and in Baffin Bay, and melting of the Greenland Ice Sheet. Changes which have been observed by Inuit from Arctic Bay, Iqaluit and Pangnritung include ice freeze-up which takes place later in the year and over a longer period, thinner sea ice conditions, more snow accumulating on the ice, new areas of open water and earlier ice break-up (Enoogoo K. 2004, as cited in Ford et all 2008; Nunavut Department of Environment 2005).

> (Sea ice) has really changed, big time. I recall (in my youth) that the ice never used to go out until July. Then the ice would soon reform within a matter of two months. It used to get cold quite early even before November. I recall that we would have ice, really thick ice by November. Usually, but the first week of November, the ice was useable and we could go places. There would be quite a bit of snow on the ground, prior to the ice freezing over. Now, these days, the ice does not form until December and I think that we are all aware that the ice is forming later each year, those of us who grew up in Iqaluit (Johnny N. 2002, as cited in Nunavut Department of Environment 2005).

There is considerable variability and some uncertainty on the rate of those changes. Nevertheless, the need to identify ways to adapt to the changes that are expected in the future is becoming clearer, as the effects of change in climate are seemingly increasing with each passing year. Here we provide a brief overview of Sea Ice and Icebergs as these may exist and affect activities in Baffin Bay and the Davis Strait.

3.5.1 Sea Ice, Glaciers and Icebergs

Baffin Bay connects the Arctic Ocean and the western part of the North Atlantic via the Labrador Sea. It forms an important pathway for the exchange of water, salt, and heat between these two large oceans (Hamilton and Wu 2013). In the Area of Focus of this SEA, the ocean currents, waves, storm surges, the atmospheric circulation, the air temperature, the sea surface temperature, salt content, and ice sheet melt in Greenland all act to provide a large influence on the formation, presence and melting of sea ice, glacial ice and icebergs.

Ocean currents originate from the Arctic via Bering Strait and the Pacific Ocean with flow down through Baffin Bay and the east side of Greenland, and from the Atlantic Ocean northward on the west side of Greenland. The influence of the earth's rotation and the interaction of the ocean flows with the topography results in the ocean currents as shown in Figure 3.1. The Western Greenland Current (WGC) is a relatively warm flow travelling northward along the west coast of Greenland and slows as is turns near the top of Baffin Bay at Nares Strait. The Baffin Island Current (BIC) is a colder flow and moves southward along the east coast of Baffin Island. Smaller offshoots from the main currents illustrate the complexity of the flow in the Bay. The depth of the Baffin Bay is illustrated in blue and shows a large coastal shelf off Western Greenland and a thinner shelf off the east coast of Baffin Island.

The atmosphere plays an important role in the exchange of heat with water bodies below it. It is this exchange that is responsible for the atmospheric flows, the winds, and essentially for the weather over the short term. The main air flows that constitute the jet stream flowing across the North Atlantic from west to east are generally south of Baffin Bay and Davis Strait. Nevertheless, weather and hence sea ice and icebergs are influenced by the large airflow referred to as the NAO and the AMO. The NAO is a large-scale air flow that develops from differences in atmospheric pressure in the north in Greenland and as far south as the Azores. When the pressure is low in Greenland and high in the Azores, the NAO is strongest and winds move from west to east just south of Greenland and flow back across the Atlantic at locations near to the Equator. The winds are typically stronger when the pressure differences are greatest.

In contrast, the AMO is a change in sea surface temperature that appears to be a natural phenomenon, somewhat like the El Nino. The changes in sea surface temperature occur approximately every five to eight decades. These changes are strong enough to affect the weather and ice conditions in the North Atlantic.

3.5.1.1 Sea Ice

Sea ice is frozen sea water containing salt with a freezing point of -1.5 to -1.8°C. The salt content is important as it affects density which, in turn, can affect the internal ocean or bay circulation. As sea ice forms, it rejects the salt and the salinity of the local water increases, making it denser, causing this water to sink. This exchange is known to influence ocean circulation over many kilometres.

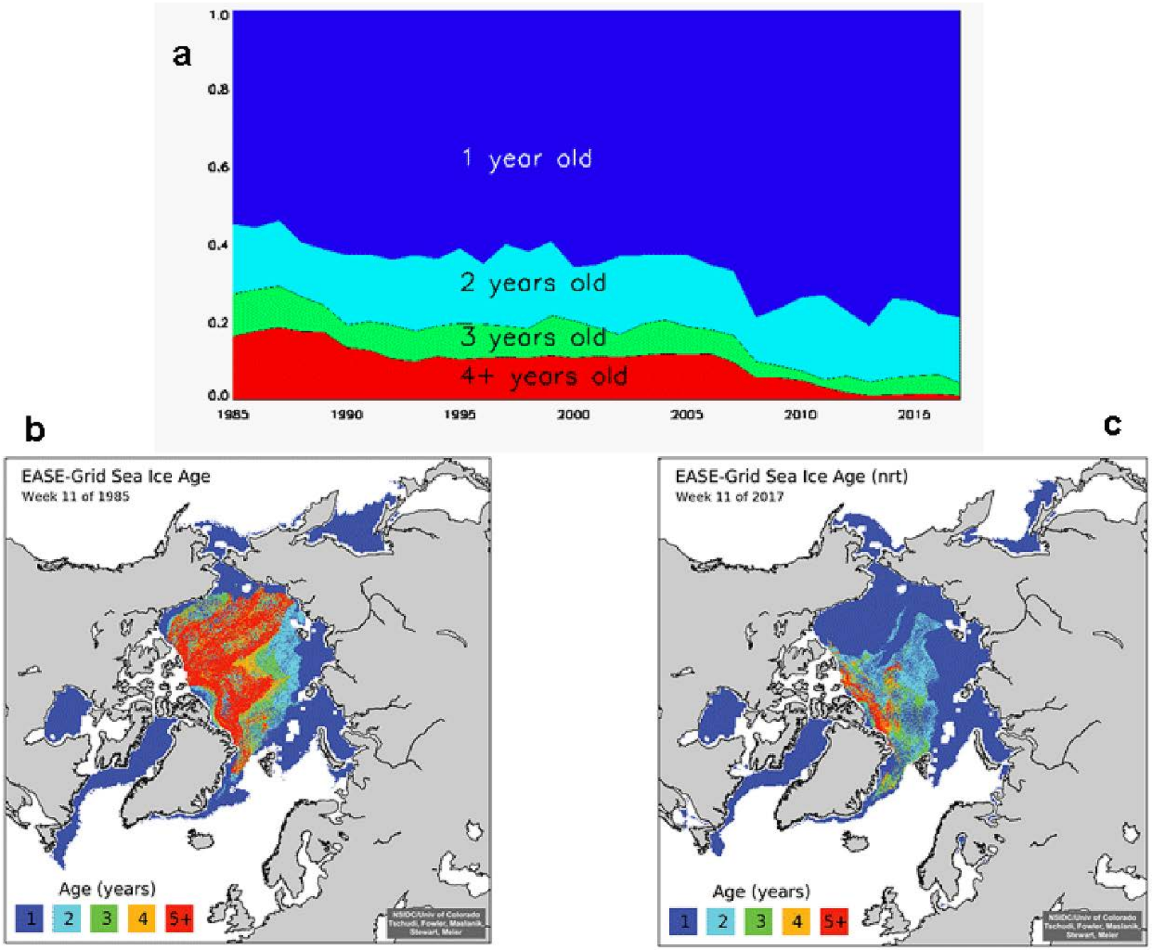
The sea ice forms, grows, and melts in lakes, bays and oceans. The winds and currents can cause the sea ice to thin out or to pack (pack ice), and bunch up, forming large hard ridges referred to as hummock ice (Tang et al. 2004b). Sea ice may form near the coast line and then be driven up on coast to become attached to the coastal land mass. This ice is referred to as land fast ice. The ice along the coast can act to absorb the energy and impact of waves and storms, thereby protecting the coast and slowing the otherwise relentless action of coastal erosion. Ice also acts to provide access to hunting and fishing (Lemmen et al. 2016).

Ice is classified by age—from one year to more than five years of age. The older ice is considerably thicker, stronger and more resilient to atmospheric changes than first year ice. The very old ice (more than four years old) makes up a smaller fraction of the ice in the Arctic in 2017 than in 1985 (see SOURCE: (Richter-Menge et al. 2017)

Figure 3.12) (NSIDC 2018).

The age of sea ice in Baffin Bay and Davis Strait is predominantly first year ice. This suggests that a substantive ice melt occurs each year over the Bay. In some years, multi-year ice is observed, mainly due to differences in ocean temperature from year to year.

The area of a water body taken up by sea ice is referred to as sea ice extent (or sea ice area) and is commonly reported in units of square kilometres (km^2). The threshold for satellite observation of an area (such as a cell – a square with sides of 25 km) to contain ice is 15% of the area, meaning that if it is greater than 15%, the water body is said to be “ice covered”, and less than that is ice free (NSIDC 2018). Ice thickness is the thickness of the ice, both above and below the water line. The thickness below the water line is the ice draft. In many cases, the measurements of the ice draft are assumed to be the ice thickness. In Baffin Bay the thickness has been assessed as the thickness of the ice draft plus about 15% (Peterson and Pettipas 2013).



SOURCE: (Richter-Menge et al. 2017)

Figure 3.12 Sea Ice Age and Coverage by Year

In a typical year, Baffin Bay is essentially ice free in September (Tang et al. 2004b; Valeur et al. 1996). As part of the annual ice cycle, the ice starts to form in September in the northwest and increases over time toward the south along Baffin Island. Ice that forms along Baffin Island coast is called West Ice and is mainly first year ice (Karlsen et al. 2001). Over time, the sea ice spreads eastward to cover a large area of Baffin Bay. The offshore sea ice tends to remain mobile throughout the winter as the ice floes are often in a state of freeze up, then break up, due to weather and storms. Icebergs are often caught up in the sea ice. The Bay is often covered by early January and the sea ice tends to be at maximum in March. The area of Davis Strait in the south may or may not be covered depending on the year. There seems to be more and thicker ice in the western part of Baffin Bay than in the east near Greenland. This has been attributed to the warmer inflow from the West Greenland Current (Hamilton and Wu 2013). Inuit from Arctic Bay have stated that: “floe-edge is a highly unstable environment and break-up is the most dangerous time to be on the ice,” (Ford et al. 2006).

Ice begins to thin and melt in April. Melting increases rapidly in June, and continues through to August, when ice free conditions begin to dominate the area (Lemmen et al. 2016). Ice growth and ice melt are local processes, and the rates of ice growth during freeze up and rates of melting are likely to be different depending on location. This is because ocean currents, winds, air temperatures, and sea temperatures all influence the amount of ice present at a specific location. Trends have been reported in sea ice retreat and sea ice advance in the Baffin Bay and Davis Strait region. The trends were three days per decade earlier for the first day of melt, and three days per decade later for first day of continuous freeze. The trend in the length of the melt season was observed to be 6 days per decade (Peterson and Pettipas 2013).

Sea ice thickness data for Baffin Bay and Davis Strait are sparse. Values in Davis Strait have been reported as 1.05 m in 1967, and 1.0 to 2.1 m in 2007 in the central part of the Strait. It was stated that ice thickness is about 13% higher than ice draft (the thickness below the waterline). It was also noted that there is evidence that low ice thickness of low ice draft is associated with high air temperature in Baffin Bay and for landfast ice in many northern locations (Peterson and Pettipas 2013).

The ice thins at different rates depending on location. For example, the northern part of Baffin Bay has an area than seems to thin and experience open water conditions sooner than most other parts. This area is referred to as the North Water, also known as the North Water polynya (Section 3.4.4.1). A polynya is an area in a water body that becomes ice free for various reasons such as air temperature, winds, upwelling and/or water currents in the region, when the area all around it remains ice bound. These areas are special because they tend to be locations where wildlife, and marine biological activities proliferate.

Sea ice extent in the Arctic has been monitored by satellite since 1979. In June, a large area in the northwest becomes ice free, and this melting extends down the Bay over June and July and is typically at a sea ice minimum in August. The monthly values for Arctic sea ice extent are shown in Figure 3.13 (NSIDC 2018). The sea ice extent reaches a maximum in March and a minimum in late September. The changes from the 1981–2010 median are also evident; specifically, the winter maximum values are not too different from the 1981–2010 median, whereas the summer minimum values are considerably lower. The lowest summer minimum value occurred in 2012.

The sea ice extent is reaching a lower value earlier in the year, meaning that the time where the Bay becomes ice free is happening sooner in the season than it did in the past. In addition, the minimum extent of sea ice has decreased substantively from the 1981–2010 median.

The average monthly sea ice in 2017 is shown in Figure 3.14 for March (when it is typically at its maximum) and for September (when it has been at its minimum). The median ice edges for those months for 1981-2010 are also shown. Highlights from the Arctic Report Card 2017 (Richter-Menge et al. 2017) for the Arctic are:

- Lowest winter maximum ice extent on record (since 1979) was observed March 7, 2017, and it was about 8% below the 1981–2010 average
- September 2017 Arctic sea ice minimum extent was 25% lower than the 1981–2010 average

- There has been a decrease in end of winter snow depth on the sea ice in the western Arctic over the past 10 years

As shown in Figure 3.14, the 2017 observations in Baffin Bay are not too different from 1981–2010, and the differences are relatively small, especially when compared to the changes in the Arctic.

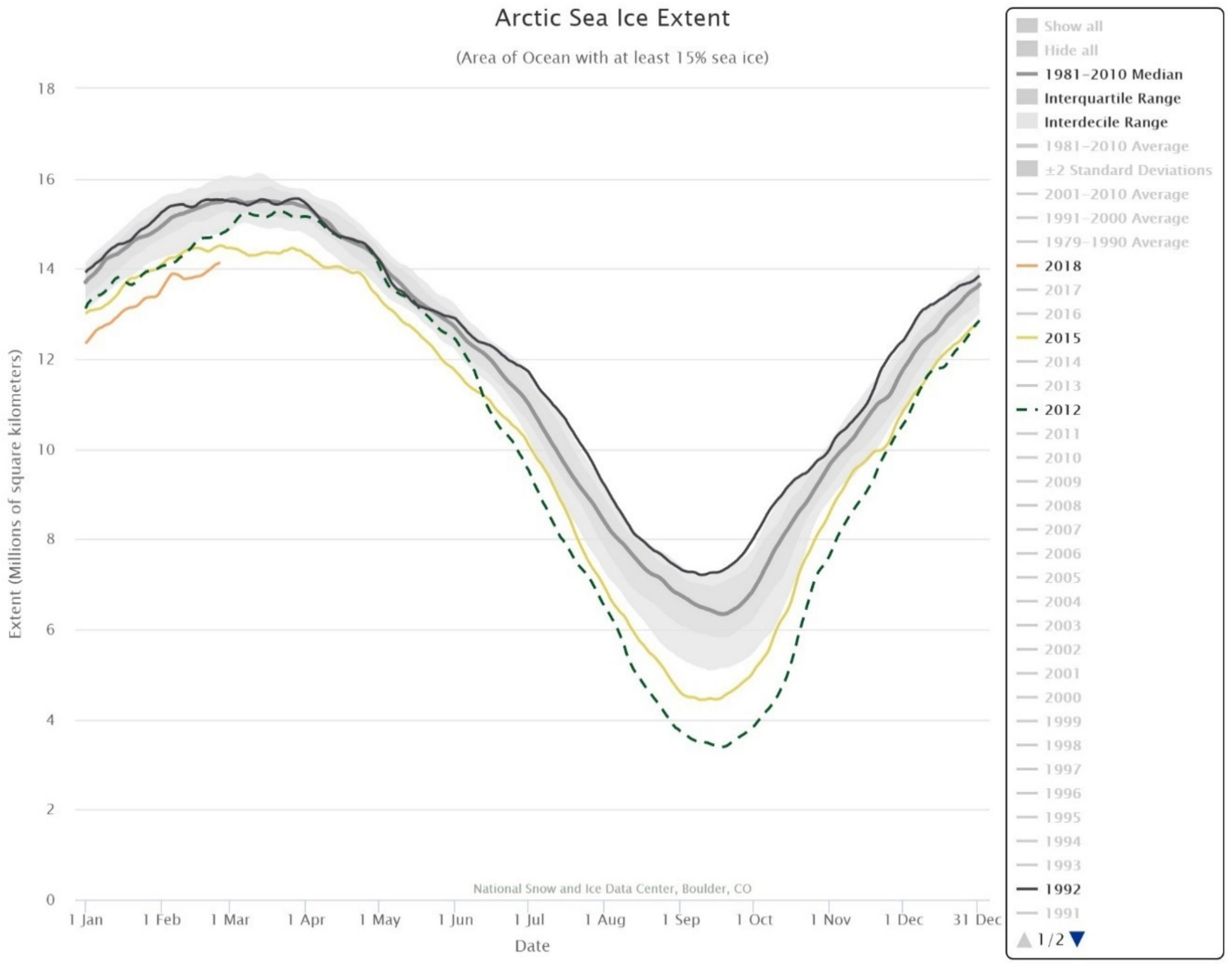
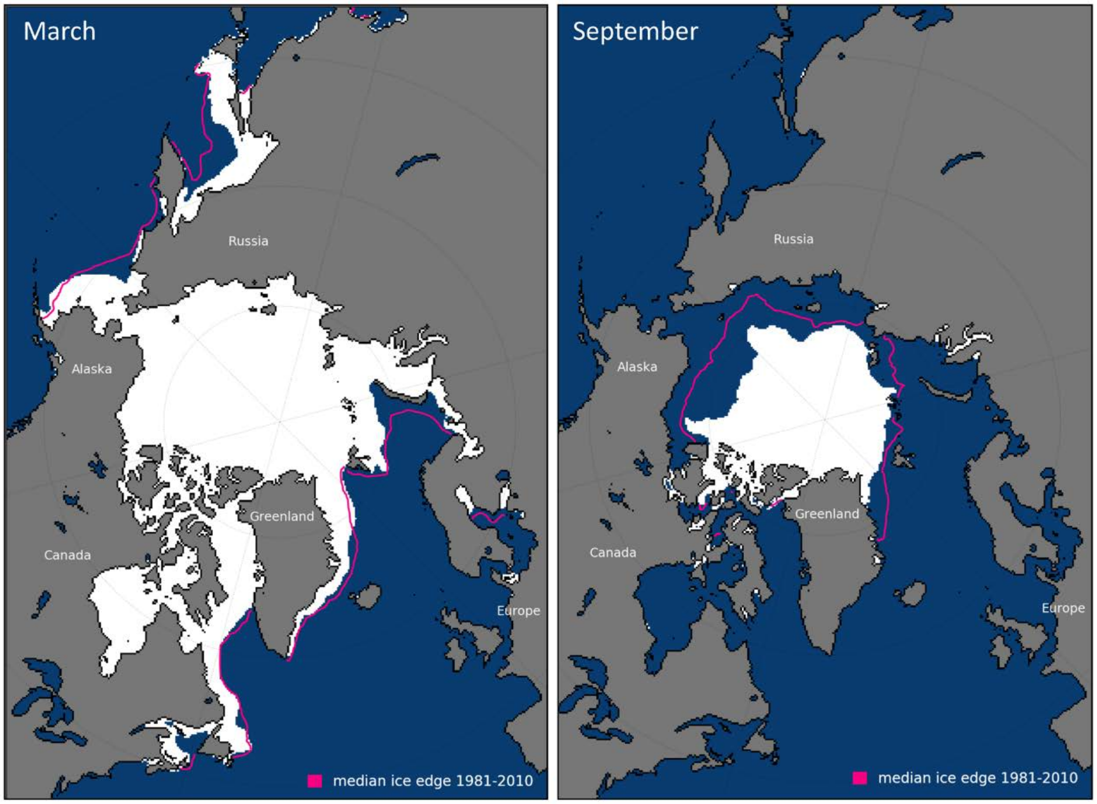


Figure 3.13 Arctic Sea Ice Extent

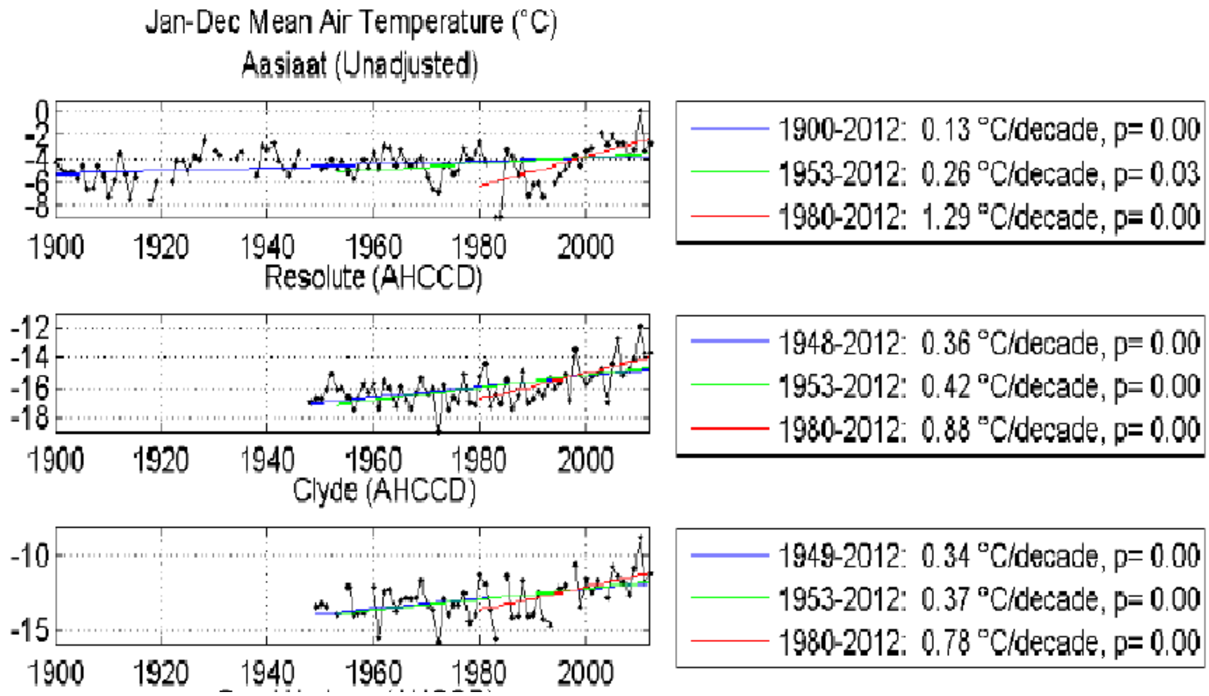


NOTE: on left March 2017, on right September 2017 (Richter-Menge et al. 2017), maps are courtesy of the National Snow and Ice Data Center, University of Colorado)

Figure 3.14 Arctic Sea Ice Extent

Observations over the longer term on surface air temperature at Clyde River and sea ice extent in Baffin Bay and Davis Strait are shown in SOURCE: Peterson et al. 2013
Figure 3.15 and SOURCE: Peterson et al. 2013
Figure 3.16. Surface air temperature and sea ice extent are highly correlated.

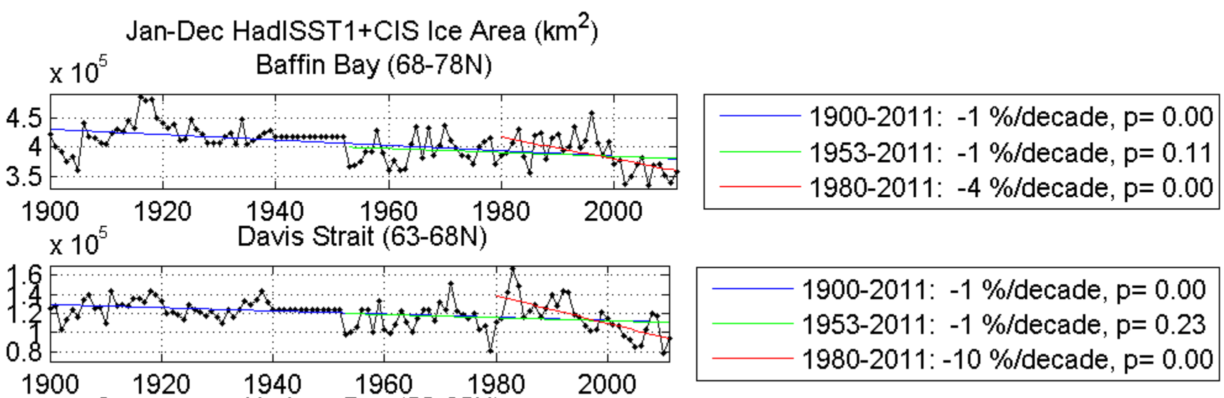
At Clyde River on the west side of Baffin Bay, the largest change in surface air temperature is observed in the more recent record during 1980–2012, where the trend is 0.78°C per decade. The warming seems to be occurring faster in recent times.



SOURCE: Peterson et al. 2013

Figure 3.15 Surface Air Temperatures—Annual Mean

Data on sea ice area are taken from HadISST1 data from the United Kingdom and the CIS data from Canadian Ice Service Digital Archive (Peterson et al. 2013). Prior to 1953, there is some uncertainty noted in the data.



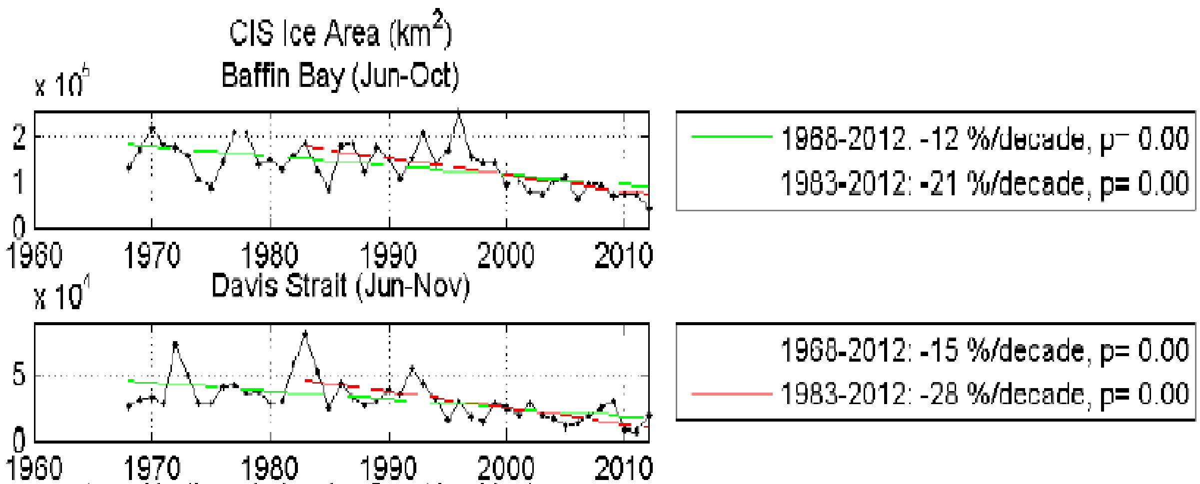
SOURCE: Peterson et al. 2013

Figure 3.16 Ice Area (x 10^5 km^2)—Annual Mean

In Baffin Bay, in winter the trend in the area of sea ice from 1953–2011 is -1% per decade, and more recently is -4% per decade. In Davis Strait, the more recent trend from 1980 to 2011 is -10% per decade. In summer, decreases in ice area are more significant, ranging from -7% per decade in Baffin Bay to -10% per decade in Davis Strait (Peterson and Pettipas 2013).

The summer sea ice values were recently updated as shown in SOURCE: (Peterson and Pettipas 2013)

Figure 3.17, and these latest values show a much stronger decline in the area of sea ice that are -21% per decade in Baffin Bay and -28% per decade in Davis Strait (Peterson and Pettipas 2013).



SOURCE: (Peterson and Pettipas 2013)

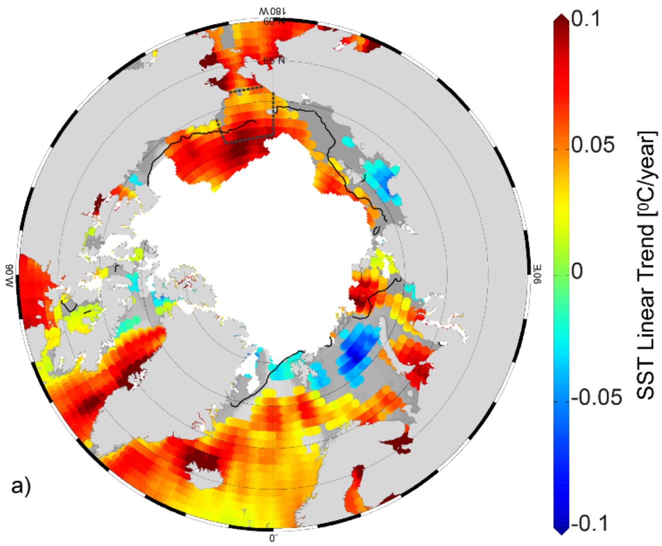
Figure 3.17 Ice Area (x 10^5 km^2)—June to October

3.5.1.2 Surface Sea Temperature

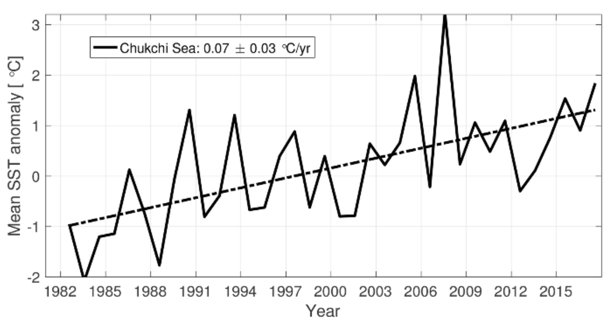
The surface sea temperature (SST) in Baffin Bay and Davis Strait is a function of the exposure to sunlight, the warm and cold water inflows and discharges, the salt content, winds, and the surface albedo.

The SSTs as measured in August provide the best representation of Arctic Ocean summer SSTs—as these are not affected so much by the cooling and subsequent ice growth in late September. The trend in linear SST and the anomalies relative to 1982–2010 are shown in SOURCE: (Richter-Menge et al. 2017)

Figure 3.18a and b respectively (Richter-Menge et al. 2017).



a)



b)

SOURCE: (Richter-Menge et al. 2017)

Figure 3.18a Linear Sea Surface Temperature in Units °C/yr for August of Each Year

Figure 3-18b Average Anomalies (°C) for August Each Year Relative to 1982–2010 mean

As shown in SOURCE: (Richter-Menge et al. 2017)

Figure 3.18a, there is considerable variability in SST over the region and from one period to another. The region off the west coast of Greenland was cooler than August 2016 (by up to 3°C).

The trends in Baffin Bay are not uniform. The trend in the NW Baffin Bay is 0 to -0.5°C, while in the central part of the Bay, the trend is approximately +0.8°C per decade. The SST trends on the west side of Greenland are higher, about 1°C per decade.

3.5.1.3 Icebergs

In contrast to sea ice, icebergs are made of a lighter, stronger ice, that is formed from glaciers, and ice shelves that typically originate on land.

Icebergs are defined as a piece or block of ice that reaches a minimum of 5 m above sea level, is longer than 15 m, and comes from breaking off a glacier (Karlsen et al. 2001). Icebergs are categorized according to approximate size and mass as shown in Table 3.6.

Table 3.6 Iceberg Categories

	Height (m)	Length (m)	Mass (tonnes)
Growlers	< 1	< 5	500
Bergy Bits	1–5	5–15	1,400
Small iceberg	5–15	15–60	100,000
Medium iceberg	16–45	61–120	750,000
Large iceberg	46–75	120–200	5,000,000
Very large iceberg	> 75	> 200	> 5,000,000
SOURCE: (Karlsen et al. 2001)			

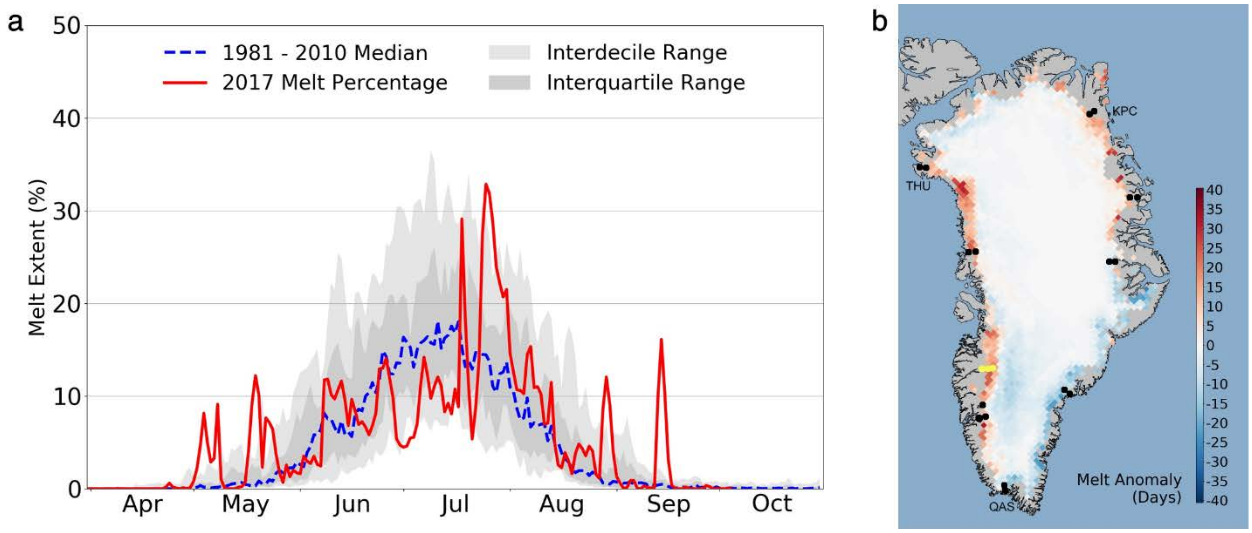
Glaciers are formed from repeated accumulation of snow over many years in the same location that remains there year-round. In time, where enough snow accumulates, it re-crystallizes and transforms into ice. The change from snow to glacial ice may take as long as a hundred years (NSIDC 2018).

There are some glaciers and hence some glacial ice in the Canadian Arctic Archipelago (the northern islands in the Arctic) including Baffin Island. As a result, there are some icebergs produced from the Canadian side of Baffin Bay and Davis Strait. However, considerably more originate from Greenland.

The Greenland Ice Sheet is a large glacial ice mass situated on the large Greenland land mass with an area about 50,000 km^2 (NSIDC 2018). As temperatures warm throughout the year, ice melts and produces freshwater, which may run off the ice sheet to the ocean or freeze when conditions change back. Observations suggest there is a balance between the glacial ice loss due to melt on the ice sheet and the accretion of snow and ice from precipitation. Depending on the year, the melt may be than the buildup.

Data from the National Snow and Ice Data Centre on the melt extent of the ice sheet in 2017 relative to 1981–2010 median are shown in SOURCE: (Richter-Menge et al. 2017), in Conjunction with NSIDC
Figure 3.19a (Richter-Menge et al. 2017). The anomalies of the number of melting days in 2017 relative to 1981–2010 means are shown in SOURCE: (Richter-Menge et al. 2017), in Conjunction with NSIDC

Figure 3.19b. As shown, the melt extent was less than the median in June and early July, but more than the median late July. As stated by the NSIDC, the surface melt in 2017 "…was consistent with the state of the North Atlantic Oscillation and the Arctic Oscillation, both of which were strongly positive". In this positive state, weather conditions are likely to be more cloudy, with less solar radiation and more precipitation, and slower melting overall.

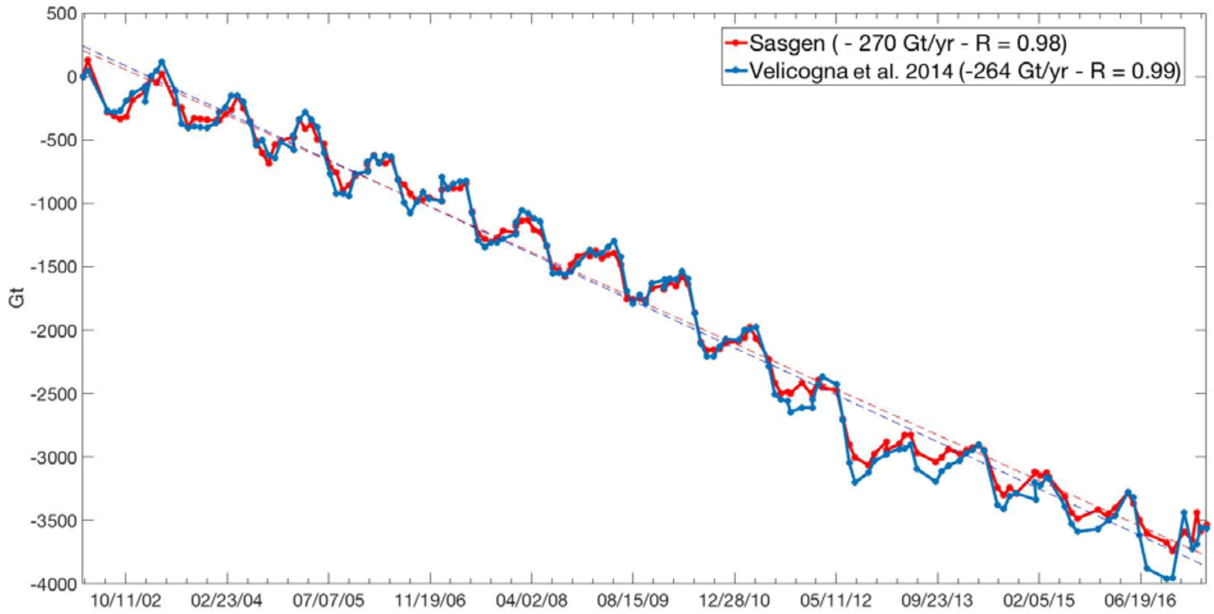


SOURCE: (Richter-Menge et al. 2017), in Conjunction with NSIDC

Figure 3.19 Spatial Extent of Ice Melt—as a Percent of the Ice Sheet

The changes in the mass (in Gigatonnes) of the Greenland ice sheet are thought to be related to production of icebergs in Baffin Bay and Davis Strait. Changes (in Gigatonnes) are shown in SOURCE: (Richter-Menge et al. 2017)

Figure 3.20. Estimates of glacial ice loss (net) are -264 to -270 Gt per year. Satellite observations of albedo for the Greenland Ice Sheet for the summer of 2017 indicate a period where albedo was the third highest in the 2000-2017 record. This higher albedo is consistent with some reduced melting in 2017 (Richter-Menge et al. 2017). Even with this reduced melting, the trend remains as strongly negative, meaning the loss of ice from Greenland continues.



SOURCE: (Richter-Menge et al. 2017)

Figure 3.20 Change in Total Mass of Greenland Ice Sheet (Gigatonnes)

Observations on Greenland ice area since 1999 suggest that there is a pattern of relative stability since 2013. The annual net area change in 2017 was below the 18-year average indicating that ice loss from Greenland was less than the average for that year.

As the glacial ice breaks off (or calves) from the ice sheet near the coast, solid ice masses fall to the water and become icebergs as they are released to the ocean. This process provides the main source of marine glacial contributions to Baffin Bay (Tang et al. 2004b).

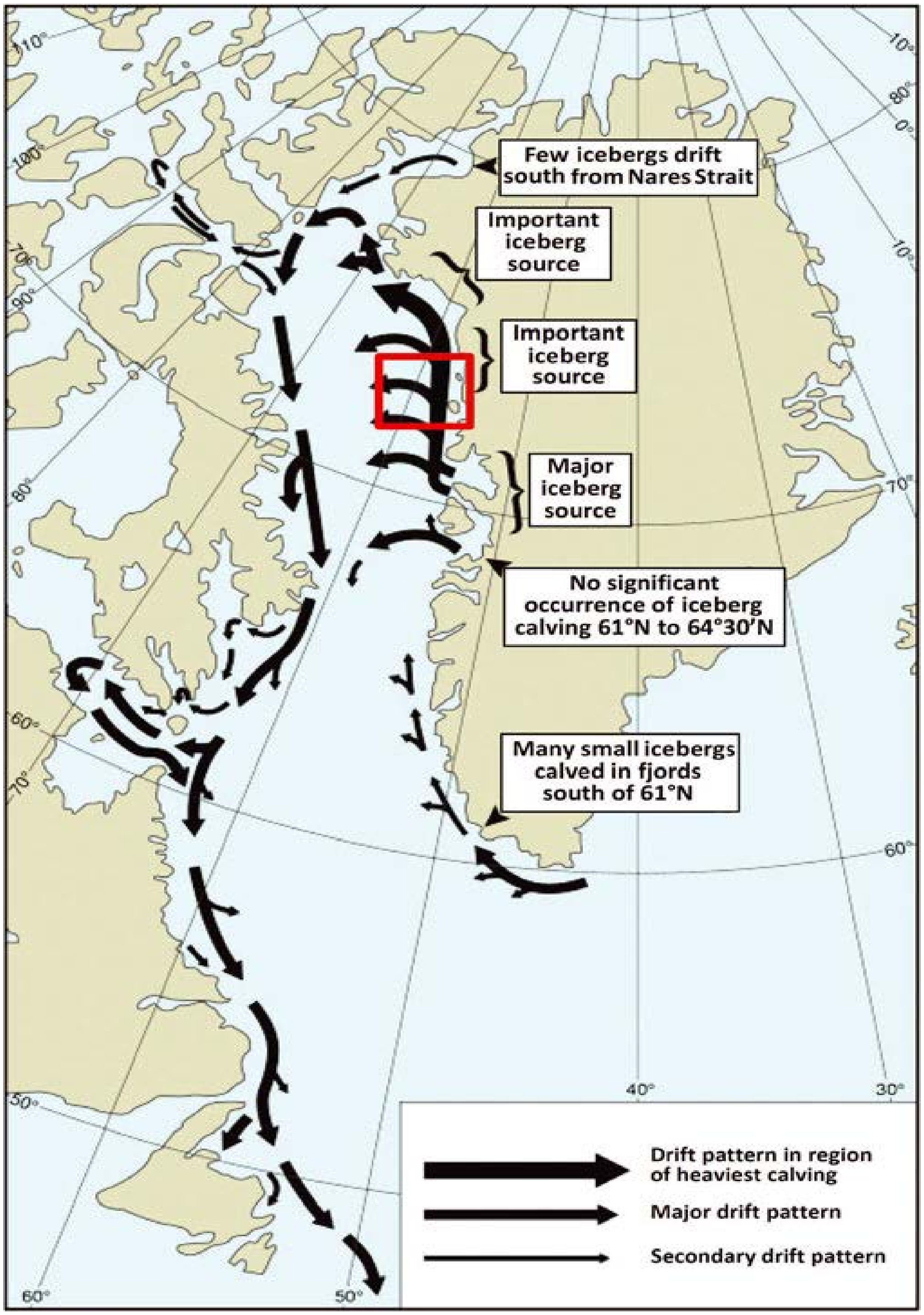
The main sources of icebergs and subsequent drift patterns in Baffin Bay and Davis Strait are shown in SOURCE: Larsen et al. (2015) and Valeur et al. (1996)

Figure 3.21 (Larsen et al. 2015; Valeur et al. 1996). The productive areas are near Disko Island on the west side of Greenland. These include Disko Bay just south of Disko Island, and in Umanak Bay, north of Disko Island (Tang et al. 2004b). Most icebergs in Baffin Bay are generated from Greenland glaciers north of Disko Bay up to Kap York (shown as major iceberg source on SOURCE: Larsen et al. (2015) and Valeur et al. (1996)

Figure 3.21), and two areas to the north (important sources on SOURCE: Larsen et al. (2015) and Valeur et al. (1996)

Figure 3.21). Icebergs from these locations may be up to 1 km in length.

The total number of icebergs calved from Greenland glacial ice in these areas and released to Baffin Bay and Davis Strait is estimated to be 25,000 to 30,000 per year. The larger icebergs (greater than one million tonnes) tend to drift north and the smaller ones tend to drift south.



SOURCE: Larsen et al. (2015) and Valeur et al. (1996)

Figure 3.21 Iceberg Drift Patterns in Baffin Bay and Davis Strait

Icebergs from Disko Bay move south and exit Baffin Bay via Davis Strait. Icebergs from Umanak Bay and the northern areas on the west coast of Greenland tend to travel northward with the West Greenland Current. They then tend to move in a westerly direction across the northern part of Baffin Bay and join the Baffin Island Current which takes them to the south. At some point, those icebergs also exit Baffin Bay via Davis Strait. In some cases, the icebergs may follow the branch of currents and head west across the Bay without going so far north.

The icebergs are typically melting as they travel southward into the Labrador Current and then into the North Atlantic. The rate of melt depends on the sea surface temperature, solar radiation, winds, and whether the icebergs are caught up with sea ice.

Iceberg movements can travel in a drift fashion as fast 10–30 km/day. They also may get hung up on land fast ice near the shore. Others have noted that icebergs move erratically with little mean drift, with drift speeds rarely exceeding 0.2 m/s (Tang et al. 2004b).

The distribution of icebergs in Baffin Bay is not uniform. The sources of the icebergs and the ocean currents result in a much greater concentration of icebergs at locations within 50 km of the Greenland coast (Valeur et al. 1996). From 50 km to 150 km offshore, the iceberg distribution is more dispersed, and beyond 150 km (in the central part of the Bay), icebergs are rarely observed.

Many icebergs drifting north in the West Greenland Current melt before leaving Baffin Bay. Those large enough to resist total melt end up leaving Baffin Bay via Davis Strait, and travel toward Labrador and Newfoundland.

Several studies have been done by the private companies to assess risk associated with icebergs on oil and gas activities in Baffin Bay and Davis Strait, although few of these are freely available to the public (Ralph and King 2018, pers. comm., February and March 2018).

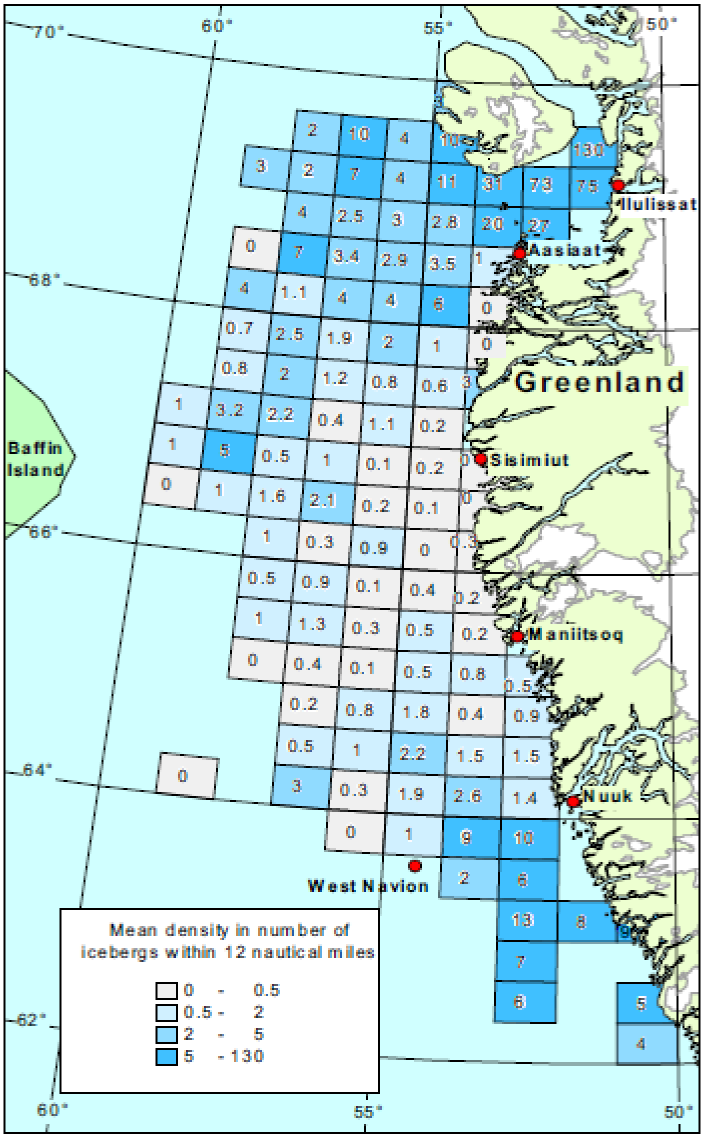
Iceberg distribution and variability was studied in Fyllas Banke near Nuuk, off the coast of southwest Greenland in the Eastern Davis Strait (Karlsen et al. 2001). Highlights from this study include:

- Icebergs observed in this region in early July to mid-September in the year 2000 are reasonably representative of a normal season
- Maximum distribution of multi-year ice occurs in this region in June, and icebergs tend to show up two months later, in July and August
- It might be beneficial to use April to June as the best exploration period in this region
- Knowledge gaps do exist, and iceberg variability and distribution studies are recommended
- For future operations offshore, it is recommended that the area be monitored continuously via satellite images, before any drilling or exploration is planned to start

In an earlier study, the mean density of icebergs within 12 nautical mile blocks in an area around Disko Bay and to the south, is shown in SOURCE: (Karlsen et al. 2001)

Figure 3.22. It is noted that the density is greater near Disko Island. The average sometimes masks the actual. In some circumstances, several icebergs were observed in the 12-nautical mile block, and these seemed to appear in a relatively fast manner. In other passes by the survey ship, no icebergs were observed.

A recent iceberg tracking study by Larsen et al. (2015) was conducted to follow 10 icebergs in the eastern part of Baffin Bay. The icebergs ranged in lengths, masses and drafts of 95 to 450 m, 330 000 to 17 million tonnes, and 70 to 260 m, and were equipped with GPS transponders. The drift patterns varied from iceberg to iceberg. Mean and maximum drift speeds were measured to be 0.4 and 2.4 km/hour, respectively. Icebergs with large surface areas moved faster, especially during periods with strong winds (Larsen et al. 2015).

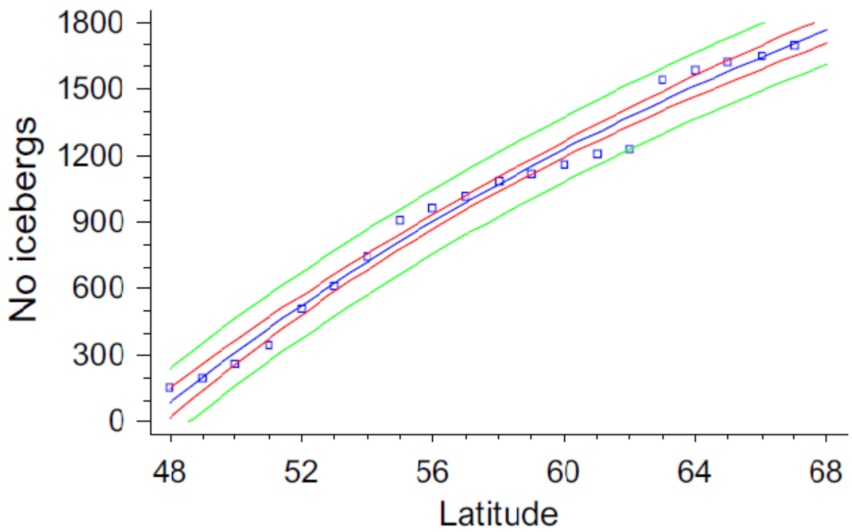


SOURCE: (Karlsen et al. 2001)

Figure 3.22 Iceberg Distribution—South West Greenland—North of 62°N—May–October 1978

In one analysis, it was found that the number of icebergs in Davis Strait could be predicted from the number of icebergs observed off Newfoundland. The data and a regression plot are shown in SOURCE: (Karlsen et al. 2001)

Figure 3.23. The ability to predict iceberg presence, distribution, and trajectory will be useful in ice management, and in reducing the risk to ocean-going vessels, as well as oil and gas exploration and production activities, in Baffin Bay and Davis Strait.



SOURCE: (Karlsen et al. 2001)

Figure 3.23 Number of Icebergs versus Latitude, from Cape Dyer 67°N to Newfoundland 48°N

3.6 Acoustic Environment

3.6.1 Underwater Noise

Information on sources and sound pressure levels (SPLs) of ambient noise provide baseline conditions against which to evaluate acoustic impacts of introduced sound signals (e.g., vessel noise, seismic explorations) as a signal-to-noise ratio. Natural (i.e., environmental and biological) sources of ambient noise in the Arctic marine environment include wind and waves (in the 100–1,000 hertz [Hz] and 1,000–10,000 Hz bands), precipitation (in the 10,000–32,000 Hz band), thermal agitation, sea ice, and marine mammals (baleen whale sounds: 100–1000 Hz band; pilot whale and narwhal whistles: 1,000–10,000 Hz band; echolocation clicks: 10,000–32,000 Hz band) (Martin et al. 2017; Richardson et al. 1995a).

Natural ambient underwater noise levels in the Arctic region are highly variable with regard to season, environmental conditions (e.g., changing wind speeds, rate of precipitation), and in relation to mechanical and thermal stresses within the ice cover (Leggat et al. 1981; Martin et al. 2017; Richardson et al. 1995a; Thiele et al. 1990). At a given location, sound transmission conditions vary with changing temperature and salinity profiles (Richardson et al. 1995a). During the winter, in areas of heavy ice cover and areas with continuous land-fast ice cover (i.e., ice frozen to the shore and/or the bottom), the dominant source of ambient noise is ice cracking induced by thermal stresses as a result of temperature changes (Richardson et al. 1995a; Stafford et al. 2017; Thiele et al. 1990). Thermally-induced ice cracking produces broadband noise in the mid- to high-frequency range (i.e., 500–5,000 Hz) (Stafford et al. 2017). Mechanically-induced ice deformation from winds and currents (e.g., in offshore areas where ice cover is kept in constant motion) generates ice cracking, fracturing, shearing, grinding, and ridging, which produce broadband pulses and tones, particularly at low frequencies (i.e., less than 100 Hz) (Richardson et al. 1995a; Stafford et al. 2017; Thiele et al. 1990). During calm winter conditions (i.e., calm winds and sea states); however, under-ice ambient noise levels in Baffin Bay can be quieter than ambient noise levels in summer (Leggat et al. 1981; Thiele et al. 1990).

During summer in Baffin Bay, the dominant source of ambient noise is also associated with ice (Leggat et al. 1981), from ice melt, iceberg collisions, ice floes, break up, and turnover of ice formations (Thiele et al. 1990). During ice melt, the release of air bubbles under pressure (i.e., exploding or imploding air cavities) can dominate the ambient soundscape (Richardson et al. 1995a; Thiele et al. 1990). In the marginal ice zone at the edge of large ice sheets, the impact of waves against the ice edge, and the break up and rafting of ice floes can generate ambient noise levels 4–12 dB higher than in open water and 10–20 dB higher than under continuous ice cover (Thiele et al. 1990). During the open water period, wind generates low frequency ambient underwater noise through the development and breaking of waves on the sea surface (Richardson et al. 1995a; Stafford et al. 2017; Thiele et al. 1990), with a direct correlation between wind speed and noise levels between 200 Hz and 30,000 Hz (Stafford et al. 2017). Noise from rain and hail can become an important component of total ambient noise at frequencies above 250–500 Hz, including the 10,000–32,000 Hz band (Leggat et al. 1981; Martin et al. 2017; Richardson et al. 1995a).

Marine mammals also contribute to the underwater ambient noise environment of the Arctic. Bowhead whales (*Balaena mysticetus*), for example, produce broadband songs (approximately 30–5,000 kHz) between November and late April/early May, as well as low frequency (less than 500 Hz) sounds that can be detected up to 30 km away (Stafford et al. 2017). Beluga whales (*Delphinapterus leucas*) produce echolocation calls (20,000–160,000 Hz) to navigate, and locate and capture prey, as well as lower frequency social calls (400–20,000 Hz) that can be detected over distances of 1–3 km (Stafford et al. 2017). Bearded seals (*Erignathus barbatus*) are highly vocal and primarily during spring produce loud underwater trills (130–4,800 Hz) that propagate 5 to 10 km, with some trills propagating greater than 20 km (MacIntyre et al. 2013). See Section 4.7 for a complete review of marine mammals within the SEA Area of Focus.

In a recent environmental impact statement for north Baffin Island (Knight Piésold Consulting 2012), ambient noise levels for the open water (i.e., mid-October to mid-July) and heavy ice cover (i.e., mid-August to mid-October) periods were obtained from an acoustic monitoring study conducted in the Alaskan Beaufort Sea (Burgess and Greene 1999) to describe potential project effects on the marine environment, including effects of a proposed shipping route to Milne Inlet through Davis Strait and Baffin Bay. Using seafloor recorders and sonobuoys to record ambient noise, Burgess and Greene (1999) reported median SPLs of 93–97 dB re 1 µPa in the 50–500 Hz band, and 97–99 dB re 1 µPa in the 20–1,000 Hz band. These results are consistent with measurements obtained for the 20–1,000 Hz band in 1996 and 1997 (Burgess and Greene 1999).

More recently, Martin et al. (2017) characterized the ambient soundscape in Baffin Bay and Melville Bay, West Greenland during a multi-year acoustic monitoring program. Results of the year-round monitoring provide representative ambient sound level measurements for Baffin Bay: median SPL of 102 dB re 1 µPa in summer (August 31–September 30, 2013) and 100 dB re 1 µPa overwinter (September 29, 2013–September 6, 2014) measured at water depths between 100 m and 770 m (Martin et al. 2017). The ambient soundscape in Baffin Bay includes little anthropogenic noise and is typical of an open ocean environment, with highest SPLs in the 10–100 Hz and 100–1,000 Hz bands (Martin et al. 2017).

Nearshore measurements during summer 2012 in Melville Bay, on the west side of Greenland, were dominated by sounds from glacial ice melt (e.g., ice cracking, pops and hisses likely from air escape), with dominant frequencies in the 1,000–10,000 Hz band and a median SPL of 116 dB re 1 µPa, 14 dB; these were higher than the SPLs measured more than 100 km offshore in Baffin Bay during summer 2013 (Martin et al. 2017).

3.6.2 Atmospheric Noise

Noise is unwanted sound that is most often a nuisance for nearby sensitive receptors and may cause unwanted effects such as influencing selection of habitat and feeding patterns. During consultation and IQ/TK collection efforts, concerns about the potential for noise effects on the marine ecosystem focused mainly on the effects of underwater noise. However, effects may also arise from airborne noise generated from oil and gas activities. Under water effects are described in the next section. Information on airborne noise in the marine environment in the Arctic region is described below. Anthropogenic activities in Baffin Bay and Davis Strait are mainly related to shipping and marine traffic to support the small number of communities along the coasts; however, anthropogenic noise from snowmobiles, motorboats, non-industrial machinery, and rifle-fire is also present. Marine traffic volumes are relatively low in Baffin Bay compared to other Arctic regions like the Norwegian and Bering Seas, Iceland and Greenland (Magnus Eger 2011). The airborne acoustics environment in Baffin Bay and Davis Strait is therefore expected to be dominated by natural sounds from weather (winds, waves, precipitation), marine life (e.g., marine birds, polar bears, walrus), and the cracking of ice when strongly influenced by winds, ocean currents or other forces. Noise during the summer when the Bay is mostly ice free is expected to be louder than during the months when the Bay is ice covered, mainly because the presence of ice tends to diminish the sounds from natural wave motions. However, few studies have been done to confirm whether this supposition is valid.

The potential effects of airborne noise from any offshore oil and gas activities are expected to be relatively small because the distance to any sensitive receptors on or over the water (or ice) is likely to be large. Nevertheless, it is useful to understand the acoustics environment in the air above Baffin Bay and Davis Strait to confirm this expectation.

There are very few publications available on acoustics or noise in the atmosphere over Baffin Bay and Davis Strait (MacGillivray 2018, pers. comm., February 22, 2018). Some studies have been reported for other areas in the North, such as Alaska. In addition, there are many studies on underwater noise in the North (see above) and some of the observations in these reports are relevant to the airborne noise environment.

One of the most basic descriptors of sound is the SPL. The SPLs are most commonly measured and described in decibels (denoted dB). In airborne noise, the A-weighted decibels (denoted dBA) are used, as these more closely correlate with the subjective loudness of a sound, as discerned by the human ear. Typical SPLs range from about 20 dBA in an extremely quiet wilderness area to between 50 and 70 dBA in towns during the day time, 90 dBA or more in industrial settings, to well over 120 dBA near to a jet-aircraft at take-off.

In the offshore marine environment, natural sounds are generated by winds, waves, precipitation, sea ice, birds, marine mammals, sea ice cracking, and grinding. In winter, during periods when winds are low, the dominant noise is ice cracking, and shearing. Baffin Bay has a long fetch and therefore high winds blowing from the north are relatively common and tend to intensify near Davis Strait. The sounds of the winds and wind gusts would dominate during high wind events. In summer, winds and wave actions would combine to dominate the acoustic environment when winds are high.

The anthropogenic activities in the Baffin Bay and Davis Strait region are mainly small volumes of marine traffic. Therefore, the acoustics environment is likely to be dominated by natural sounds in both the winter and the summer. In the winter, the dominant sounds are likely to be ice cracking induced by changes in temperature. Strong winds would also play a large role. In the summer, the dominant source of ambient noise is also associated with ice, from ice melt, iceberg collisions, ice floes, and break up of ice formations. The winds, and waves, and to a lesser extent the precipitation would also contribute to the airborne acoustic environment over the Bay.

3.7 Geology

Understanding the geology is important to the assessment of effects for the SEA of the Baffin Bay and Davis Strait region in terms of knowing the characteristics of the seafloor and seismic stability. An understanding of slope stability on the continental shelf and slumping is also important to the assessment of potential effects from the Scenarios described in Section 2.3.3.1. The geological setting of the Area of Focus is complex, with various natural processes forming the bedrock and surficial characteristics of the region (see Figure 3.24). Baffin Bay is the northwestern extension and terminus of the North Atlantic-Labrador Sea rift system (INAC 1995). Davis Strait is a physiographic high that separates Baffin Bay from the Labrador Sea (Skaarup et al. 2006). Baffin Bay and Davis Strait are both oblong basins; Baffin Bay has sills to the north and south that restrict water flow (see Section 3.3 for more details on the bathymetry of the Area of Focus).

The Baffin Bay and Davis Strait region was subjected to tensional forces when Greenland and North American separated in response to active seafloor spreading in the Labrador Sea (MacLean et al. 1989). Seafloor spreading began earliest in the southern Labrador Sea and progressed northward into the northern Labrador Sea by the late Cretaceous and early Tertiary (MacLean et al. 1989).

The progressive northward stepping of seafloor spreading in the North Atlantic resulted in graben (a valley with a distinct escarpment on each side caused by the displacement of a block of land downward) and partial graben development in the Baffin Bay and Davis Strait region in the early Cretaceous (INAC 1995). These include Lancaster Sound, Jones Sound, Cumberland Sound, Frobisher Bay, and Hudson Strait (MacLean et al. 1989). Oceanic crust began to form in the region in the Paleocene but seafloor spreading appears to have continued until the Oligocene (INAC 1995).

Exploration of the seafloor in the Area of Focus began with hydrocarbon exploration and development in the 1970s (Blasco et al. 2010). During this period, single and multi-channel seismic, echosounder, and side-scan sonar surveys were undertaken along with borehole sampling (Blasco et al. 2010). Since then there have been other, limited, geophysical, sediment, and seismic surveys. As a result, some areas within the Area of Focus have been described in detail (e.g., Scott Seep), while information on other areas is sparse; for example, seismic exploration of the northeastern Baffin Shelf has been limited (INAC 1995).

3.7.1 Bedrock and Surficial Geology

This description of the coastal and submarine geological setting in the Area of Focus includes a discussion on seismicity and the potential for geohazard events.

Bedrock and surficial rock types present in the region are discussed according to their age. The oldest rocks in the Area of Focus are of Precambrian origin, while rocks from the Paleozoic, Mesozoic, and Cenozoic are also present.

The oldest rocks in the Area of Focus are found on the margins of Baffin Bay and Davis Strait where Precambrian igneous and metamorphic rocks form the bedrock adjacent to the coast (MacLean et al. 1989). Bedrock interpreted to be basement highs composed of Precambrian crystalline rocks also occasionally occur as outcrops on the seabed on the northern Baffin Island shelf (Bennett et al. 2013). The landmasses surrounding Baffin Bay (Baffin Island, eastern Devon Island, Ellesmere Island, and western Greenland) also consist predominantly of Precambrian igneous and metamorphic rocks in metamorphosed clastics, volcanics, granites, and migmatites (MacLean et al. 1989). Protozeroic rocks, similar to those found on Baffin Island, also likely underlie the Mesozoic sediments in Baffin Bay (INAC 1995). Lancaster Sound is bordered to the north and south by Proterozoic and Lower Paleozoic rocks exposed on Devon and Bylot Island, and on the Borden Peninsula of Baffin Island (INAC 1995).

Lower Paleozoic sedimentary rocks occur in western and northwestern Baffin Island and northern Greenland and are widely distributed in the Canadian Arctic islands (MacLean et al. 1989). On Baffin Island, the strata consist of carbonate and detrital rocks primarily of Ordovician and Silurian age, along with rocks of Cambrian age (MacLean et al. 1989).

Ordovician rocks underlie much of the southeast Baffin Island shelf between Frobisher Bay and Cumberland Sound, as confirmed by the presence of late Ordovician bedrock at five sampling locations (MacLean et al. 1989). Based on seismic reflection, magnetic, and gravity data, Ordovician strata also appear to extend north to Cape Dyer (MacLean et al. 1989). Ordovician to Silurian rocks may also be present in the offshore, but there is no existing seismic evidence to support this (INAC 1995). Middle and Upper Ordovician rocks also occur as outliers at the head of Frobisher Bay, and on the continental shelf between Frobisher Bay, Cumberland Sound, and Cape Dyer (MacLean et al. 1989).

The dominant Phanerozoic (Cambrian and younger) rocks on the shelves of Baffin Bay and Davis Strait are of Late Cretaceous and Tertiary origin, though older rocks also occur (MacLean et al. 1989). The oldest Mesozoic bedrock in the Area of Focus is found in Cumberland Sound, south of Cape Dyer (MacLean et al. 1989). Pre-Upper Cretaceous sedimentary rocks may also be present on the northeast Baffin Island Shelf between the Scott and Buchan Troughs, as seismic reflection data have indicated a structural depression containing approximately 4 km of rocks, with velocities in ranges commonly associated with sedimentary rocks (MacLean et al. 1989).

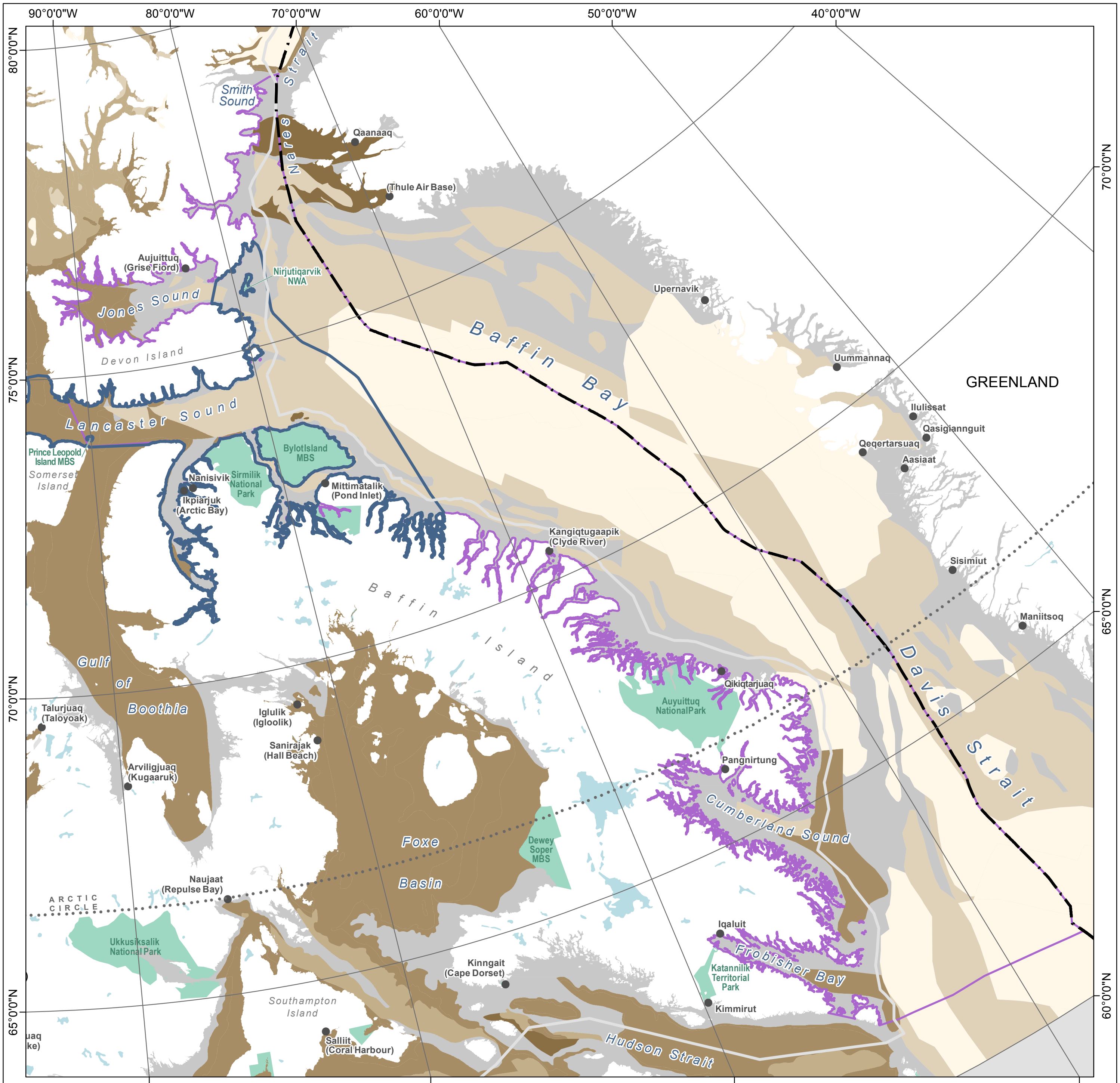
The opening of Baffin Bay and Davis Strait, which occurred during the Paleocene and continued until the early Oligocene (INAC 1995; MacLean et al. 1989), was associated with the outpouring of basalt both onshore and offshore in the Davis Strait region (MacLean et al. 1989).

Sedimentation in Baffin Bay has been characterized by the influx of coarse elastic materials across the rifted and rapidly foundering margin of Baffin Island (INAC 1995). Sediments in Baffin Bay were derived from the surrounding highlands of the Baffin Island coast, and clastics originating from the Lower Paleozoic hinterlands of the Canadian Arctic islands via major rift-controlled drainage systems (INAC 1995).

On the northern Baffin Island shelf there are eight major transverse troughs that lie offshore of fiords or large inlets (Bennett et al. 2013; Praeg et al. 2007). The troughs are characterized by steep sides and have been over-deepened by glacial erosion (Bennett et al. 2013; Praeg et al. 2007). Quaternary sediment accumulations are generally thinner on the walls of the trough (less than 25 m) and thicker (up to 180 m) in bedrock depressions on the trough floor. The inter-trough areas of the northern Baffin Island shelf are marked by longitudinal ridges and depressions developed within the Quaternary succession (Bennett et al. 2013). The fill of the Baffin Basin consists of Mesozoic, Tertiary, and Quaternary sediments (INAC 1995).

In the Area of Focus, sedimentary strata are thickest along the narrow eastern Baffin Island shelf and the broader West Greenland shelf (INAC 1995). Baffin Fan is a 12 km thick sedimentary wedge of Eocene to Pleistocene age in northwestern Baffin Bay that has been determined to have resource potential similar to that of the Beaufort-Mackenzie Basin (Harrison et al. 2011).

Marine sediments in the Area of Focus are described in greater detail in Section 3.9.



Base Features

- Community[1]
- Limit of Exclusive Economic Zone[4]
- Nunavut Settlement Area[3]
- Tallurutiup Imanga / Lancaster Sound NMCA[2]
- Protected Area or National Park[4]

Project Features

- Area of Focus[2]

Geological Era[5]

- Cenzoic
- Mesozoic and Cenzoic
- Mesozoic
- Paleozoic
- Precambrian
- Unclassified

1:10,000,000

0 50 100 200 300

Kilometres

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Figure 3.24 Generalized Geology

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N.I.R.B.

References:
[1]Atlas of Canada Base Maps, 2017
[2]NIRB, 2017
[3]Nunavut Planning Commission, 2010
[4]National Framework Canada, 2017
[5]Geological Survey of Canada, 2007

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Date: Apr 13, 2018
Project Number: 12322100
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Revision: 01

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3.7.2 Seismicity and Geohazard Events

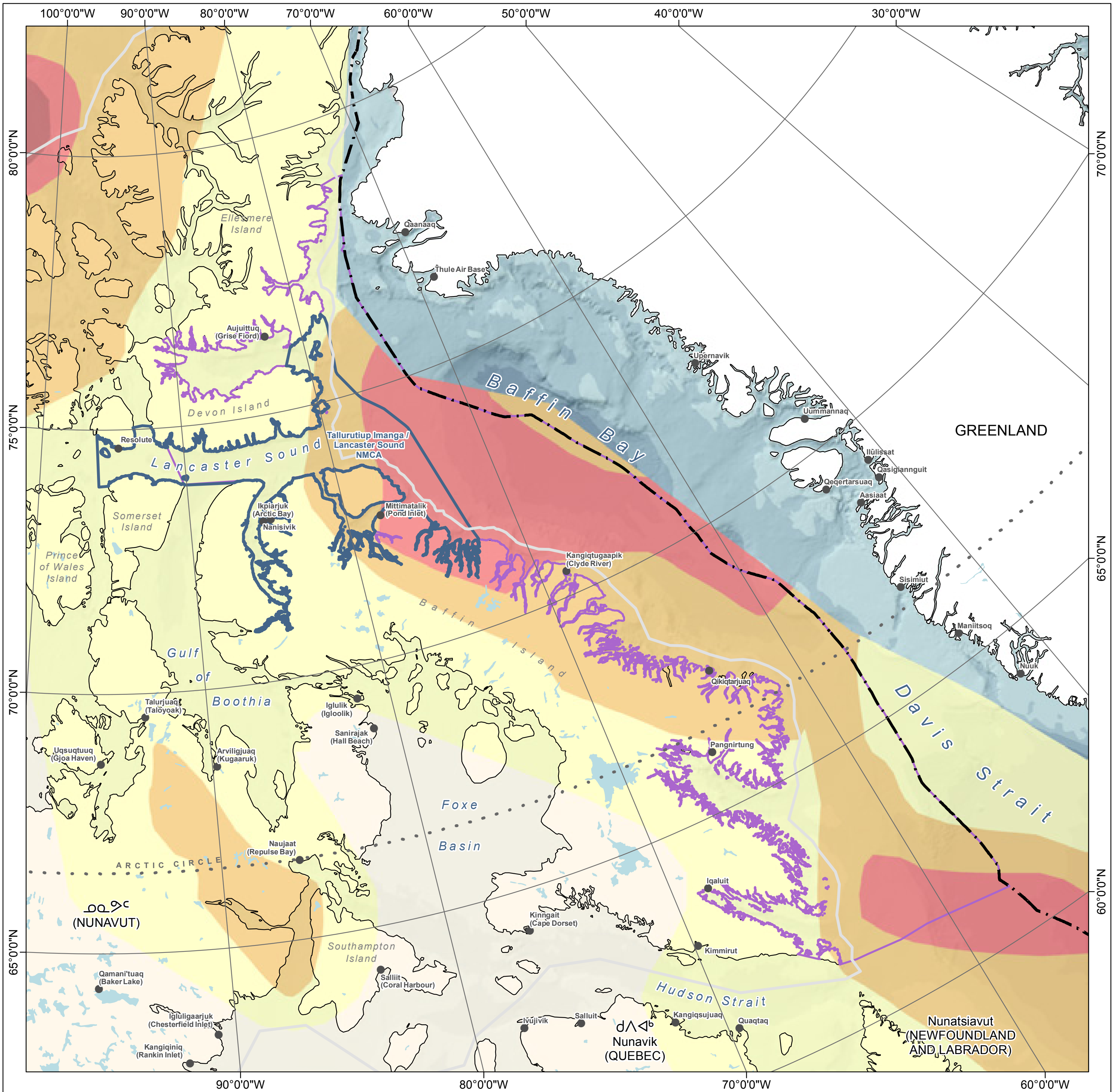
3.7.2.1 Seismicity

In general, Canada's eastern continental margin is tectonically passive, and seismicity is relatively rare throughout much of the region; however, the Baffin Bay and Davis Strait region is unique from other passive margins in Canada because it is seismically active (Bennett et al. 2013). Seismic hazard maps (see Figure 3.25) show that Baffin Bay has a level of hazard comparable to that of coastal British Columbia (Adams and Halchuk 2003; Basham et al. 1997). The seismic hazard map (see Figure 3.25) shows that the relative hazard of seismic events in the Area of Focus, based on a scale from low to high, ranges from low-moderate to moderate-high.

A large number of seismic events (including a 7.3 M earthquake in 1933) have occurred in the deep water of the Baffin Fan (Bennett et al. 2013; Harrison et al. 2011). This 7.3 M earthquake occurred on November 20, 1933 and is the largest instrumentally-recorded passive margin earthquake in Canada and is also the largest known earthquake north of the Arctic Circle (Bennett et al. 2013; Bent 2002). The shallow geology of the area where the earthquake occurred is dominated by the widespread deposition of glaciogenic debris flows on the Lancaster Sound Trough-Mouth Fan (Li et al. 2011) (Bennett et al. 2013). No evidence of slope failure in the area of the earthquake has been observed (Bennett et al. 2013). On the shelves, clusters of seismic events occur at Buchan Trough, Scott Trough and Home Bay (Bennett et al. 2013).

According to the National Earthquake Database (NRCan 2018), there have been 4,156 earthquakes within a 1,500 km radius from a central point in the Area of Focus (69.862768 ºN, -2.176617 ºW) from 1985 to present (February 2018) (see Table 3.7). Almost all of these events were in the magnitude of 1-4. There were 20 events with a 5.0 M, and only one event with a 6.0 M; no events above 6.0 M were measured in the region during this period (see Table 3.7). Most these events occurred in the central part of Baffin Bay and Davis Strait, and along the east coast of Baffin Island (see Figure 3.26).

Baffin Bay is the northwestern extension of the North Atlantic-Labrador Sea rift system (Bennett et al. 2013). The Canadian Baffin Bay margin is a passive continental margin that lies offshore of four islands in the Area of Focus, including Baffin Island, Bylot Island, Devon Island, and Ellesmere Island (Bennett et al. 2013). The shelf off Baffin Island is approximately 50–60 km wide, with shelf breaks occurring at approximately 300 m water depth (Bennett et al. 2013). The Baffin Island shelf is crossed by several transverse troughs located at the mouths of major inlets and fiords (Bennett et al. 2013). Bylot and Devon Islands are both surrounded by steep slopes from the shoreline of the Baffin Fan, which covers the bottom of northern Baffin Bay and Lancaster Sound, and a distinct continental shelf is not recognized off Ellesmere Island, where the seabed slopes gently at an average of 0.4° from the shoreline to the abyssal plain without significant changes in gradient (Aksu and Hiscott 1989; Bennett et al. 2013). The major fault patterns of the Baffin Bay region are oriented northwest-southeast and northeast-southwest and can be attributed to seafloor spreading (Bennett et al. 2013).



Base Features

- Community[1]
- Limit of Exclusive Economic Zone[4]
- Nunavut Settlement Area[3]
- Tallurutiup Imanga / Lancaster Sound NMCA[2]

Bathymetry[4] Depth (m)

< 200, 200 - 1000, 1000 - 2000, 2000 - 3000, > 3000

Project Features

- Area of Focus[2]

Relative Hazard[5]

High

Low

1:12,000,000

0 50 100 200 300 400

Kilometres

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Figure 3.25 Canadian Seismic Hazard Map

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Verified By: J. Beckett
Revision: 01

References:
[1]Atlas of Canada Base Maps, 2017
[2]NIRB, 2017
[3]Nunavut Planning Commission, 2010
[4]Natural Earth, 2016
[5]Natural Resources Canada, 2015

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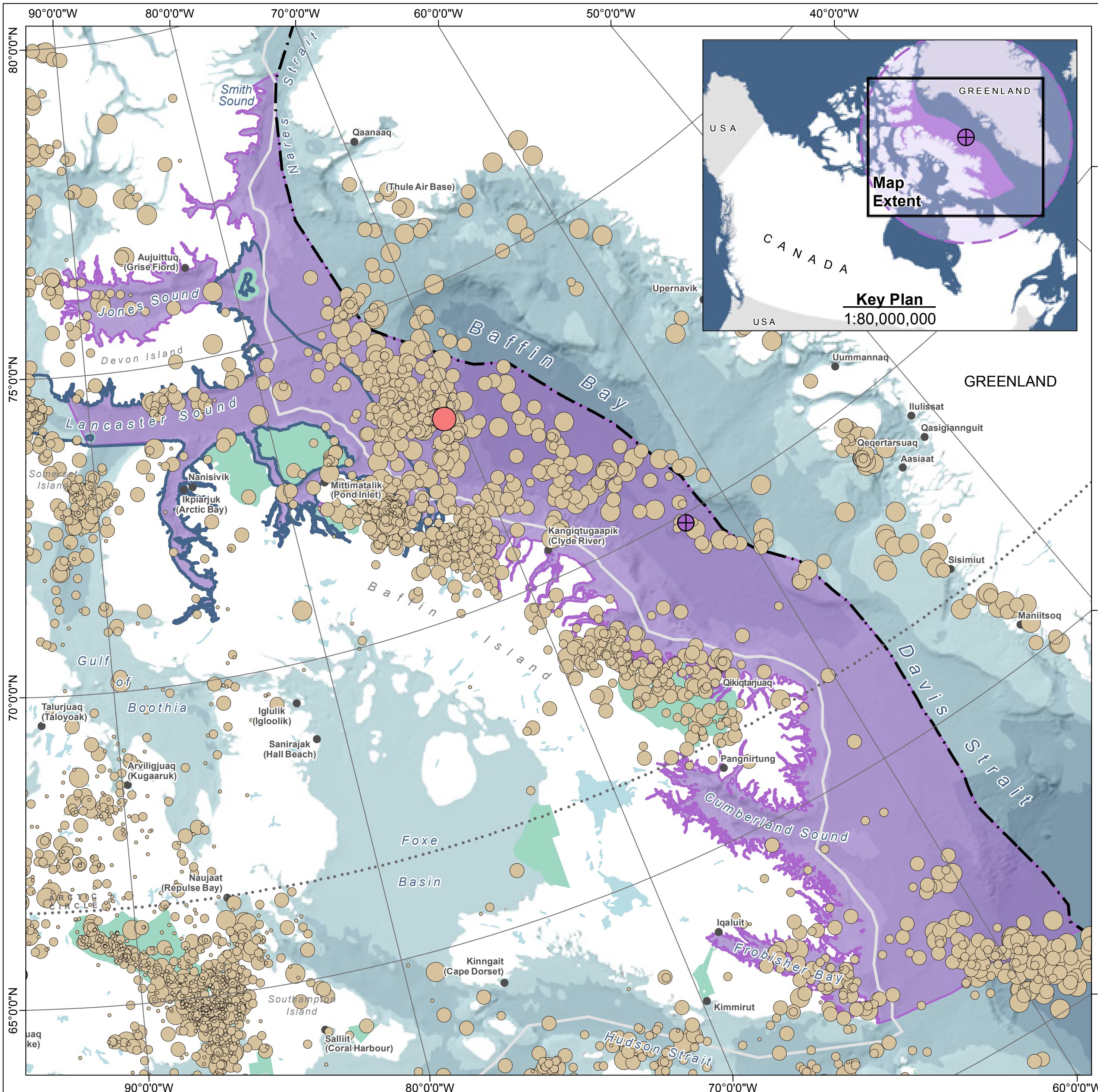
Table 3.7 Summary of Seismic Events Within a 1,500 km Radius of a Central Point in the Area of Focus (January 1985-February 2018)

Magnitude	< 1	1	2	3	4	5	6	7	8	9	Total
Total No. Events	15	630	2,063	1,238	189	20	1	0	0	0	4,156
NOTE: Coordinates for central point in Area of Focus are 69.862768 ºN, -62.176617 ºW											
SOURCE: NRCan (2018) National Earthquake Database											



Base Features

- Community[1]
- Limit of Exclusive Economic Zone[4]
- Nunavut Settlement Area[3]
- Tallurutiup Imanga / Lancaster Sound NMCA[2]
- Protected Area or National Park[4]

Bathymetry[5] Depth (m)

< 200, 200 - 1000, 1000 - 2000, 2000 - 3000, > 3000

Project Features

- Area of Focus[2]

Known Earthquakes[6]

Magnitude

- 0.4 - 2.0
- 2.1 - 2.7
- 2.8 - 3.5
- 3.6 - 5.9
- 1933 7.3 M Earthquake[7]
- Central Point in the Area of Focus
- Area Within 1500 km of Centre of Study Area (See Key Plan)

1:10,000,000

0 50 100 200 300

Kilometres

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Figure 3.26

Earthquakes Within a 1,500 km Radius of a Central Point in the Area of Focus (Jan. 1985 - Feb. 2018)

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[1]Atlas of Canada Base Maps, 2017
[2]NIRB, 2017
[3]Nunavut Planning Commission, 2010
[4]National Framework Canada,2017
[5]Natural Earth, 2016
[6]National Earthquake Database, 2018
[7]Bent, 2002

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Seismic events greater than 6.0 M may trigger slope failures on the steep slopes along the margins of transverse troughs but would not have much effects on the bank tops (Bennett et al. 2013).

3.7.2.2 Geohazards

Bennett et al. (2013) have identified the geohazards existing on the northern Baffin Island shelf, including ice scour, steep and uneven seabed caused by glacial features, glacial fluting, hydrocarbon venting features, and slope failures on transverse trough margins. These geohazards are consistent with those observed on other glaciated continental shelves; however, the high level of seismic activity in the area is an additional hazard on the northern Baffin Island shelf (Bennett et al. 2013).

ICE SCOUR

Ice scour has disturbed much of the seabed of the northern Baffin Island Shelf (Bennett et al. 2013). These scours are a result of both modern and relict icebergs, with drafts deep enough to contact the seabed and cause long scours with side berms as the ice is moved by wind and currents (Bennett et al. 2013). The large modern icebergs present in Baffin Bay cannot account for all of the ice scour observed in northern Baffin Bay and Lancaster Sound (Bennett et al. 2013). Rather, relict iceberg scours are observed in areas where the icebergs can no longer reach the seabed due to an increase in water depth or a decrease in iceberg size (Bennett et al. 2013; Lewis and Woodworth-Lynas 1990).The age of these scours is not known; however, their occurrence in water depths beyond what can be scoured by the modern-day iceberg regime and their supposition on glacial sediments, suggest they were likely formed during deglaciation of Late Pleistocene ice shelves and ice sheets (Bennett et al. 2013; Lewis and Woodworth-Lynas 1990). The modern icebergs are capable of scouring depths up to at least 430 m in Baffin Bay and Lancaster Sound; however, relict iceberg scour has been observed at a depth of 850 m (Bennett et al. 2013).

Bennett et al. (2013) used multibeam echosounder data to map the distribution of ice scours in northern Baffin Bay and Lancaster Sound. Their results show that relict ice scour was observed over most of the region in water depths that range up to 850 m. The relict scours typically had an incised depth of 1–4 m into the seabed (maximum scour depth observed was 19 m), and their width ranged from 65–500 m across. The length of all these scours is not known due to incomplete multibeam coverage, but scours were observed to be several tens of kilometres long (Bennett et al. 2013).

There is less iceberg scour in Lancaster Sound Bay as most icebergs (approximately 80%) only intrude approximately 100 km into Lancaster Sound from Baffin Bay before being turned around in a counterclockwise drift pattern (Bennett et al. 2013). As a result, icebergs are then pushed back out into Baffin Bay and continue south with the Baffin Island Current (Bennett et al. 2013).

GLACIAL FEATURES

Lancaster Sound and part of Baffin Bay were occupied by glacial ice during the last glaciation and there is evidence of other previous glaciations as far back as the early Pleistocene (Klassen and Fisher 1988) (Bennett et al. 2013; Li et al. 2011). Multibeam echosounder data were used by Bennett et al. (2013) to map the distribution of glacial features in northern Baffin Bay and Lancaster Sound, including fluting, sediment wedges, and ice scour (see next section for details on glacial fluting). Three large sediment wedges were observed in the western end of Lancaster Sound. These wedges were 50 to 200 m high and collectively cover approximately 5,400 km² of the seabed. These wedges were likely deposited during the late Pleistocene retreat of ice in Lancaster Sound (Bennett et al. 2013). A similar seabed morphology is also observed seaward of these wedges in Baffin Bay, where a succession of till deltas and wedges have been deposited on the Lancaster Sound Trough-Mouth Fan (Bennett et al. 2013; Li et al. 2011). The Baffin Fan is also a large sediment wedge located in northwestern Baffin Bay (Harrison et al. 2011).

Lancaster Sound has been interpreted as the site of a large paleo-ice stream during the last glaciation (Bennett et al. 2013; De Angelis and Kleman 2005). Moraines present on Bylot Island, along with submarine escarpments located offshore of the northern coast of Bylot Island, suggest that glacial ice in Lancaster Sound was over 1,600 m thick (Bennett et al. 2013; Klassen and Fisher 1988).

GLACIAL FLUTING

Glacial fluting are elongate streamlined ridges of sediment, aligned in the direction of ice flow, that are produced beneath a glacier. Streamlined drumlins and seabed lineations are the result of glacial fluting and are observed along the southern portion of Lancaster Sound in northern Navy Board Inlet, and northeast of Bylot Island in Baffin Bay (Bennett et al. 2013). The high slope angles (up to 60°) associated with some of these glacial features could pose a hazard to seabed infrastructure (Bennett et al. 2013).

Previous work in the region has indicated an ice flow direction from west to east during the last glaciation (De Angelis and Kleman 2005; Klassen and Fisher 1988). The streamlined drumlins and lineations located northeast of Bylot Island in Baffin Bay indicate an ice flow direction to the southeast (Bennett et al. 2013). The length of the lineations is not known due to incomplete multibeam coverage in the region, but these flutes are known to be up to approximately 1,000 m wide, rise up to 75 m above the seabed, and incise as deep as 75 m into the subsurface (Bennett et al. 2013). These lineations and drumlins were observed over approximately 3,100 km² of the seafloor, but additional multibeam data are required to determine the full extent of glacial fluting (Bennett et al. 2013).

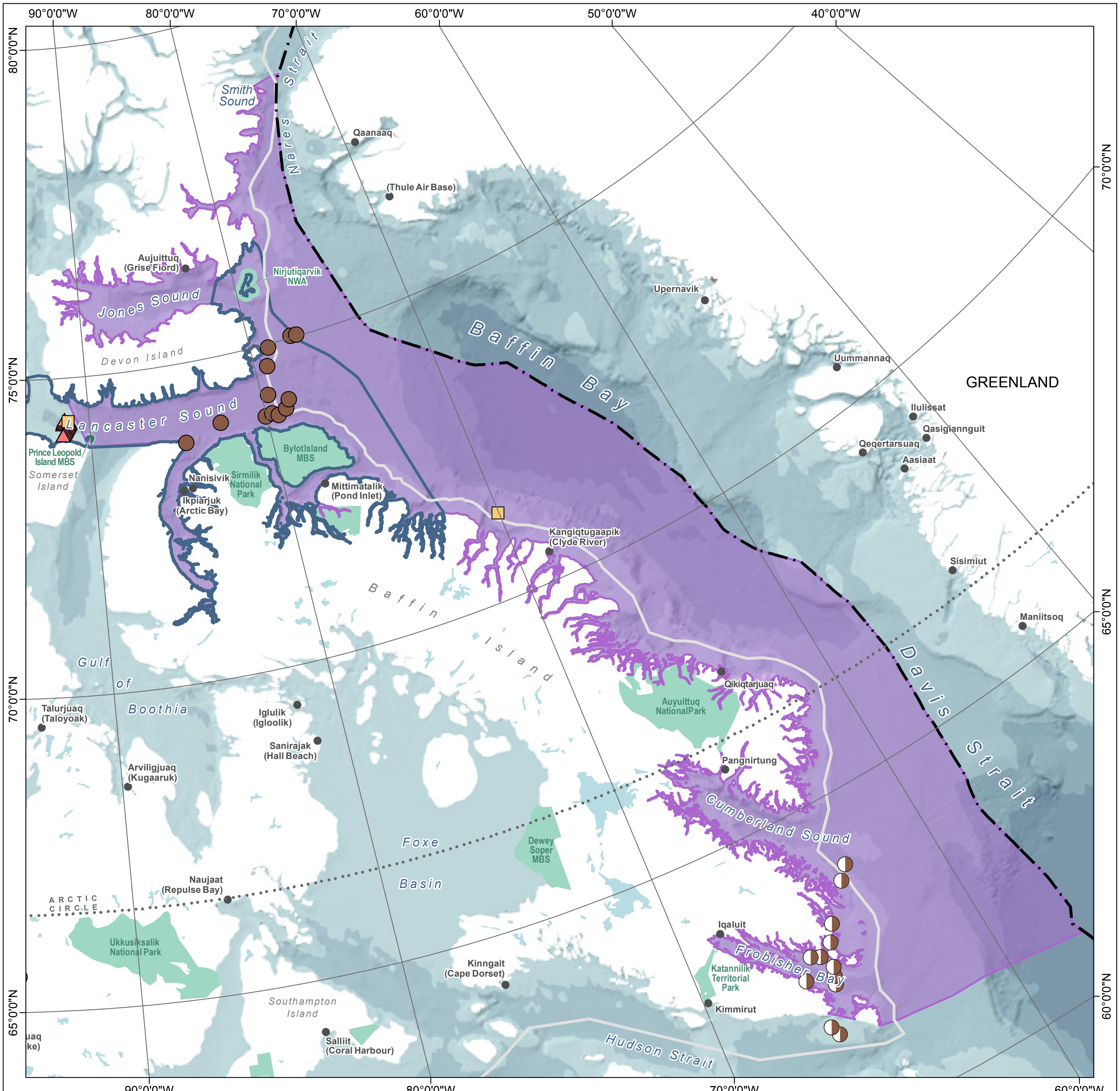
While ice scours occur throughout Lancaster Sound, they have not been observed in areas where glacial fluting has occurred (Bennett et al. 2013). Evidence of grounded glacial ice on the seabed does exist to the east and west of glacial fluting in Lancaster Sound (Bennett et al. 2013; Li et al. 2011). Thick ice was grounded 270 km from the mouth of Lancaster Sound in approximately 1,300 m water depth during the last glacial maximum (Bennett et al. 2013), but as the glaciers receded, the ice would have thinned sufficiently enough to be floating in eastern Lancaster Sound and would have protected the seabed flutes from modification by ice scour (Bennett et al. 2013; Li et al. 2011).

Glacial lineations have also been observed throughout the bottom of Scott Trough and seismic profiles have shown that these lineations can be up to 35 km long, 750 m wide, and 45 m high, and are comprised of till (Bennett et al. 2013). The lineations in Scott Trough are interpreted to be glacial sole marks formed during the last glaciation, when an ice stream flowed out of Scott Inlet (Bennett et al. 2013). Similar glacial features to those described above are also present in the other transverse troughs on the northern Baffin Island shelf (Bennett et al. 2013).

HYDROCARBON VENTING AND NATURALLY OCCURRING OIL SEEPS

Hydrocarbons are naturally occurring in the marine environment of Baffin Bay and Davis Strait due the presence of naturally-occurring oil seeps. The leakage of hydrocarbons from the seafloor is known as cold seepage and differs from hydrothermal venting in terms of the rate, composition, and temperature of eruption (Blasco et al. 2010). The locations of known naturally-occurring oil seeps, areas where surface oil slicks were noted, and areas with pockmarks that are potentially associated with hydrocarbon seeps in the Area of Focus are shown in Figure 3.27. The only documented naturally-occurring oil seeps in Baffin Bay are in Scott Inlet and in western Lancaster Sound (see Figure 3.27) (Blasco et al. 2010; Foster et al. 2015).

The hydrocarbon seep at Scott Inlet was first observed in 1976 by the discovery of an oil slick on the sea surface, appearing to be bubbling from depth, during a seismic survey off the east coast of Baffin Island (Loncarevic and Falconer 1977). Subsequent surveys at this site verified the presence of the slick and attempted to determine the origin and nature of the seep (Blasco et al. 2010). These surveys included: remote sensing techniques; collection of gravity, magnetic, and high-resolution seismic data; bedrock, sediment, and water column sampling; geochemical and chemical analyses; and submersible investigation of the seafloor and water column in the area of the slick (Bennett et al. 2013; Blasco et al. 2010; Levy and MacLean 1981; MacLean et al. 1981). These investigations produced evidence suggesting that hydrocarbons were leaking from the seafloor in the area of Scott Inlet-Buchan Gulf off the east coast of Baffin Island (Bennett et al. 2013; Blasco et al. 2010; MacLean et al. 1981). They also determined that the primary site of seepage occurred near the south wall of the outer part of Scott Trough (Blasco et al. 2010). Gas has also been observed escaping from the seabed in underwater video collected by remotely operated vehicle (ROV) (Bennett et al. 2013). Based on the evidence collected, MacLean et al. (1981) suggested that hydrocarbons were originating from the seabed along the south margin of outer Scott Trough. Praeg et al. (2007) have hypothesized that hydrocarbon seepage is mostly confined to the walls of Scott Trough where Quaternary sediment is thinnest.



Base
- Community
- Limit of Exclusive Economic Zone[4]
- Nunavut Settlement Area[3]
- Tallurutiup Imanga / Lancaster Sound NMCA[2]
- Protected Area or National Park[4]

Bathymetry[5] Depth (m)
- < 200
- 200 - 1000
- 1000 - 2000
- 2000 - 3000
- > 3000

Project Features
- Area of Focus[2]

Known Oil Seeps [6,7]
- Pock Marks
- Known Oil Seep (Active)
- Surface Oil Slicks
- Potential Surface Oil Slick

1:10,000,000
0 50 100 200 300
Kilometres

Nunavut Impact Review Board Strategic Environmental Assessment

Figure 3.27
Known and Potential Naturally Occurring Oil Seeps and Surface Oil Slicks

NUNAMI STANTEC LIMITED

N.I.R.B.

Prepared By: Nunami Stantec Limited
Projection: Canada Lambert Conformal Conic, North American 1983
Date: Apr 13, 2018
Project Number: 12322100
Produced By: L. Trudell
Verified By: J. Beckett
Revision: 01

References:
[1]Atlas of Canada Base Maps, 2017
[2]NIRB, 2017
[3]Nunavut Planning Commission, 2010
[4]National Framework Canada, 2017
[5]Natural Earth, 2016
[6]Blasco et al., 2010
[7]Jauer and Budkewitsch, 2010

Filepath: S:\1232\projects\123221001\figures\report\SEA\fig_123221001_NIRB_SEA_03.27_Known_and_Potential_Naturally_Occurring_Oil_Seeps_in_the_Area_of_Focus.mxd

Video footage taken during submersible dives in 1981 showed a distinctive layer of white bacteria on the seafloor below the area of the oil slick (MacLean et al. 1981). Subsequent submersible dives in 1985 determined that the site included a large, circular seabed depression, possibly a pockmark, that contained surficial sediments covered in the same white bacteria observed on previous dives (Grant et al. 1986). The bacteria-covered sediments within the depression were solidified into a carbonate crust, and it was determined that this crust was trapping oil beneath it (Grant et al. 1986). These bacteria were analyzed, and it was determined that they belong to the genus *Beggiota* (Bennett et al. 2013; Blasco et al. 2010; Grant et al. 1986). Grant et al. (1986) suggest that a set of underlying fissures extending into the seafloor below the crust is a possible mode of transport for the oil from depth. The geological and biological characteristics of the Scott Seep are similar to those of oil and gas seeps in other oceans of the world in terms of microfauna, carbonate-bound sediments, and possible pockmark association (Blasco et al. 2010).

There is a documented relationship between unique ecosystems and the subsea seepage of liquids and gases (Foster et al. 2015). Blasco et al. (2010) suggest that the Scott Seep requires further investigation to determine its linkage with hydrocarbons, including multibeam and ROV surveys, collection of oil samples for analysis, and benthic samples for ecological and sediment properties.

Foster et al. (2015) analyzed the hydrocarbon concentrations in 11 sediment cores collected from northern Baffin Bay (including the North Water polynya), Lancaster Sound, Scott Inlet, and Gibbs Fiord in 2008 and 2009 to assess the sources of hydrocarbons and their temporal and spatial variabilities. PAH concentrations did not exceed concentrations for concern for marine aquatic life, except for the cores from the North Water polynya (Foster et al. 2015). Cores from sites within the North Water polynya had the highest PAH concentration of the cores sampled. Sediment core samples were tested for hydrocarbon biomarkers, and values indicated that organic carbon present at all sites was derived from both terrigenous higher plants and marine algae (Foster et al. 2015). Biomarker ratios and chemical profiles of the cores indicated that petrogenic sources dominate over combustion sources, thus long-range atmospheric transport was determined to be less important than inputs from weathering (Foster et al. 2015). Based on these results, Baffin Bay appears to have a very low level of contamination with regards to hydrocarbons, as the current burden of PAHs at these 11 sites was determined to be predominantly the result of local, diffuse, petrogenic sources in Baffin Bay, rather than from combustion sources typically associated with industrial activity (Foster et al. 2015).

Other hydrocarbon seeps have been interpreted from satellite imagery offshore Davis Strait and Baffin Bay (Jauer and Budkewitsch 2010) and, due to the numerous hydrocarbon basins in Baffin Bay, it is believed other venting features will be encountered in the area (Bennett et al. 2013). Surface oil slicks have been observed in southeast Lancaster Sound and at the eastern entrance to the Sound (see Figure 3.27) (Blasco et al. 2010). Potential surface oil slicks have been observed at the entrance to Cumberland Sound, the tip of the Hall Peninsula, the entrance to Frobisher Bay, and the southeast tip of the Meta Incognita Peninsula in northeast Hudson Strait (see Figure 3.27) (Jauer and Budkewitsch 2010).

SLOPE FAILURE

Slope failures can be triggered by many factors, including over-steepened slopes, rapid sedimentation, seismic activity, glacial loading, weak geological layers, and high pore water pressure in slope sediments (Hampton and Locat 1996). Sediment failure can also occur along trough margins during deglaciation, when glacial ice retreats from a trough and removes support from margin sediments (Longva et al. 2008).

The specific trigger of the slope failures observed on the Scott Trough margin is not known; however, many of the factors outlined above are present on the northern Baffin Island shelf (Bennett et al. 2013). Multibeam data have shown a series of gullies along the southern margin of Scott Trough extending from the bank tops and upper trough slopes in 230–350 m water depth to the bottom of the trough in 560–600 m water depth (Bennett et al. 2013). These gullies were clustered in three areas of the slope between the southern bank top and the bottom of Scott Trough and, further down slope from the gullies, there are sediment bedforms oriented perpendicular to the direction of the gullies (Bennett et al. 2013). These bedforms may have been caused by strong currents observed along the inner wall of Scott Trough (Bennett et al. 2013; Praeg et al. 2007).

There are other transverse troughs on the northern Baffin shelf, and similar slope conditions are likely to exist; however, additional data are required to confirm the presence of sediment failure and gullies in the region (Bennett et al. 2013).

As previously mentioned, seismic events greater than 6.0 M may trigger slope failures on the steep slopes along the margins of transverse troughs but would not have much effect on the bank tops (Bennett et al. 2013). And while there is no evidence of slope failure in the area of the 7.3 M 1933 earthquake, widespread slope failure is observed elsewhere on the continental slope (e.g., area offshore of Clyde Inlet) (Aksu and Hiscott 1989; Bennett et al. 2013).

3.8 Coastal Landforms

Baffin and Ellesmere Islands are the largest islands in the Canadian Arctic Archipelago, and are both in the top 10 largest islands in the world (Mathieson et al. 2010). Ellesmere Island is the tenth-largest island in the world, with an area of 196,235 km², while Baffin Island is the third largest island, with an area of 476,068 km² (Mathieson et al. 2010). Ellesmere Island is the northernmost island in the Canadian Arctic Archipelago and is separated from northwest Greenland by a narrow passage (Nares Strait) (Mathieson et al. 2010). Baffin Island is a continuation of the eastern edge of the Canadian Shield, and the east coast of the island is deeply indented by Cumberland Sound and Frobisher Bay (Atkinson et al. 2016). The coastal zone of eastern Baffin Island contains the Davis Strait Highlands, which form a belt of mountains and plateaus that is broken up by many vertically-walled fiords of up to 2,000 m elevation (Nunami Stantec Ltd. 2010).

Precipitous fiords and cliffs are common along the east coast of Baffin Island, and the coasts of Lancaster Sound and Nares Strait, including Ellesmere Island, where numerous fiords indent the entire coastline (Mathieson et al. 2010). Large glaciers on Baffin and Ellesmere Islands often reach from mountain tops out into the sea. On the east coast of Ellesmere Island, glaciers extending into the sea break calve large icebergs into the Nares Strait.

Coastlines within the Area of Focus vary considerably, and shorelines can also be scoured by drifting fragments of ice or huge log jams of ice driven up onto beaches. During the winter months, sea ice is jammed fast to the coasts and extends over the ocean as a solid sheet. Polynyas (described in Section 3.4.6) may occur throughout the area. Nunavummiut stated that shoreline erosion is becoming apparent (Nunavut Tunngavik Inc. 2005). It has been observed that there has been increased coastline erosion around the community of Grise Fiord due to the occurrence of larger waves (Nunavut Department of Environment n.d.). The two main controls over the long-term stability and migration of shorelines are changes in mean sea level and shore erodibility (Atkinson et al. 2016). Rising sea level, in the absence of other factors, eventually inundates backshore topography, and the rate of shoreline retreat depends on the changes in sea level and the land surface slope (Atkinson et al. 2016). An example of this in the Area of Focus is a large foreland at the northern end of Baffin Island, where local sediment abundance is undergoing submergence (St-Hilaire-Gravel et al. 2015). If sediment supply is sufficient, this can counteract the landward migration associated with sea-level rise and shorelines may remain stable or advance seaward as it aggrades to keep pace with rising sea level (Atkinson et al. 2016).

3.9 Marine Sediment

Understanding the marine sediments in the Area of Focus is important to the assessment of effects for the SEA of the Baffin Bay and Davis Strait region in terms of knowing the characteristics of the seafloor and the stability of the seafloor. An understanding of slope stability on the continental shelf and slumping is also important to the assessment of potential effects from the Scenarios described in Section 2.3.3.1. In this section, the properties, and types of marine sediment present in the Area of Focus are described, along with sedimentation rates and dispersion patterns. Further details on the history and presence of sedimentary rocks in the Area of Focus are provided in Section 3.7.1.

Sedimentation in Baffin Bay has been characterized by the influx of coarse elastic material across the rifted and rapidly foundering margin of Baffin Island (INAC 1995). These marine sediments were derived from the surrounding highlands of the Baffin Island coast and by clastics brought from the Lower Paleozoic hinterlands of the Canadian Arctic islands (e.g., Devon Island and Ellesmere Island) by major rift-controlled drainage systems (INAC 1995).

Sediment transport in Baffin Bay is affected by fresh meltwater flux from land, icebergs, and seasonal pack ice (Holland et al. 2001; Perner et al. 2011; Tang et al. 2004b). Sedimentation in the deep areas of Baffin Bay is different than that of glacially-dominated margins farther south in eastern Canada in that sedimentation rates are low, leveed deep-water channels are absent, and sediment supply is largely derived from the break-up of ice shelves (Aksu and Piper 1987; Bennett et al. 2013). Baffin Bay is potentially a site of major ice-rafted sedimentation and a source for sediment far to the south, as tens of thousands of icebergs are calved into Baffin Bay each year (Aksu and Piper 1979).

Sedimentary thicknesses in the Area of Focus are not well known; however, seismic reflection and refraction data have indicated that the sediment thickness is greatest in the northern part of Baffin Bay (14 km thick), and thinnest in Davis Strait (2 km thick) (MacLean et al. 1989). The greater sediment thickness in the northern part of Baffin Bay is likely a reflection of high rates of sediment transport into the area through an ancestral Lancaster Sound fluvial drainage system (MacLean et al. 1989). The upper portion of the stratigraphic sequence for the central part of northern Baffin Bay consists of consolidated and semi-consolidated, flat-lying sediments that are underlain by more disturbed sedimentary rocks (MacLean et al. 1989). The undisturbed upper portion of the sequence was deposited following the cessation of seafloor spreading, while deposition of the lower portion likely occurred as seafloor spreading was still taking place (MacLean et al. 1989).

In the northern part of Baffin Bay, a change in the structural style of sediments occurs near the entrance to Lancaster Sound (MacLean et al. 1989). In this area, undeformed prograding sediments to the east pass westwards into sequences that were highly deformed by Paleozoic or early Mesozoic structures (MacLean et al. 1989). Keen et al. (1974) proposed that this change occurred near the transition from continental to ocean crust.

Surficial sediments units present in the Area of Focus include Tiniktartuq Mud, Baffin Shelf Drift, Davis Strait Silt, and Cape Aston Sand (Bennett et al. 2013). The surficial sediments in the bottoms of the troughs consist mainly of postglacial hemipelagic muds of the Tiniktartuq Mud unit (Bennett et al. 2013). The Tiniktartuq Mud unit is up to 7 m thick and consists of grayish-brown to olive-gray clay with 5 to 30% sand and coarser material (Bennett et al. 2013). The adjacent bank tops consist of the glacial ice-contact sediments of the Baffin Shelf Drift unit and the glaciomarine sandy mud and gravel of the Davis Strait Silt unit, with localized concentrations of post-glacial Cape Aston Sand (Bennett et al. 2013). The Baffin Shelf Drift unit consists of glacial ice-contact sediment that has been remolded in contact with grounded glacial ice. The Davis Strait Silt unit is of glaciomarine origin and consists of olive gray to black, poorly-sorted mud with gravel, and generally occurs in water depths greater than 150 m (Bennett et al. 2013). There is a history of sediment failure in Scott Trough during the Pleistocene as debris flow deposits have been observed in the Davis Strait Silt (Bennett et al. 2013). The Cape Aston Sand unit occurs in water depths less than 80 m and consists of approximately 80% sand, with variable gravel and clay (Bennett et al. 2013). The Cape Aston Sand unit is of similar age to the Tiniktartuq Mud unit but is likely the result of the deposition of coarse-grained material from the eroded forelands of Baffin Island (Bennett et al. 2013).

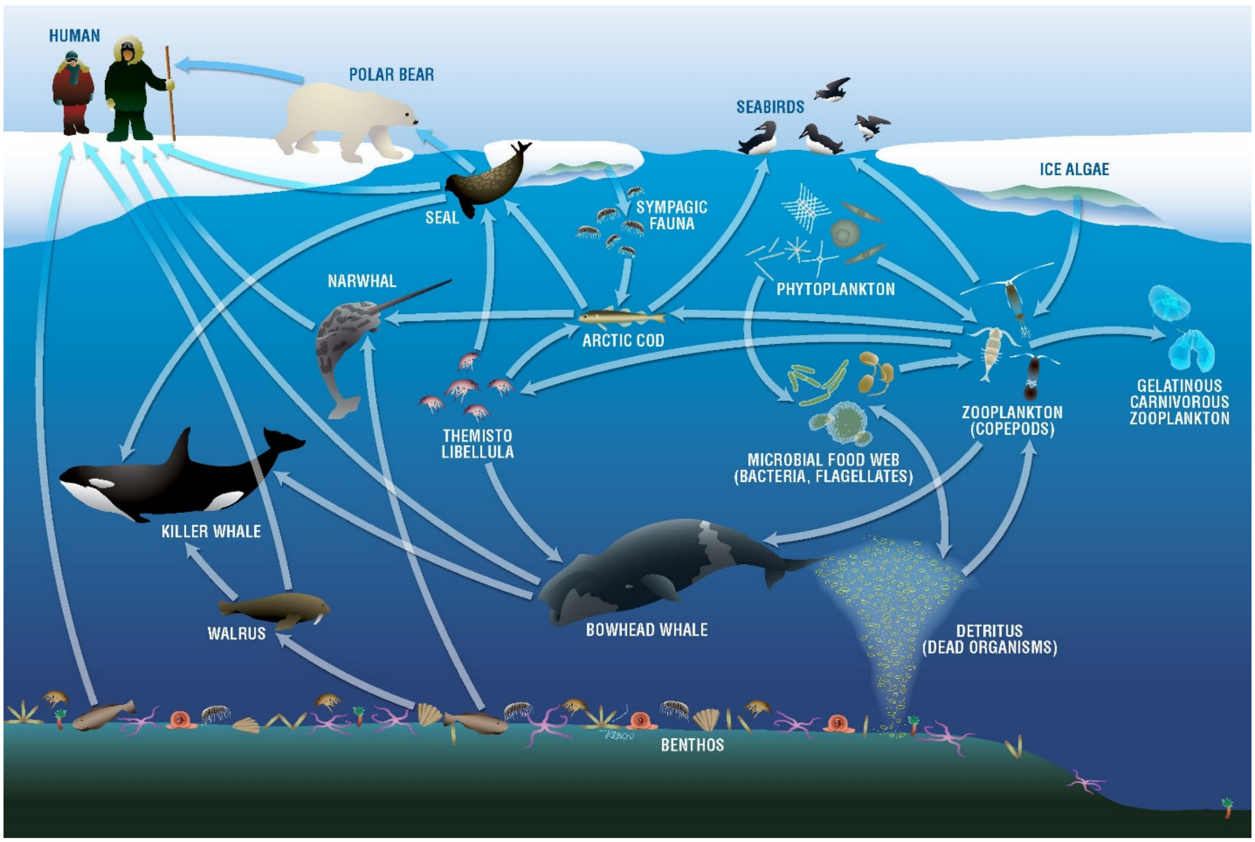
A series of piston cores were collected during an expedition in northern Baffin Bay and Lancaster Sound by Campbell and de Vernal (2009). In northern Baffin Bay, the lowermost sediment penetrated by these cores was glacial till that was very dark brown sandy clay with sandy laminations and pebbles (Campbell and de Vernal 2009). The till was overlain by laminated glaciomarine sediments consisting of carbonate-rich gray silty clay with occasional sandy layers and pebbles (Campbell and de Vernal 2009). The uppermost sediment consisted of post-glacial bioturbated olive gray silty clay (Campbell and de Vernal 2009). Similar stratigraphy has also been observed in western Lancaster Sound and Barrow Strait (Bennett et al. 2013; MacLean et al. 1989). Cores taken in central Baffin Bay exhibited alternating layers of light to dark gray, yellowish, olive, and brownish to reddish mud, with various grain sizes from sandy mud to clay (Campbell and de Vernal 2009). Cores from the Nares Strait and Jones Sound were found to contain thick, organic-rich sequences of Holocene sediment (Campbell and de Vernal 2009). In Lancaster Sound, sediments were observed to consist of post-glacial gray-brown mud overlaying very-cohesive dark gray sand-silt-mud (Campbell and de Vernal 2009). This cohesive dark gray material was interpreted to be glacio-marine or ice-contact sediments based on analysis of the core samples and accompanying seismic reflection data (Campbell and de Vernal 2009).

Further data are required to determine if trough margin gullies on the northern Baffin Island shelf are active conduits for sediment transport (Bennett et al. 2013).

4 ENVIRONMENTAL SETTING—BIOLOGICAL ENVIRONMENT

The existing biological environment of the Area of Focus is described for each of the selected VECs; species at risk; coasts and shorelines; plankton; benthic flora and fauna; fish and fish habitat; waterbirds; marine mammals; special and sensitive areas; and areas of concern or importance.

The schematic representation of the Canadian Arctic marine food web (Darnis et al. 2012) is relevant to all aspects of the biology discussed in the following sections.



SOURCE: Darnis et al. 2012

Figure 4.1 Schematic Representation of Canadian Arctic Marine Food Web

4.1 Species at Risk

There are 24 listed species that may occur in or near the Area of Focus. These include seven species of marine mammals, seven species of marine fish, and 10 species of waterbirds (see Table 4.1). These species have varying levels of federal protection under the *Species at Risk Act* (SARA), and/or have been identified as species of conservation concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), and/or as regionally rare by the International Union for the Conservation of Nature (IUCN).

Table 4.1 below provides a list of these species, along with their conservation status under SARA, and by COSEWIC and IUCN. The life histories of these species and their distribution within the Area of Focus are provided in Sections 4.5 (fish and fish habitat), 4.6 (waterbirds), and 4.7 (marine mammals), respectively.

Table 4.1 Listed Species Known to Occur in or Near the Baffin Bay and Davis Strait Area of Focus

Species	Scientific Name	SARA Status (Schedule 1 or 2)	COSEWIC Status	IUCN Status	Report Reference
Marine Mammals					
Atlantic walrus (High Arctic population)	*Odobenus rosmarus*	-	Special Concern	Vulnerable	Section 4.7.4
Atlantic walrus (Central / Low Arctic population)		-	Special Concern	Vulnerable	Section 4.7.4
Beluga Whale (Eastern High Arctic – Baffin Bay population)	*Delphinapterus leucas*	-	Special Concern	Least Concern	Section 4.7.6
Beluga Whale (Cumberland Sound population)		Threatened (Schedule 1)	Threatened	Least Concern	Section 4.7.6
Beluga Whale (Eastern Hudson Bay population)		-	Endangered	Least Concern	Section 4.7.6
Beluga Whale (Western Hudson Bay population)		-	Special Concern	Least Concern	Section 4.7.6
Beluga whale (Ungava Bay population)		-	Endangered	Least Concern	Section 4.7.6
Bowhead Whale (Eastern Canada – West Greenland population)	*Balaena mysticetus*	-	Special Concern	Least Concern	Section 4.7.9
Fin Whale (Atlantic population)	*Balaenoptera physalus*	Special Concern (Schedule 1)	Special Concern	Endangered	Section 4.7.11
Killer Whale (Northwest Atlantic – Eastern Arctic population)	*Orcinus orca*	-	Special Concern	Data Deficient	Section 4.7.7
Narwhal	*Monodon monoceros*	-	Special Concern	Least Concern	Section 4.7.5
Polar Bear	*Ursus maritimus*	Special Concern (Schedule 1)	Special Concern	Vulnerable	Section 4.7.12
Marine Fish					
Atlantic Cod (Arctic Lakes population)	*Gadus morhua*	-	Special Concern	Vulnerable	Section 4.5.1.1
Atlantic Cod (Newfoundland and Labrador population)		-	Endangered	Vulnerable	Section 4.5.1.1

Table 4.1 Listed Species Known to Occur in or Near the Baffin Bay and Davis Strait Area of Focus

Species	Scientific Name	SARA Status (Schedule 1 or 2)	COSEWIC Status	IUCN Status	Report Reference
Atlantic Wolffish	*Anarhichas lupus*	Special Concern (Schedule 1)	Special Concern	Not Assessed	Section 4.5.1.2
Northern Wolffish	*Anarhichas denticulatus*	Threatened (Schedule 1)	Threatened	Not Assessed	Section 4.5.1.11
Spotted Wolffish	*Anarhichas minor*	Threatened (Schedule 1)	Threatened	Not Assessed	Section 4.5.1.14
Lumpfish	*Cyclopterus lumpus*	-	Threatened	Not Assessed	N/A
Roundnose Grenadier	*Coryphaenoides rupestris*	-	Endangered	Endangered	N/A
Thorny Skate	*Amblyraja radiata*	-	Special Concern	Vulnerable	Section 4.5.1.15
Waterbirds					
Yellow-billed Loon	*Gavia adamsii*	-	-	Near Threatened	Section
Common Eider	*Somateria mollissima*	-	-	Near Threatened	Section 4.6.1
Long-tailed Duck	*Clangula hyemalis*	-	-	Vulnerable	Section 4.6.1
Atlantic Puffin	*Fratercula arctica*	-	-	Vulnerable	Section 4.6.2
Ivory Gull	*Pagophila eburnea*	Endangered (Schedule 1)	Special Concern	Near Threatened	Section 4.6.2
Red Knot, *rufa* subspecies	*Calidris canutus rufa*	Endangered (Schedule 1)	Endangered	Near Threatened	Section 4.6.3
Red Knot, *islandica* subspecies	*Calidris canutus islandica*	Special Concern (Schedule 1)	Special Concern	Near Threatened	Section 4.6.3
Semipalmated Sandpiper	*Calidris pusilla*	-	-	Near Threatened	Section 4.6.3
Buff-breasted Sandpiper	*Calidris subruficollis*	Special Concern (Schedule 1)	Special Concern (Schedule 1)	Near Threatened	Section 4.6.3
Red-necked Phalarope	*Phalaropus lobatus*	-	Special Concern	Least Concern	Section 4.6.3

4.2 Coast and Shoreline

As first mentioned in Section 3.8, the coastlines in the Area of Focus vary considerably. As a result, many different types of habitat are available for marine plants and invertebrates that occur along the shoreline, and in intertidal areas. The coast and shoreline in the Area of Focus, along with marine plants that may occur are described in the following section.

Baffin and Ellesmere Islands have open and rocky coastal environments (Mathieson et al. 2010). The open coastal region between Baffin and Ellesmere Island represent a complex of many islands, promontories, fiords, and embayments (Mathieson et al. 2010).

In general, the diversity of marine plants is lower in the Canadian Arctic than on the east and west coasts (see Table 4.2). Typically, subarctic areas with occasional ice cover have more diverse fauna than the Arctic (Hooper and Whittick 1984; Mathieson et al. 2010; Munda 1991; South and Hooper 1980). Seaweeds in the Area of Focus are subject to continuous ice scour, and it has been postulated that the lower species diversity observed in the Arctic, when compared to that of the Atlantic and Pacific Oceans, may be a result of ice scouring (Archambault et al. 2010; Darnis et al. 2012)

Mathieson et al. (2010) compared the species composition of seaweeds in four areas: Ellesmere Island to Baffin Island, Hudson Strait, Hudson Bay, and James Bay. There results show that the highest species diversity was observed from Ellesmere Island to Baffin Island (133 species), followed by Hudson Strait (106 species). Of these 133 species, 49 were *Chlorophyta* sp. (green algae), 65 were *Heterokontophyta* sp. (brown algae), 49 were *Rhodophyta* sp. (red algae), 2 were *Bacillariophyta* sp. (diatoms), and 1 was *Cyanophyta* sp. (blue-green algae or cyanobacteria) (Mathieson et al. 2010). The flora identified by Mathieson et al. (2010) is comparable to that of other Arctic sites with consistent ice cover.

Mathieson et al. (2010) also observed an invasive species from Europe, *Dumontia contorta*, in the Ellesmere Island to Baffin Island area.

A list of the most common species of green algae, brown algae, and red algae identified by Mathieson et al. (2010) is provided in Table 4.3.

Many of the fiords on the south coast of Ellesmere Island have soft bottoms and algal growth is poor in these areas (Taylor n.d.). *Laminaria* sp. has been observed in Flagler Bay on the east coast of Ellesmere Island and in Nares Strait (Taylor n.d.). At Foulk Fjord in northwest Greenland, *Enteromorpha* sp. has observed along with a continuous belt of *Fucus* sp., and two species of *Laminaria* were observed in deeper water (Taylor n.d.). During the Nunavut Coastal Resource Inventory (NCRI) in Grise Fiord, interviewees noted that there has been increased shoreline erosion due to larger waves (Nunavut Department of Environment n.d.).

During the NCRI in Qikiqtarjuaq, interviewees noted that kelp in the area is growing bigger and longer (Nunavut Department of Environment 2010). It was also noted that kelp tastes better when it is colder (Nunavut Department of Environment 2010).

Table 4.2 Seaweed Taxa on Canada's Three Ocean Coastlines

Taxa	Canadian Arctic	Eastern Canada	Western Canada
Chlorophyta (Green Algae)	61	90	120
Phaeophyceae (Brown Algae)	75	120	134
Rhodophyta (Red Algae)	66	130	380
Tribophyceae (Yellow-Green Algae)	3	9	6
Total	**210**	**350**	**650**
SOURCE: Mathieson et al. (2010)			

Table 4.3 Common Seaweeds from Four Sites in the Eastern Canadian Arctic

Green Algae	Brown Algae	Red Algae
Chlorochytrium dermatocolax *Ulva flexuosa* *Ulva intestinalis* *Ulva lactuca*	*Agarum clathratum* *Chordaria flagelliformis* *Desmarestia aculeata* *Dictyosiphon foeniculaceus* *Ectocarpus siliculosus* *Fucus distichus ssp. edentatus and evanescens* *Fucus vesiculosus* *Petalonia fascia* *Pylaiella littoralis* *Ralfsia fungiformis* *Saccharina latissima* *Sphacelaria plumosa* *Stictyosiphon tortilis*	*Ahnfeltia plicata* *Harveyella mirabilis* *Neodilsea integra* *Odonthalia dentata* *Palmaria palmata* *Phycodrys fimbriata* *Phyllophora truncata* *Polysiphonia arctica* *Polysiphonia stricta* *Ptilota serrata* *Rhodomela lycopodioides* *Scagelothamnion pusillum*
SOURCE: (Mathieson et al. 2010))		

4.3 Plankton

Plankton include the most basal levels of the marine food web; however, they comprise the largest and most diverse ecosystem component on Earth. The most dominant feature of planktonic life at high latitudes is the pronounced seasonality (Huntley et al. 1983).

The following sections provide an overview of marine microbes, phytoplankton, and zooplankton species that may be present in the Area of Focus.

4.3.1 Microbes

Marine microbes include single-celled eukaryotes, bacteria, and archaea, and these form the basis of the Arctic food web (Archambault et al. 2010). Eukaryotes are organisms with complex cells or consist of a single cell with complex structures. Eukaryotes also include single-celled protists. Bacteria are microscopic living organisms, usually one-celled, that are found everywhere on Earth. Archaea are unicellular microorganisms that are genetically distinct from bacteria and eukaryotes and are often found inhabiting extreme environmental conditions. Archambault et al. (2010) have estimated that there are 9,500 to 54,000 microbe species in the Arctic. Of these, 4,500 to 45,000 are bacterial species, 450 to 4,500 are planktonic eukaryotes, and are 500 to 5,000 archaea species (Archambault et al. 2010).

Studies on microbes in the Arctic have identified water masses as being much more important than depth or geography in determining the makeup of microbial communities in the Arctic (Archambault et al. 2010; Galand et al. 2009; Hamilton et al. 2008). The potential effects of climate change on microbial communities is enormous, as when currents shift and change position relative to each other in a layered ocean, the relative position of different microbial communities will also change, potentially affecting historical biogeochemical cycling patterns (Archambault et al. 2010; Hamilton et al. 2008; Lovejoy et al. 2004; Massana et al. 2006).

4.3.2 Phytoplankton

Phytoplankton are single-celled photosynthetic organisms that are adapted to live in the upper water column of coastal and offshore regions (Archambault et al. 2010). While marine phytoplankton make up less than 1% of the Earth's photosynthetic biomass, they contribute more than 45% of the annual net primary production of the planet (Archambault et al. 2010). Numerically, cyanobacteria represent a major portion of global marine phytoplankton (Archambault et al. 2010).

Most marine phytoplankton species range in size from 0.2 to 200 µm (Archambault et al. 2010). The highest diversity of marine phytoplankton in Canada has been recorded in the coastal fringe along the Arctic Ocean (Archambault et al. 2010). Archambault et al. (2010) report that, in general, the two most important phytoplankton taxa in the Arctic are multiple sympagic (sea-ice related) diatom species (Bacillariophyceae) and dinoflagellates. Further, they report that the Eastern Arctic has the greatest number of marine phytoplankton taxa (778 taxa), when compared to the western Arctic (418 taxa) and Central Arctic (242 taxa) regions (Archambault et al. 2010).

The Baffin Bay region is poorly-studied in terms of primary production, at least partly due to logistical issues arising from high ice concentrations and a short open-water season (Boertmann and Mosbech 2011). However, a distinct subsurface chlorophyll maximum was identified in northern Baffin Bay during summer (see Figure 4.2) (Boertmann and Mosbech 2011).

There are two categories of primary producers present in Arctic ecosystems; these are ice algae growing on the underside of sea ice, and phytoplankton growing in open waters (Soreide et al. 2010). The availability of food as a result of primary production in phytoplankton, ice algae and marine plants, is a major contributing factor in the abundance of marine organisms observed at recurrent open water sites, such as the North Water polynya (Nunavut Department of Environment n.d.). The high occurrence of pennate diatoms in Arctic waters is a direct consequence of melting processes of annually formed sea ice, which contributes to the release of sympagic diatoms to the upper water column[16] (Archambault et al. 2010).

The spring phytoplankton bloom in the Arctic is the single-most important event in determining the productive capacity of Arctic marine food webs (Merkel et al. 2012). The exact timing of the spring phytoplankton bloom varies each year according to the duration of the winter ice cover, oceanography, and meteorological conditions (Merkel et al. 2012). In general, Arctic oceans have a brief and intense phytoplankton bloom immediately after the break-up of sea ice (Merkel et al. 2012). However, this general picture can also be influenced by the presence of large polynyas (Section 3.4.6), where sea ice breaks up earlier and local upwelling can lead to very high production (Merkel et al. 2012).

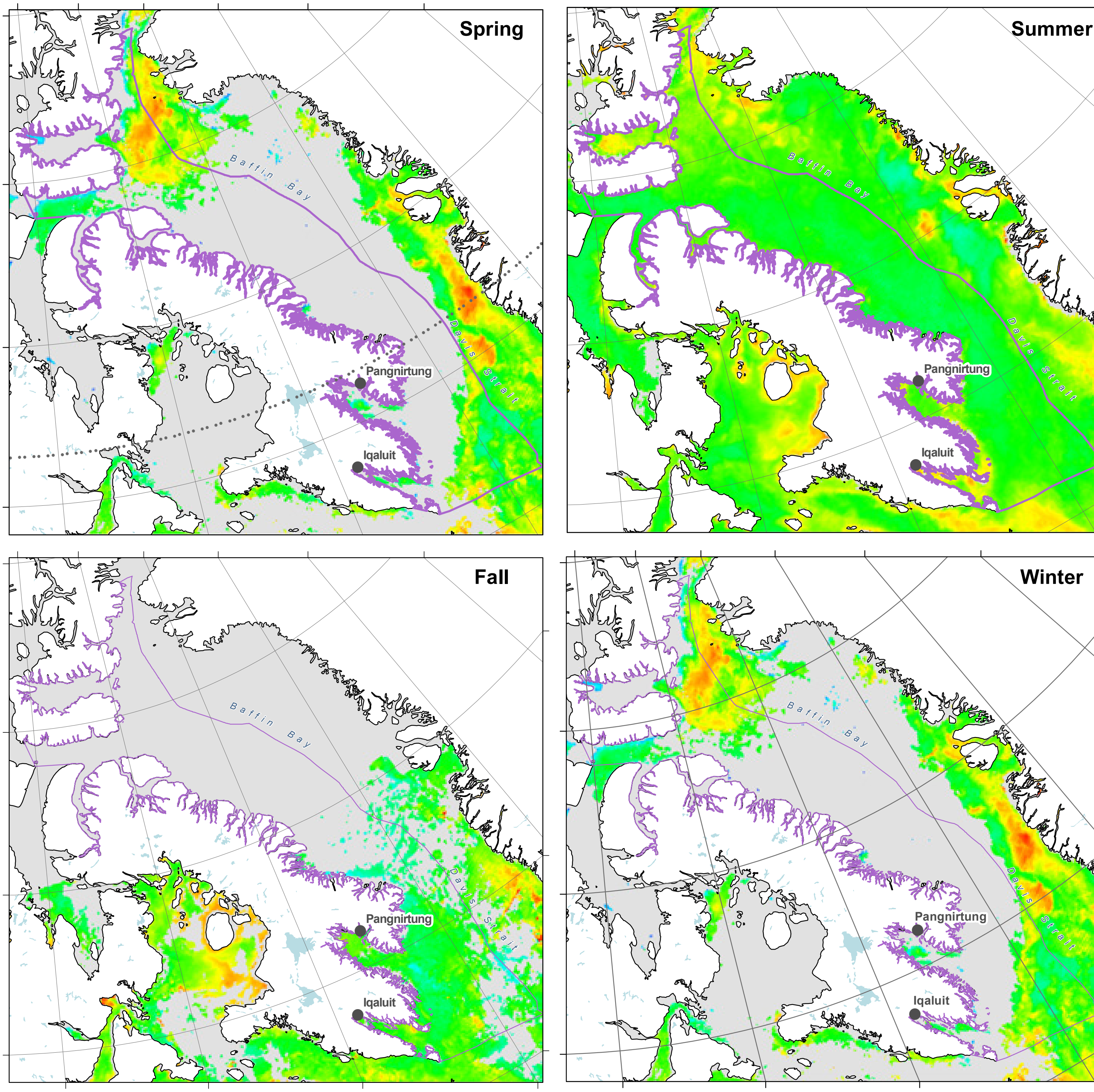
Soreide et al. (2010) followed the seasonal biomass development of ice algae and phytoplankton, their food quality, and their interaction with the copepod *Calanus glacialis* (more information of *Calanus* sp. is presented below in following section) in northern Svalbard. They used polyunsaturated fats as an index of algal quality and abundance; they determined the first peak of production occurred in late April at the onset of the ice algae bloom, and a second peak to occur in early July after the break-up of ice at the onset of the phytoplankton bloom (Soreide et al. 2010).

This primary production regime may be altered by earlier ice break up and associated changes to the timing of phytoplankton blooms (Soreide et al. 2010). This could potentially cause a mismatch between primary production and zooplankton (such as *Calanus* sp.) with possible repercussions throughout the entire arctic marine food web (Soreide et al. 2010).

The International North Water Polynya Study was a large multidisciplinary project between 1997 and 1999 (Odate et al. 2002; Tremblay et al. 2002). During this study, it was observed that the phytoplankton spring bloom occurred earlier (late April) and was an order of magnitude higher than other productive Arctic regions (Odate et al. 2002; Tremblay et al. 2002).

Welch et al. (1992) determined that 90% of annual carbon fixation in the Lancaster Sound region is contributed by phytoplankton; 10% by ice algae, and 1% by kelp.

[16] Diatoms are microscopic unicellular algae that may be solitary or occur in colonies. Pennate diatoms are those with bilateral symmetry; similar anatomical parts are arranged on both sides of the organism. A sympagic environment is one where water exists mostly as solid ice, and sympagic diatoms occur under the ice in these environments.



Base Features

● Community

Project Features

Area of Focus[2]

Chlorophyll *a* concentration[3] (mg/m^3)

0.01 0.03 0.1 0.3 1 3 10 30 60

1:20,000,000

0 100 200 400 600

Kilometres

References:
[1]Atlas of Canada Base Maps, 2017
[2]NIRB, 2017
[3]NASA Goddard Space Flight Center, 2017

Nunavut Impact Review Board
Strategic Environmental Assessment

Figure 4.2
Chlorophyll Concentrations (Seasonal Average)

NUNAMI STANTEC LIMITED

N.I.R.B. NUNAVUMI AVATILIKIYIN KATIMAYIN

Prepared By: Nunami Stantec Limited
Projection: Canada Lambert Conformal Conic, North American 1983
Date: Apr 13, 2018
Project Number: 12322100
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Revision: 01

Filepath: S:\1232\projects\123221001\figures\report\SEA\fig_123221001_NIRB_SEA_04.2_Chlorophyll_Concentrations_Seasonal_Average_in_the_Area_of_Focus.mxd

When compared to the Atlantic and Pacific coasts of Canada, the Canadian Arctic has the highest number of marine phytoplankton taxa (see Table 4.4) (Archambault et al. 2010). A full list and numbers of marine phytoplankton taxa found in the Canadian Arctic, as well as the Atlantic and Pacific coasts of Canada, is provided below in Table 4.4.

Table 4.4 Numbers of Extant Marine Phytoplankton Taxa in Canada's Three Oceans

Group	Division	Canadian Arctic	Atlantic Ocean	Pacific Ocean
Archaeplastida/ Chloroplastida	Chlorophyta	21	4	5
	Prasinophyta	28	27	7
Chromaveolata/Alveolata/ Dinozoa/Dinoflagellata	Dinophyceae (dinoflagellates)	195	190	103
Chromaveolata	Cryptophyceae	15	8	4
Chromaveolata/Haptophyta	Prymnesiophyceae	26	41	21
Chromaveolata/Stramenopiles	Coscinodiscophyceae	172	161	181
	Fragilariophyceae	68	29	32
	Bacillariophyceae	393	84	110
	Bacillariophyta (diatoms)	633	274	323
	Bicosoecida	5	3	0
	Chrysophyceae	12	18	6
	Dictyochophyceae	11	6	4
	Rhaphidophyceae	2	1	3
	Synurales	3	0	0
	Xanthophyceae	1	0	0
Excavata/Euglenozoa	Euglenida	11	8	2
	Kinetoplastea	3	3	1
Opisthokonta	Choanomonada	16	29	0
Cyanophycae	N/A	12	0	0
Incertae sedis	N/A	18	14	3
Total Phytoplankton		**1,002**	**626**	**482**
NOTE: Incertae sedis is term used for a taxonomic group where its broader relationships are unknown or undefined				
SOURCE: Archambault et al. (2010)				

4.3.3 Zooplankton

Marine zooplankton are key elements of marine ecosystems, as they serve as the link connecting the primary producers (phytoplankton) to higher trophic levels (Archambault et al. 2010; Kjellerup et al. 2015). As a result, the distribution of zooplankton and community structure is important for predicting the distribution of predator species, such as fish, seabird, and marine mammals (Kjellerup et al. 2015).

Archambault et al. (2010) conducted a species inventory of Arctic zooplankton and reported 131 families and 372 species. In comparison with the Atlantic and Pacific coasts of Canada, there is a slightly lower number of zooplankton taxa present in the Canadian Arctic (see Table 4.5). A list of marine zooplankton taxa present in the Canadian Arctic, as well as the Atlantic and Pacific coasts of Canada is provided below in Table 4.5.

Table 4.5 Numbers of Marine Zooplankton in Canada's Three Marine Regions

Taxonomy			Canadian Arctic		Eastern Canada		Western Canada	
Phylum	Class	Order	Families	Species	Families	Species	Families	Species
Cnidaria	Hydrozoa	Anthoathecatae	8	18	6	19	10	18
		Leptothecatae	4	5	7	15	5	11
		Siphonophorae	2	3	4	7	6	18
		Trachymedusae	2	7	4	7	3	6
		Narcomedusae	1	3	1	2	3	4
	Scyphozoa	Stauromedusae	0	0	2	5	0	0
		Coronatae	1	1	0	0	2	3
		Semaeostomeae	1	1	3	5	3	3
Ctenophora	Tentaculata	Cydippida	2	3	2	2	2	4
		Lobata	1	1	1	1	1	1
	Nuda	Berioda	1	1	1	1	1	2
Mollusca	Gastropoda	Thecosomata	1	1	1	2	5	7
		Gymnosomata	1	1	2	3	4	5
		Neotaenioglossa	0	0	0	0	2	3
Annelida	Polychaeta	Aciculata	11	17	7	27	5	16
		Canalipalpata	9	11	7	14	1	1
Arthropoda	Branchiopoda	Diplostraca	2	4	1	6	1	1
	Ostracoda	Halocyprida	2	7	3	6	1	45
		Myodocopida	1	1	0	0	2	1
		Podocopida	1	10	1	1	1	1
	Maxillopoda	Calanoida	24	104	22	96	24	185
		Harpacticoida	15	65	0	0	3	4
		Cyclopoida	3	7	2	5	1	4
		Poecilostomatoida	3	6	17	52	4	11
		Monstrilloida	1	1	1	5	1	3
		Siphonostomatoida	0	0	1	1	1	1
		Mormonilloida	1	2	0	0	1	2
		Pedunculata	0	0	1	4	0	0
	Malacostraca	Mysida	1	11	1	9	1	17
		Isopoda	2	3	5	6	1	1

Table 4.5 Numbers of Marine Zooplankton in Canada's Three Marine Regions

Taxonomy			Canadian Arctic		Eastern Canada		Western Canada	
Phylum	**Class**	**Order**	**Families**	**Species**	**Families**	**Species**	**Families**	**Species**
		Amphipoda	21	61	18	41	17	53
		Euphausiacea	1	5	1	7	2	18
		Decapoda	4	5	9	16	3	8
		Lophogastrida	0	0	0	0	2	4
Chaetognatha	Sagittoidea	Phragmophora	1	2	1	1	1	2
		Aphragmophora	1	2	1	7	2	6
Chordata	Appendicularia	Copelata	2	3	2	4	2	5
	Thaliacea	Salpida	0	0	1	4	1	5
		Doliolida	0	0	0	0	2	2
Total Zooplankton			**131**	**372**	**136**	**381**	**127**	**481**
SOURCE: table compiled by Archambault et al. (2010) based on a synthesis of data (Hsiao 1983) collected before 1970 to depths less than 200m with additions from additional sources for the Atlantic.								

Up to 80–90% or more of total zooplankton abundance and biomass is accounted for by a much smaller number of species depending on the location and season (Archambault et al. 2010). In the Canadian Arctic, calanoid copepods are the dominant taxa, though other taxa, such as amphipods (e.g., *Themisto libellula*), are present (Archambault et al. 2010). For example, zooplankton biomass in Davis Strait is dominated by a small number of species that include calanoid copepods (*Calanus finnmarchius*, *Calanus glacialis*, and *Calanus hyperboreus*) and the cyclopoid *Oithona similis* (Huntley et al. 1983).

A study by Kjellerup et al. (2015) is one of the most extensive zooplankton investigations of southern Baffin Bay and Davis Strait. They looked at the vertical distribution of zooplankton in the upper 500 m in September 2009. They determined that the zooplankton community was dominated by copepods (55% of abundance in upper 500 m), primarily *Calanus* sp. (*Calanus glacialis, Calanus finnmarhicus, and Calanus hyperboreus*). These Calanus sp. have been shown to co-exist in southern Baffin Bay and Davis Strait (Kjellerup et al. 2012). Other taxa identified by Kjellerup et al. (2015) include *Limacina helicina*, *Chaetognatha* sp. and *Cirrepedia nauplii*. Acoustic surveys have shown that a particularly high biomass of both zooplankton and polar cod (*Boreogadus saida*) occurs in the central part of the basin, and that in September, more copepods are present in the surface waters in the western part of the Area of Focus than in the east, where copepods were located deeper in the water column (Kjellerup et al. 2015).

Calanus sp. represent high-quality food for higher trophic levels, as they can store up to 50–70% lipids by dry mass (Conover 1988; Falk-Petersen et al. 2009; Kjellerup et al. 2015). The high lipid content of this species has been determined to be one of the main reasons for large populations of fish and marine mammal species observed in Arctic waters (Bradstreet and Cross 1982; Falk-Petersen et al. 2009; Kjellerup et al. 2015).

Generally, zooplankton reproduction either coincides or immediately follows a brief but intense phytoplankton bloom, where young stages of zooplankton feed in the surface waters (Huntley et al. 1983). Soreide et al. (2010) determined that the reproduction of *Calanus glacialis* coincided perfectly with ice algae blooms occurring in late April, and phytoplankton blooms in early July. High-quality ice algae enabled early maturation and reproduction in female copepods, and then offspring had access to abundant high-quality food from phytoplankton blooms two months later. It has also been indicated that calanoid copepods ascend from depth at a specific time of year that coincides with blooms of primary production (ice algae and phytoplankton) (Laidre et al. 2008a).

4.4 Benthic Flora and Fauna

The coast and shoreline, along with the marine plants that are found along the shorelines and intertidal zone are described above in Section 4.2. In the following sections, an overview of benthic flora and fauna in the Area of Focus is provided.

Benthic habitat has a central role in the Arctic marine ecosystem in terms of elemental cycling, ecosystem function, and biodiversity (Merkel et al. 2012). Multiple biological and physical parameters affect benthic communities, including temperature, depth, food input, sediment composition, disturbance level (e.g., ice scouring), and current regimes (Gray 2002; Merkel et al. 2012; Piepenburg 2005a; Wlodarska-Kowalczuk et al. 2004)

In terms of benthic macrofaunal assemblages in the Arctic, Cusson et al. (2007) emphasized that patterns of species composition were highly variable, even at sites in proximity to one another, and that temperature and salinity were the most important environmental variables in determining species richness. During the NCRI in the community of Qikiqtarjuaq, interviewees noted that there were fewer naked sea butterflies (*Clione limacina*) at the floe edge than there used to be, and that the presence of naked sea butterflies near old multi-year ice can help estimate the timing of ice formation (Nunavut Department of Environment 2010).

4.4.1 Benthic Flora

Macroalgae are found in the euphotic and intertidal zones and are subject to continuous ice scouring (Darnis et al. 2012). There are fewer species of macroalgae in the Arctic than in the Atlantic and Pacific Oceans, possibly as a result of ice scouring (see Section 0) (Archambault et al. 2010; Darnis et al. 2012).

Marine plants that may occur below the intertidal include kelps (e.g., *Laminaria* sp.), though their occurrence is limited to the extent of the photic zone as they are photosynthetic organisms (Mathieson et al. 2010).

4.4.2 Benthic Fauna

The number of marine benthic infaunal taxa in the Canadian Arctic is slightly lower than that of Atlantic Canada but is greater than that of the pacific coast of Canada (see Table 4.6). A list of benthic infaunal taxa in the Canadian Arctic, as well as the east and west coasts of Canada is provided in Table 4.6.

Cusson et al. (2007) found that the deepest sites sampled in Davis Strait had the highest species richness, and that habitats were similar among sites. This supports the overall trend that greater species richness is observed on the continental slope than the continental shelf. In the Davis Strait region, annelids and arthropods were abundant at sites located on the continental slope (Cusson et al. 2007).

Table 4.6 Numbers of Marine Benthic Infaunal Taxa in Canada's Three Marine Regions

Phylum	Class	Canadian Arctic	Eastern Canada	Western Canada
Annelida	–	313	343	347
	Polychaeta	306	342	331
Arthropoda	–	430	323	242
	Malacostraca	385	291	203
	Maxillopoda	3	16	25
	Ostracoda	31	3	9
Brachiopoda	–	4	3	1
Chordata	–	21	14	0
Cnidaria	–	9	36	5
	Anthozoa	7	17	4
	Hydrozoa	2	18	0
Echinodermata	–	35	52	24
	Asteroidea	11	14	2
	Holothuroidea	7	14	7
	Ophiuroidea	14	17	13
Echiura	–	1	1	1
Ectoprocta	–	3	8	0
Hemichordata	–	0	2	1
Mollusca	–	154	223	173
	Bivalvia	70	92	92
	Gastropoda	73	116	116
Nematoda	–	1	1	1
Nemertea	–	3	5	6
Platyhelminthes	–	1	3	2
Porifera	–	4	6	0
Sipuncula	–	10	8	8
Others	N/A	3	16	3
Total		**992**	**1,044**	**814**
NOTE: " – " Class not specified				
SOURCE: Archambault et al. (2010)				

4.4.3 Select Benthic Invertebrates Known to Occur in the Area of Focus

In the following section, the distribution, life histories, and local importance of select benthic invertebrate species is described.

4.4.3.1 Blue Mussel (*Mytilus edulis*)

In the North Atlantic, blue mussels occur from Baffin Island down to North Carolina (Newell 1989) and are known to be widely distributed in the eastern Canadian Arctic (Stewart and Lockhart 2004).

Blue mussels are sessile filter-feeding organisms that feed primarily on phytoplankton (Newell 1989). Blue mussels occur in both intertidal and subtidal areas and require hard substrates (e.g., bedrock, boulder, cobble, docks, pilings) for attachment (Newell 1989).

Blue mussels are slower-growing at northern latitudes due to colder water temperatures; however, while being slower-growing, blue mussels are known to grow larger in northern areas than further south in eastern Canada (Newell 1989).

Blue mussels are an important prey source for seabirds, marine fish, and some species of marine mammals (Bustnes 1998; Stewart and Lockhart 2004). There are no commercial fisheries for blue mussels in the Area of Focus, but this species is commercially important elsewhere in eastern Canada (Nunami Stantec 2012). In Nunavut, there have been exploratory fisheries for blue mussels in Arviat, Chesterfield Inlet, and Whale Cove (Nunami Stantec 2012). Blue mussels are harvested regularly as a local food source (Stewart and Lockhart 2004), and Inuit living in Kimmirut and Qikiqtarjuaq reported harvesting blue mussels during the summer months (Priest and Usher 2004).

4.4.3.2 Clam (Mya truncata)

Within the Area of Focus, clams are known to occur in the coastal fiords of Baffin Island, nearshore areas of the Baffin Island shelf, and Lancaster Sound (Aitken and Fournier 1993; Hobson and Welch 1992).

Clams are infaunal suspension feeders that feed on phytoplankton in the water column (Nunami Stantec 2012). Clams are found buried in sandy or muddy substrates and are most common in areas less than 50 m in water depth (Aitken and Fournier 1993).

Clams are a major food source for walrus. A single walrus is estimated to consume between 4,500 and 6,500 clams per day (Welch and Martin-Bergmann 1990).

Clams are not harvested commercially in the Area of Focus, but they are harvested in other parts of Canada (Nunami Stantec 2012). Within the Area of Focus, clams are occasionally harvested for local consumption (Nunami Stantec 2012). Inuit from Arctic Bay, Clyde River, Grise Fiord, Iqaluit, Kimmirut, Pangnirtung, Pond Inlet, Qikiqtarjuaq, and Resolute Bay report harvesting clams during the summer months (Priest and Usher 2004). Some Inuit in the community of Qikiqtarjuaq dive for clams year-round both during the ice, and ice-free seasons (Burke and Michael 2018). It was noted in the Nunavut Coastal Resource Inventory (NCRI) for Qikiqtarjuaq that there are annual variations in number of clams, but that numbers rebound after years with fewer clams (Nunavut Department of Environment 2010). During the

NCRI for Grise Fiord, interviewees noted that they had concern that clams in the Grise Fiord region could become overharvested if not managed properly (Nunavut Department of Environment n.d.).

4.4.3.3 Green Sea Urchin (Strongylocentrotus droebachiensis)

Green sea urchins are found along the coasts of Baffin Island and Hudson Strait (Atkinson and Wacasey 1989). Green sea urchins generally occur in shallow subtidal environments and prefer rocky substrates; this species is not commonly found on sandy or muddy bottoms (Himmelman 1986).

Macroalgae are the primary food source of green sea urchins, and aggregations of urchins are generally correlated with high abundances of macroalgae (Himmelman 1986). Green sea urchins are known to be subject to mass mortalities when food supplies (macroalgae) are depleted in an area (Brady and Scheibling 2006).

There is little information available on green sea urchins in the Arctic, but it is known that this species decreases in abundance and size with depth, that larvae are planktonic, and that spawning generally occurs in the spring (Brady and Scheibling 2006; Himmelman 1986).

Green sea urchins are commercially harvested elsewhere in eastern Canada and may have limited commercial potential in Nunavut (Nunami Stantec 2012). However, green sea urchins are harvested elsewhere for food in Nunavut off the Belcher Islands, outside of the Area of Focus (Stewart and Lockhart 2004).

4.4.3.4 Icelandic Scallop (Chlamys islandica)

In general, the distribution of Icelandic scallop in the Arctic is very patchy, and dense aggregations are uncommon (Crawford 1992). Within the Area of Focus, Icelandic scallops are found in fiords along the east coast of Baffin Island, including Cumberland Sound, and in the Hudson Strait (Crawford 1992; Parks Canada 1995). The northern limit of Icelandic scallop in the Area of Focus is Cambridge Fiord on the east coast of Baffin Island.

Icelandic scallop are an epibenthic species most commonly found at depths of 20-60 m on substrates consisting of shells, gravel, stones, rocks, and occasionally mud (Pedersen 1994). Icelandic scallops are often found in areas with strong tidal currents (Pedersen 1994).

Icelandic scallop are epifaunal suspension feeders that primarily consume phytoplankton (Pedersen 1994). Growth is seasonal in Icelandic scallop and they are slower growing in Arctic waters than in other areas further south in eastern Canada (Crawford 1992). Icelandic scallops spawn in June and July (Crawford 1992).

There have been exploratory fisheries for Icelandic scallop within the Area of Focus in Cumberland Sound and Frobisher Bay (Cosens et al. 1990; Crawford 1992), and there are commercial fisheries for Icelandic scallop elsewhere in eastern Canada and Greenland (Pedersen 1994).

4.4.3.5 Snow Crab (Chionoecetes opilio)

Snow crab occur in the North Atlantic from Greenland to the Gulf of Maine (DFO 2015b). The distribution of snow crab in Nunavut waters is poorly understood; however, it is known that within the Area of Focus, snow crab occurs in the Davis Strait (Nunami Stantec 2012).

Snow crab most commonly occur on soft substrates at depths of 70–160 m (Powles 1968). Snow crab prey upon clams, polychaete worms, brittle stars, crustaceans, and fish (DFO 2015b; Squires and Dawe 2003).

Snow crab mating generally occurs during the spring months, and female snow crab carry eggs for one to two years prior to larval hatch (DFO 2003). Hatching normally occurs in late spring and summer, after which the larvae remain planktonic for three to four months before settlement in benthic habitat (DFO 2003).

Snow crab are an important commercial species in eastern Canada (Comeau et al. 1998); however, there are no fisheries for snow crab in the Area of Focus. In general, snow crab stocks are variable and subject to natural fluctuation, and recent studies have suggested an overall decline in the abundance and size of snow crab in the North Atlantic (DFO 2015b).

4.4.3.6 Whelk (Buccinium sp.)

While the general distribution of whelk is poorly known, they are known to occur offshore of Grise Fiord, Pond Inlet, and Clyde River based on the stomach contents of bearded seals (Finley and Evans 1983).

Whelks are poorly adapted to the intertidal zone and are mainly found below the low tide mark and 100 m but are known to occur in even deeper waters (Food and Aquaculture Organization of the United Nations 2008). Whelks prefer sand, sandy-mud, and stony bottom (Food and Aquaculture Organization of the United Nations 2008).

Whelks are slow-growing and have a mostly sedentary lifestyle, but are able to move quickly in response to predators or prey (Giguere 1997). Whelks prey upon molluscs and other invertebrates (Giguere 1997).

There are some commercial fisheries for whelk elsewhere in eastern Canada (Nunami Stantec 2012).

4.4.4 Cold-water Corals

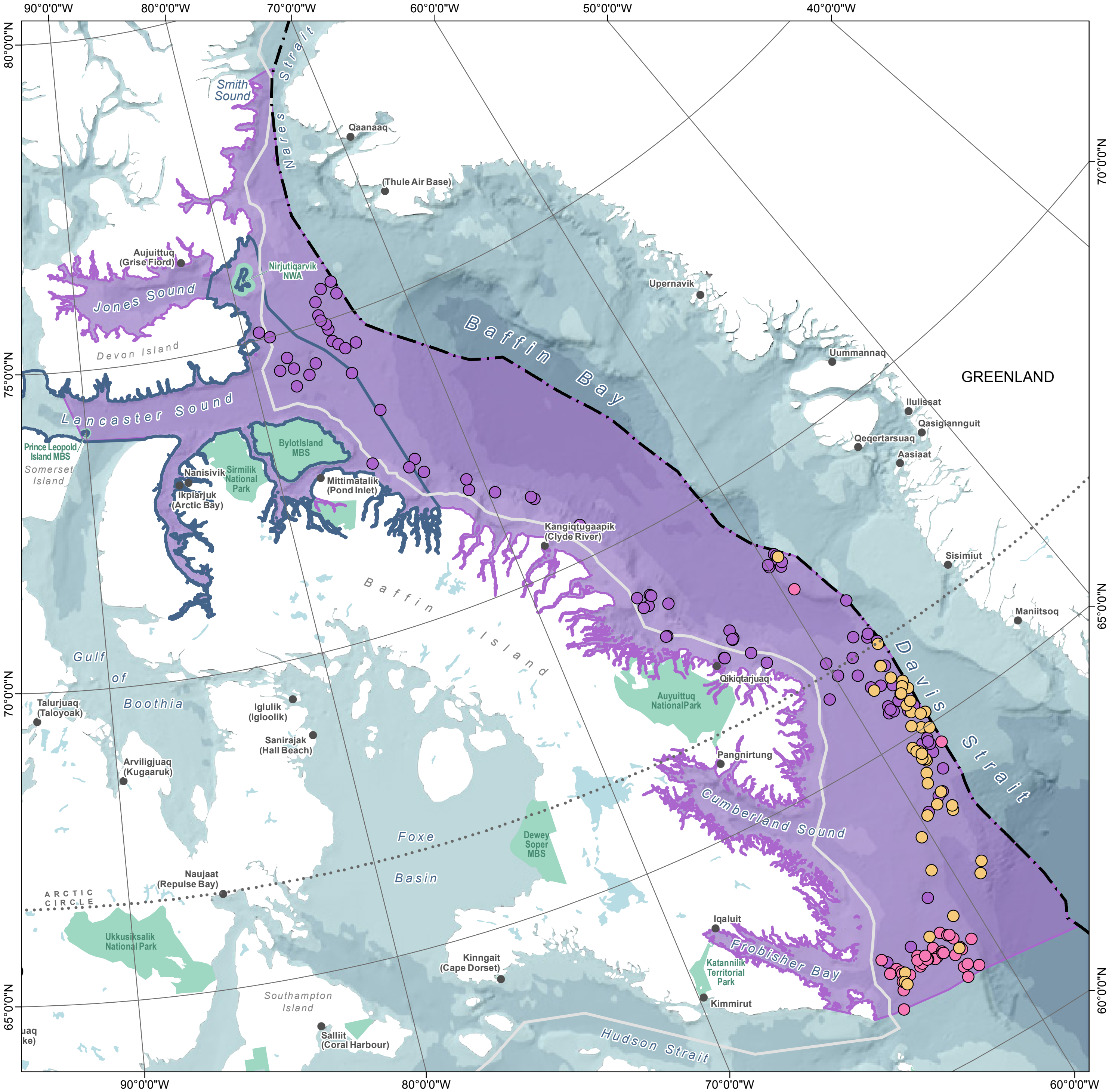
Cold-water corals are sessile benthic invertebrates that have been shown to play an important role in benthic ecosystems by providing habitat for other species of invertebrates and fishes (Buhl-Mortensen et al. 2010; Mortensens and Buhl-Mortensen 2005). Studies which have looked at species associations 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). Cold-water corals found on continental margins provide resting, feeding, and spawning sites for other species, including commercial fish species (Baillon et al. 2012; Buhl-Mortensen et al. 2010; Costello et al. 2005; Watling et al. 2011). Cold-water corals are particularly vulnerable to disturbance (e.g., bottom fishing) due to their slow growth rates and longevity (Roberts et al. 2006).

Different species of cold-water corals provide habitats of varying physical size and life spans (Roberts et al. 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.

Temperature and the presence of suitable substrate (on which to settle, secrete a basal holdfast, and build their skeleton) are two important environmental controls for cold-water corals (Edinger et al. 2011; Mortensens and Buhl-Mortensen 2005; Roberts et al. 2009). Some species live unattached on soft bottoms (e.g., Scleractinian cup corals), while others (e.g., large gorgonians) require hard substrates (Roberts et al. 2009).

Cold-water corals are present in the Area of Focus, with the largest concentrations of records occurring on the slope of the Northeast Baffin Shelf in western Baffin Bay, and in the western part of Davis Strait off the Southeast Baffin Shelf (see Figure 4.3) (Edinger et al. 2007). Records of corals in the Area of Focus come from multispecies research vessel surveys and fisheries observer records (Edinger et al. 2007; Wareham 2009).An overview of the distribution of six major groups of corals, including Antipatharians (black corals), large gorgonians, small gorgonians, soft corals, sea pens, and solitary cup corals, is provided below.

Edinger and Gilkinson (2009) identified five areas of high coral diversity and abundance in the Newfoundland and Labrador Region, including some parts of the Eastern Arctic. They identified an area which begins in the Area of Focus at the tip of the Hall Peninsula of Baffin Island, offshore to the eastern extent of Northwest Atlantic Fisheries Organization (NAFO) division 0B, and south past the extent of the Area of Focus to the Saglek Bank (Edinger and Gilkinson 2009).



Base Features

- Community[1]
- Limit of Exclusive Economic Zone[4]
- Nunavut Settlement Area[3]
- Tallurutiup Imanga / Lancaster Sound NMCA[2]
- Protected Area or National Park[4]

Bathymetry[5] Depth (m)

< 200, 200 - 1000, 1000 - 2000, 2000 - 3000, > 3000

Project Features

- Area of Focus[2]

Coral Distribution[6]

- Large Gorgonian
- Small Gorgonians
- Seapen

1:10,000,000

0 50 100 200 300

Kilometres

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Figure 4.3 Cold-Water Coral Distributions

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Projection: Canada Lambert Conformal Conic, North American 1983
Date: Apr 13, 2018
Project Number: 12322100
Produced By: L. Trudell
Verified By: J. Beckett
Revision: 01

References:
[1]Atlas of Canada Base Maps, 2017
[2]NIRB, 2017
[3]Nunavut Planning Commission, 2010
[4]National Framework Canada,2017
[5]Natural Earth, 2016
[6]Kenchington et. al. 2016

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4.4.4.1 Antipatharians

Based on fisheries observer records, Antipatharians, or black corals, occur within the Area of Focus (Wareham 2009). There are records for black corals in the central part of the Area of Focus where Baffin Bay transitions into Davis Strait, and on the Southeast Baffin Shelf at the southern extent of the Area of Focus (Wareham 2009).

4.4.4.2 Large Gorgonians

The distribution of large gorgonians in the Area of Focus is shown above in Figure 4.3. Multispecies surveys have shown bamboo coral (*Keratoisis* sp.) in the central part of southern Baffin Bay where it transitions into northern Davis Strait (Wareham 2009). Multispecies surveys and fisheries observer data show that there is bamboo coral in central Davis Strait and off the Southeast Baffin Shelf. At the southern end of the Area of Focus, there are records of the large gorgonians *Paragorgia arborea* (bubblegum coral) and *Primnoa resedaeformis* (popcorn coral) (Edinger et al. 2007; Wareham 2009). There is a voluntary fisheries closure for these species in a 12,500 km^2 area located in the northern Labrador Sea in an area referred to as the Hatton Basin. The Canadian Association of Prawn Producers, Groundfish Enterprise Allocation Council, and Northern Coalition enacted this closure to protect coral concentrations, namely large gorgonians (DFO 2015d).

In addition to multispecies surveys and fisheries observer records, large and dense bamboo coral forests (*Keratoisis* sp.) have been identified in southeast Baffin Bay from ROV surveys (Neves et al. 2015).

4.4.4.3 Small Gorgonians

The distribution of small gorgonians in the Area of Focus is shown above in Figure 4.3. Multispecies surveys and fisheries observer records show that the small gorgonian *Acanella arbuscula* is found along the edge of the Northeast Baffin Shelf in Baffin Bay, in southcentral Baffin Bay, and Southeast Baffin Shelf in Davis Strait (multiple records) (Wareham 2009). Though there were fewer records, the small gorgonian *Acanthogorgia armata* is also present on the edge of the Northeast and Southeast Baffin Shelves (Wareham 2009). There were also several records of the small gorgonians *Anthothela grandiflora* and *Radicipes gracilis* off the Southeast Baffin Shelf at the southern extent of the Area of Focus (Wareham 2009).

4.4.4.4 Soft Corals

Alcyonacean soft corals are also present in the Area of Focus. *Gersemia rubiformis* and *Duva florida* were recorded at the edge of the Northeast Baffin Shelf, and on the Southeast Baffin Shelf (Wareham 2009). The soft coral *Anthomastus grandiflorus* occurs off the off the Southeast Baffin Shelf in the southern Davis Strait and northern Labrador Sea (Wareham 2009).

4.4.4.5 Sea Pens

The distribution of sea pens in the Area of Focus is shown above in Figure 4.3. Multispecies surveys and fisheries observer records show that sea pens are present along the slope of the Northeast Baffin Shelf, southcentral Baffin Bay, and on the slope of the Southeast Baffin Shelf in the southern Davis Strait and northern Labrador Sea (Wareham 2009). Most of these records did not identify to the species level, except for *Umbellula lindahli*, which was recorded in western and central Baffin Bay, and *Halipteris finmarchica* in western Davis Strait and northwestern Labrador Sea (Wareham 2009). There are also significant concentrations of sea pens (*Umbellula* sp.) at the outflow of Lancaster Sound in Baffin Bay (Kenchington et al. 2011).

4.4.4.6 Solitary Cup Corals

Solitary scleractinian cup corals are also present at the southern portion of the Area of Focus off the Southeast Baffin Shelf (Wareham 2009). Most of these records were for *Flabellum alabastrum*; however, single records exist for *Vaughanella margaritata* and *Desmophyllum dianthus* (Wareham 2009).

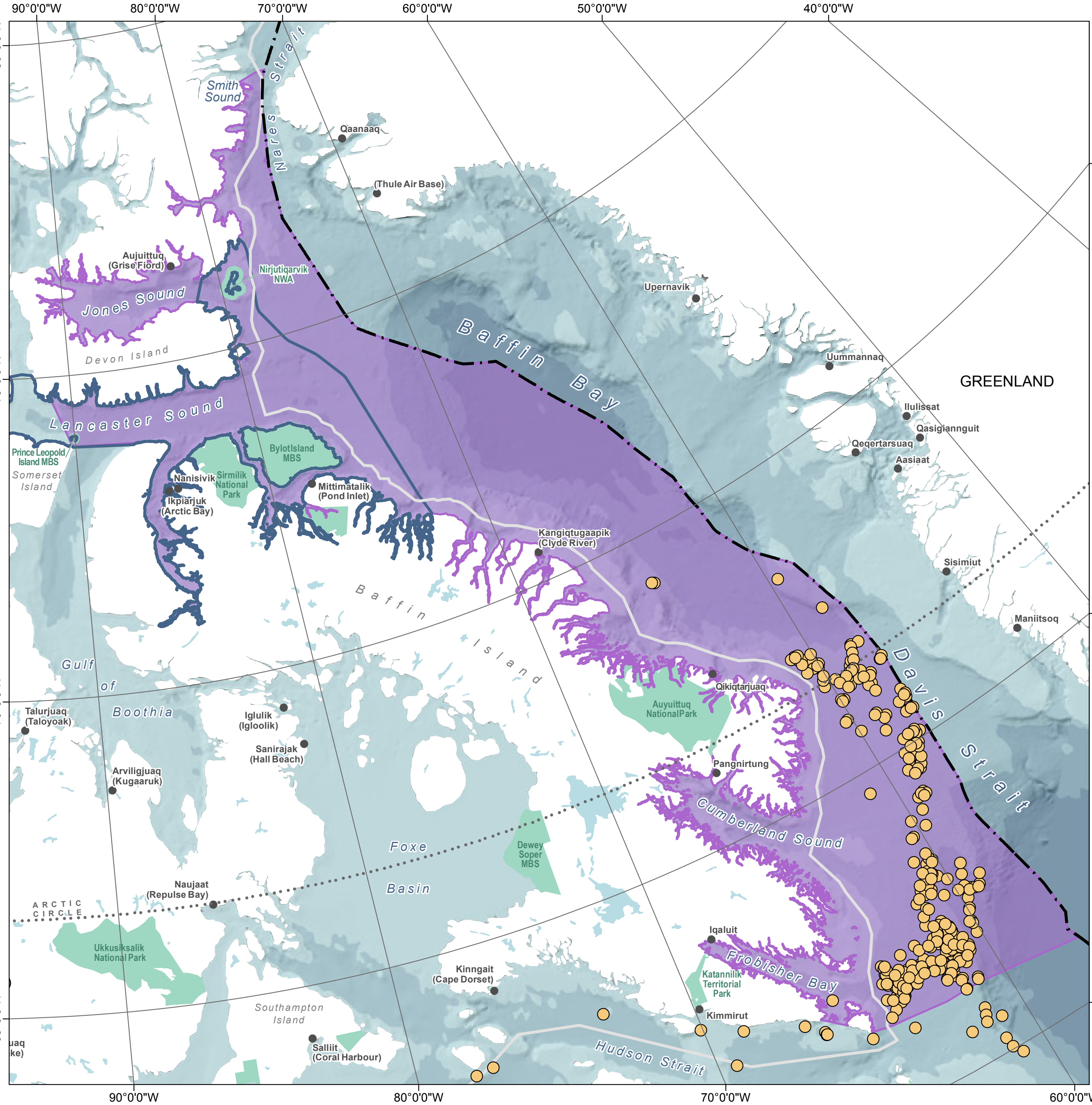
4.4.5 Sponges

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. 2012; Kenchington et al. 2013). 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 Area of Focus come from Fisheries and Oceans Canada (DFO) multispecies surveys, observer records, and species distribution modelling (Knudby et al. 2013).

The deep-sea sponges of the genus *Geodia* (*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 (see Figure 4.4) (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 (see Figure 4.4) (Knudby et al. 2013).

Results of the species distribution modelling determined that depth and salinity were generally the two most important variables in predicting the distribution of *Geodia* sp. (Knudby et al. 2013). There is a high probability that there are additional sponge grounds in the Area of Focus, and that sponges are likely to occur in the western part of Baffin Bay.



Base Features

- Community
- Limit of Exclusive Economic Zone[4]
- Nunavut Settlement Area[3]
- Tallurutiup Imanga / Lancaster Sound NMCA[2]
- Protected Area or National Park[4]

Bathymetry[5] Depth (m)

< 200 | 200 - 1000 | 1000 - 2000 | 2000 - 3000 | > 3000

Project Features

- Area of Focus[2]

Sponge Distribution[6,7]

- Geodia species

1:10,000,000

0 50 100 200 300 Kilometres

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Figure 4.4 Sponge Distributions

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[3]Nunavut Planning Commission, 2010
[4]National Framework Canada, 2017
[5]Natural Earth, 2016
[6]Knudby et al., 2013
[7]Kenchington et al., 2016

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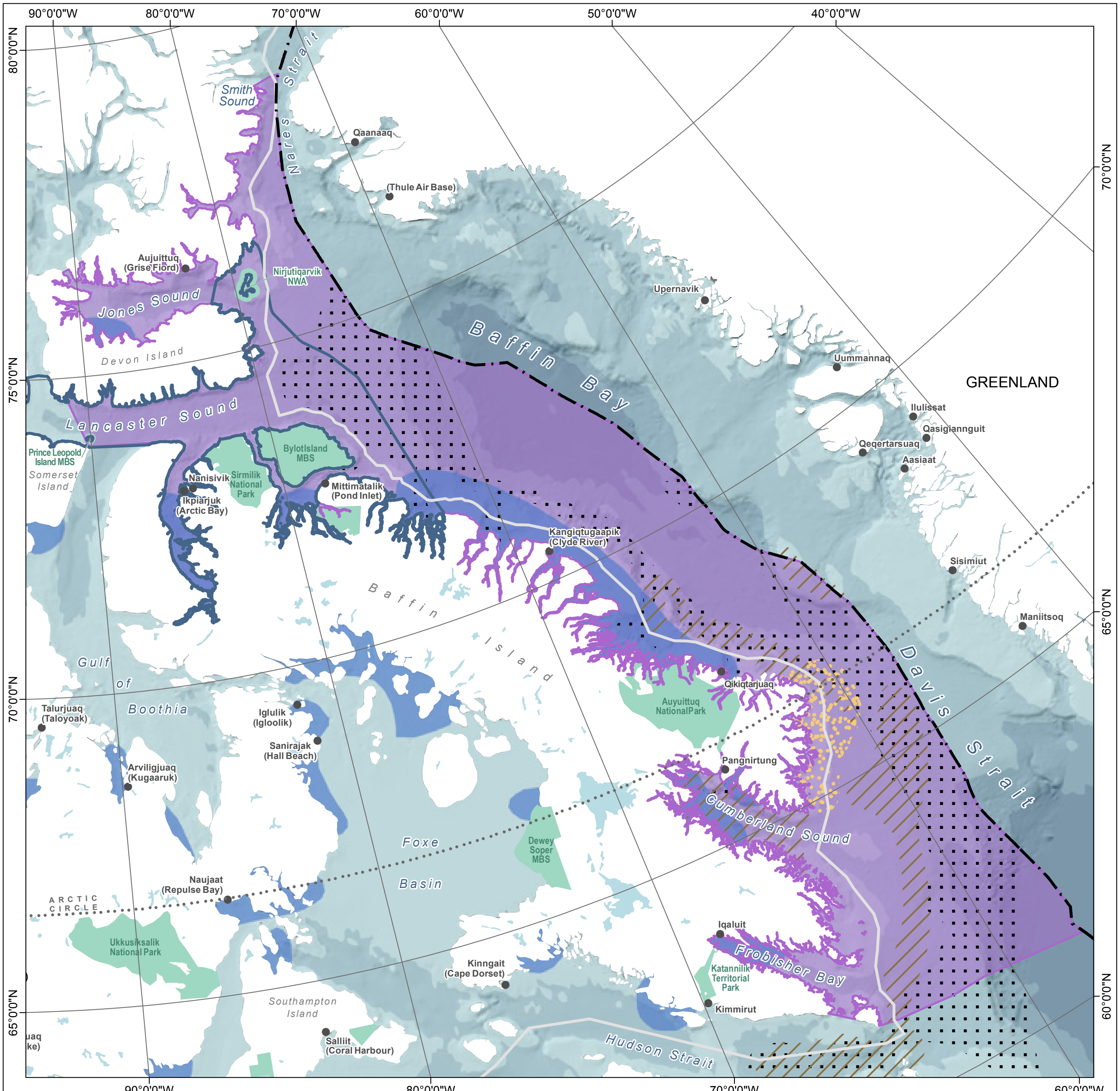
4.5 Fish and Fish Habitat

The following section describes the marine fishes (including ichthyoplankton, pelagic shrimp and squid) that may occur in or near the Area of Focus.

Biophysical features that describe fish habitat have been previously presented in Section 3 (physical environment) and in Sections 4.2, 0, and 4.4 (coast and shoreline, plankton, and benthic flora and fauna).

Sampling effort in the Canadian Arctic has not been sufficient to allow for a precise assessment of fish diversity and there is a need to develop systematic surveys (Darnis et al. 2012). However, the species diversity of marine fishes is lower in the Arctic when compared to that of the Atlantic and Pacific coasts of Canada (Darnis et al. 2012).

Coad and Reist (2004b) identified 189 marine fish species in the Arctic, of which 182 are found in Nunavut marine waters (Nunami Stantec 2012). Spatial information on fish abundance in the Area of Focus is available for northern shrimp, Greenland shark, Greenland halibut and arctic char (see Figure 4.5). A list of those marine fishes identified by Coad and Reist (2004b) that may occur in or near the Area of Focus is provided below in Table 4.7, along with their potential distribution in or near the Area of Focus.



Base Features

- Community
- Limit of Exclusive Economic Zone[4]
- Nunavut Settlement Area[3]
- Tallurutiup Imanga / Lancaster Sound NMCA[2]
- Protected Area or National Park[4]

Bathymetry[5] Depth (m)

< 200 | 200 - 1000 | 1000 - 2000 | 2000 - 3000 | > 3000

Project Features

- Area of Focus[2]

Areas of Abundance

- Northern Shrimp[6,7]
- Greenland Shark[6]
- Greenland Halibut[8]
- Arctic Char[6]

1:10,000,000

0 50 100 200 300

Kilometres

Nunavut Impact Review Board Strategic Environmental Assessment

Figure 4.5

Areas of Abundance for Northern Shrimp, Greenland Shark, Greenland Halibut and Arctic Char

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[3]Nunavut Planning Commission, 2010
[4]National Framework Canada, 2017
[5]Natural Earth, 2016
[6]Mercier et al, 1994
[7]Stephenson, S.A. and Hartwig, L. (Eds.), 2010
[8]Stephenson, S.A. and Hartwig, L., Arctic Marine Workshop, 2010

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Table 4.7 Marine Fishes that May Occur in the Area of Focus

Common Name	Scientific Name	Potential/Observed Distribution in or Near Area of Focus
Adolf's Eelpout	*Lycodes adolfi*	Baffin Bay and Davis Strait Offshore
Alligatorfish	*Aspidophoroides monopterygius*	Hudson Strait, Labrador Sea
American Plaice	*Hippoglossoides platessoides*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Nearshore and Offshore
Arctic Alligatorfish	*Ulcina olrikii*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Nearshore and Offshore, High Arctic Archipelago
Arctic Brotula	*Bythites fuscus*	Labrador Sea
Arctic Char	*Salvelinus alpinus*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Nearshore and Offshore, Lancaster Sound, High Arctic Archipelago
Arctic Cisco	*Coregonus autumnalis*	Lancaster Sound
Arctic Cod	*Boreogadus saida*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Nearshore and Offshore, Lancaster Sound, High Arctic Archipelago
Arctic Eelpout	*Lycodes reticulatus*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Nearshore and Offshore, Lancaster Sound, High Arctic Archipelago
Arctic Sculpin	*Myoxocephalus scorpioides*	Hudson Strait, Baffin Bay and Davis Strait Nearshore, Lancaster Sound
Arctic Shanny	*Stichaeus punctatus*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Nearshore and Offshore
Arctic Skate	*Amblyraja hyperborea*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Nearshore and Offshore, Lancaster Sound
Arctic Staghorn Sculpin	*Gymnocanthus tricuspis*	Hudson Strait, Baffin Bay and Davis Strait Nearshore, Lancaster Sound, High Arctic Archipelago
Arctic Telescope	*Protomyctophum articum*	Labrador Sea, Baffin Bay and Davis Strait Offshore
Atlantic Argentine	*Argentina silus*	Labrador Sea
Atlantic Cod	*Gadus morhua*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Nearshore and Offshore, Lancaster Sound
Atlantic Gymnast	*Xenodermichthys copei*	Labrador Sea
Atlantic Hagfish	*Myxine glutinosa*	Labrador Sea, Baffin Bay and Davis Strait Offshore
Atlantic Halibut	*Hippoglossus hippglossus*	Labrador Sea, Baffin Bay and Davis Strait Offshore
Atlantic Herring	*Clupea harengus*	Hudson Strait, Lancaster Sound
Atlantic Hookear Sculpin	*Artediellus atlanticus*	Labrador Sea, Baffin Bay and Davis Strait Nearshore and Offshore
Atlantic Poacher	*Leptagonus decagonus*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Nearshore and Offshore, Lancaster Sound
Atlantic Salmon	*Salmo salar*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Offshore
Atlantic Snailfish	*Liparis atlanticus*	Hudson Strait

Table 4.7 Marine Fishes that May Occur in the Area of Focus

Common Name	Scientific Name	Potential/Observed Distribution in or Near Area of Focus
Atlantic Soft Pout	*Melanostigma atlanticum*	Labrador Sea
Atlantic Spiny Lumpsucker	*Eumicrotremus spinosus*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Nearshore and Offshore, Lancaster Sound, High Arctic Archipelago
Atlantic Warbonnet	*Chirolophis ascanii*	Hudson Strait
Atlantic Wolffish	*Anarhichas lupus*	Hudsib Strait, Labrador Sea, Baffin Bay and Davis Strait Offshore
Aurora Pout	*Gymnelus retrodorsalis*	Baffin Bay and Davis Strait Nearshore, Lancaster Sound, High Arctic Archipelago
Banded Gunnel	*Pholis fasciata*	Hudson Strait, Lancaster Sound, High Arctic Archipelago
Barsukov's Pout	*Gymnelus barsukovi*	Hudson Strait
Bigeye Sculpin	*Triglops nybelini*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Nearshore and Offshore, Lancaster Sound, High Arctic Archipelago
Bigeye Smoothhead	*Bajacalifornia megalops*	Labrador Sea
Black Dogfish	*Centroscyllium fabricii*	Labrador Sea, Baffin Bay and Davis Strait Offshore
Black Scabbardfish	*Aphanopus carbo*	Labrador Sea
Black Seasnail	*Paraliparis bathybius*	Baffin Bay and Davis Strait Offshore
Black Swallower	*Chiasmodon niger*	Labrador Sea, Baffin Bay and Davis Strait Offshore
Blackfin Waryfish	*Scopelosaurus Lepidus*	Labrador Sea, Baffin Bay and Davis Strait Offshore
Blacksnout Snailfish	*Paraliparis copei*	Labrador Sea
Blue Antimora	*Antimora rostrata*	Labrador Sea
Boa Dragonfish	*Stomias boa*	Labrador Sea, Baffin Bay and Davis Strait Offshore
Brook Trout	*Salvelinus fontinalis*	Hudson Strait
Butterfish	*Peprilus triacanthus*	Labrador Sea
Can-Opener Smoothfish	*Chaenophryne longiceps*	Labrador Sea
Canadian Eelpout	*Lycodes Polaris*	Hudson Strait, Baffin Bay and Davis Strait Nearshore and Offshore, Lancaster Sound, High Arctic Archipelago
Capelin	*Mallotus villosus*	Hudson Strait, Baffin Bay and Davis Strait Nearshore and Offshore, Lancaster Sound
Carapine Grenadier	*Lionurus carapinus*	Labrador Sea
Checker Eelpout	*Lycodes vahlii*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Nearshore and Offshore
Checkered Wolf Eel	*Lycenchelys kolthoffi*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Offshore
Chevron Scutepout	*Lycodonus mirabilis*	Labrador Sea, Baffin Bay and Davis Strait Offshore
Cisco	*Coregonus artedi*	Hudson Strait, Lancaster Sound
Common Wolf Eel	*Lycenchelys paxillus*	Labrador Sea, Baffin Bay and Davis Strait Offshore

Table 4.7 Marine Fishes that May Occur in the Area of Focus

Common Name	Scientific Name	Potential/Observed Distribution in or Near Area of Focus
Daggertooth	*Anotopterus pharaoh*	Hudson Strait
Dainty Mora	*Halargyreus johnsonii*	Labrador Sea
Daubed Shanny	*Lumpenus maculatus*	Hudson Strait, Baffin Bay and Davis Strait Offshore, Lancaster Sound
Deepwater Chimera	*Hydrolagus affinis*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Offshore
Deepwater Redfish	*Sebastes mentella*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Nearshore and Offshore, Lancaster Sound
Diamondcheek Lanternfish	*Lampanyctus intricarius*	Labrador Sea
Doubleline Eelpout	*Lycodes eudipleurostictus*	Baffin Bay and Davis Strait Offshore, Lancaster Sound
Duckbill Barracudina	*Magnisudis atlantica*	Labrador Sea
Dusky Slickhead	*Alepocephalus agassizii*	Labrador Sea, Baffin Bay and Davis Strait Offshore
Fangtooth	*Anoplogaster cornuta*	Labrador Sea
Fish Doctor	*Gymnelus viridis*	Hudson Strait, Baffin Bay and Davis Strait Nearshore and Offshore, Lancaster Sound, High Arctic Archipelago
Fourhorn Sculpin	*Myoxocephalus quadricornis*	Hudson Strait, Baffin Bay and Davis Strait Nearshore, Lancaster Sound, High Arctic Archipelago
Fourline Snakeblenny	*Eumesogrammus praecisus*	Hudson Strait, Baffin Bay and Davis Strait Nearshore
Gelatinous Snailfish	*Liparis fabricii*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Nearshore and Offshore, Lancaster Sound, High Arctic Archipelago
Glacier Lanternfish	*Benthosema glacialis*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Offshore
Goitre Blacksmelt	*Bathylagus euryops*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Nearshore and Offshore
Golden Redfish	*Sebastes norvegicus*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Nearshore and Offshore, Lancaster Sound
Greater Eelpout	*Lycodes esmarkii*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Nearshore and Offshore
Greenland Cod	*Gadus ogac*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Nearshore, Lancaster Sound
Greenland Halibut	*Reinhardtius hippoglossoides*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Nearshore and Offshore, Lancaster Sound, High Arctic Archipelago
Greenland Shark	*Somniosus microcephalus*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Nearshore and Offshore, Lancaster Sound
Grubby	*Myoxocephalus aenaeas*	Hudson Strait
Günther's Grenadier	*Coryphaenoides guentheri*	Labrador Sea

Table 4.7 Marine Fishes that May Occur in the Area of Focus

Common Name	Scientific Name	Potential/Observed Distribution in or Near Area of Focus
Jewel Lanternfish	*Lampanyctus crocodilus*	Hudson Strait
Kelp Snailfish	*Liparis tunicatus*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Nearshore and Offshore, Lancaster Sound, High Arctic Archipelago
Krøyer's Lanternfish	*Notoscopelus kroeyerii*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Offshore
Lake Whitefish	*Coregonus clupeaformis*	Hudson Strait, Baffin Bay and Davis Strait Nearshore, Lancaster Sound
Large-Eye Snaggletooth	*Borostomias antarcticus*	Labrador Sea, Baffin Bay and Davis Strait Offshore
Largeye Lepidion	*Lepidion eques*	Hudson Strait, Labrador Sea
Largescale Lanternfish	*Symbolophorus veranyi*	Hudson Strait
Laval Eelpout	*Lycodes lavalaei*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Nearshore
Leatherfin Lumpsucker	*Eumicrotremus derjugini*	Hudson Strait, Baffin Bay and Davis Strait Nearshore, Lancaster Sound
Lightless Loosejaw	*Malacosteus niger*	Labrador Sea
Linen Skate	*Dipturus linteus*	Baffin Bay and Davis Strait Nearshore
Longear Eelpout	*Lycodes seminudus*	Baffin Bay and Davis Strait Nearshore, Lancaster Sound
Longfin Hake	*Urophycis chesteri*	Hudson Strait, Labrador Sea
Longfin Snailfish	*Careproctus longipinnis*	Hudson Strait
Longhorn Sculpin	*Myoxocephalus octodecemspinosus*	Hudson Strait
Lumpfish	*Cyclopterus lumpus*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Nearshore and Offshore
Lütken's Eelpout	*Lycodes luetkenii*	Baffin Bay and Davis Strait Offshore
Manylight Viperfish	*Chauliodus sloani*	Labrador Sea, Baffin Bay and Davis Strait Nearshore and Offshore
Manyray Smoothhead	*Alepocephalus bairdii*	Labrador Sea
Marlin-Spike	*Nezumia bairdii*	Labrador Sea
McAllister's Eelpout	*Lycodes mcallisteri*	Baffin Bay and Davis Strait Nearshore and Offshore
Moray Wolf Eel	*Lycenchelys muraena*	Baffin Bay and Davis Strait Offshore
Moustache Sculpin	*Triglops murrayi*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Nearshore and Offshore
Newfoundland Eelpout	*Lycodes terraenovae*	Labrador Sea, Baffin Bay and Davis Strait Offshore
Ninespine Stickleback	*Pungitius pungitius*	Hudson Strait, Baffin Bay and Davis Strait Nearshore, Lancaster Sound
Northern Cutthroat Eel	*Synaphobranchus kaupii*	Labrador Sea, Baffin Bay and Davis Strait Offshore
Northern Sand Lance	*Ammodytes dubius*	Hudson Strait, Baffin Bay and Davis Strait Nearshore

Table 4.7 Marine Fishes that May Occur in the Area of Focus

Common Name	Scientific Name	Potential/Observed Distribution in or Near Area of Focus
Northern Wolffish	*Anarhichas denticulatus*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Offshore
Ocean Pout	*Zoarces americanus*	Hudson Strait
Paamiut Eelpout	*Lycodes paamiuti*	Labrador Sea, Baffin Bay and Davis Strait Offshore
Pale Eelpout	*Lycodes pallidus*	Hudson Strait, Baffin Bay and Davis Strait Nearshore and Offshore
Pallid Sculpin	*Cottunculus thomsonii*	Labrador Sea, Baffin Bay and Davis Strait Nearshore
Pelican Gulper	*Eurypharynx pelecanoides*	Labrador Sea
Polar Cod	*Arctogadus glacialis*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Nearshore and Offshore, Lancaster Sound, High Arctic Archipelago
Polar Sculpin	*Cottunculus microps*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Offshore, Lancaster Sound
Pouty Snailfish	*Paraliparis garmani*	Labrador Sea, Baffin Bay and Davis Strait Offshore
Prickly Dreamer	*Spiniphryne gladisfenae*	Labrador Sea
Rakery Lanternfish	*Lampanyctus macdonaldi*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Offshore
Richardson's Snaggletooth	*Astronesthes richardsoni*	Labrador Sea
Ribbed Sculpin	*Triglops pingelii*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Nearshore, Lancaster Sound, High Arctic Archipelago
Rock Grenadier	*Coryphaenoides rupestris*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Offshore, Lancaster Sound
Roughhead Grenadier	*Macrourus berglax*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Nearshore and Offshore
Roughnose Grenadier	*Trachyrincus murrayi*	Labrador Sea
Round Skate	*Rajella fyllae*	Labrador Sea, Baffin Bay and Davis Strait Offshore
Round Whitefish	*Prosopium cylindraceum*	Hudson Strait
Russet Grenadier	*Nematonurus armatus*	Labrador Sea
Saddled Eelpout	*Lycodes mucosus*	Hudson Strait, Baffin Bay and Davis Strait Nearshore, Lancaster Sound, High Arctic Archipelago
Sars Wolf Eel	*Lycenchelys*	Baffin Bay and Davis Strait Offshore
Sea Tadpole	*Careproctus reinhardti*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Offshore, Lancaster Sound
Sharpchin Barracudina	*Paralepis coregonoides*	Labrador Sea, Baffin Bay and Davis Strait Offshore
Shortbeard Grenadier	*Coryphaenoides brevibarbis*	Labrador Sea
Shorthorn Sculpin	*Myoxocephalus Scorpius*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Nearshore, Lancaster Sound, High Arctic Archipelago

Table 4.7 Marine Fishes that May Occur in the Area of Focus

Common Name	Scientific Name	Potential/Observed Distribution in or Near Area of Focus
Shortspine Tapirfish	*Polyacanthonotus rissoanus*	Labrador Sea, Baffin Bay and Davis Strait Offshore
Shorttail Skate	*Amblyraja jenseni*	Hudson Strait, Labrador Sea
Silver Rockling	*Gaidropsarus argentatus*	Labrador Sea, Baffin Bay and Davis Strait Nearshore and Offshore
Slender Eelblenny	*Lumpenus fabricii*	Hudson Strait, Baffin Bay and Davis Strait Nearshore, Lancaster Sound, High Arctic Archipelago
Slender Snaggletooth	*Rhadinesthes decimus*	Labrador Sea
Slender Snipe Eel	*Nemichthys scolopaceus*	Labrador Sea, Baffin Bay and Davis Strait Offshore
Smooth Flounder	*Pleuronectes putnami*	Baffin Bay and Davis Strait Nearshore
Smooth Lumpfish	*Cyclopteropsis jordani*	Hudson Strait, Baffin Bay and Davis Strait Nearshore, Lancaster Sound
Snakeblenny	*Lumpenus lumpretaeformis*	Hudson Strait, Baffin Bay and Davis Strait Nearshore and Offshore
Snubnosed Spiny Eel	*Notocanthus chemnitzii*	Labrador Sea, Baffin Bay and Davis Strait Offshore
Soft Skate	*Malacoraja spinacidermis*	Baffin Bay and Davis Strait Offshore
Spark Anglemouth	*Gonostoma bathyphilum*	Labrador Sea
Spinytail Skate	*Bathyraja spinicauda*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Offshore
Spotted Wolffish	*Anarhichas minor*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Offshore
Stout Eelblenny	*Lumpenus medius*	Hudson Strait, Baffin Bay and Davis Strait Nearshore
Stout Sand Lance	*Ammodytes hexapterus*	Hudson Strait, Lancaster Sound
Stout Sawpalate	*Serrivomer beanii*	Labrador Sea, Baffin Bay and Davis Strait Offshore
Taillight Gulper	*Saccopharynx ampullaceus*	Labrador Sea
Thorny Skate	*Amblyraja radiata*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Nearshore and Offshore
Threadfin Snailfish	*Rhodichthys regina*	Baffin Bay and Davis Strait Offshore
Threebeard Rockling	*Gaidropsarus ensis*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Nearshore and Offshore
Threespine Stickleback	*Gasterosteus aculeatus*	Hudson Strait, Baffin Bay and Davis Strait Nearshore, High Arctic Archipelago
Twohorn Sculpin	*Icelus bicornis*	Hudson Strait, Baffin Bay and Davis Strait Nearshore and Offshore, Lancaster Sound, High Arctic Archipelago
Variegated Snailfish	*Liparis gibbus*	Hudson Strait, Baffin Bay and Davis Strait Nearshore and Offshore, Lancaster Sound
Veiled Anglemouth	*Cyclothone microdon*	Labrador Sea, Baffin Bay and Davis Strait Nearshore and Offshore

Table 4.7 Marine Fishes that May Occur in the Area of Focus

Common Name	Scientific Name	Potential/Observed Distribution in or Near Area of Focus
White Barracudina	*Arctozenus risso*	Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Offshore
White Sea Eelpout	*Lycodes marisalbi*	High Arctic Archipelago
Witch Flounder	*Glyptocephalus cynoglossus*	Labrador Sea
SOURCE: Coad and Reist (2004b)		

4.5.1 Select Fish Species Known to Occur in the Area of Focus

The following sections provide descriptions of species that fall into one or more of the following categories:

- Are locally, culturally and commercially important
- Are listed under the SARA
- Are listed by COSEWIC

4.5.1.1 Atlantic Cod

Atlantic cod are common in the Area of Focus and may occur in the Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait nearshore and offshore, and Lancaster Sound (Coad and Reist 2004b).

There is a limited commercial fishery for Atlantic cod in the Area of Focus, but this species is of very high commercial importance elsewhere in eastern Canada (Coad and Reist 2004b).

Atlantic cod in the Arctic marine environment are not listed under SARA or by COSEWIC; however, Atlantic cod of the Arctic Lakes population are listed as Special Concern by COSEWIC but are not listed under SARA (see Table 4.1 in Section 4.1) (COSEWIC 2010). The Arctic Lakes population of Atlantic cod exist in three coastal lakes on eastern coast of Baffin Island, including Ogac Lake, Qasigialiminiq Lake, and Tariujarusiq Lake (COSEWIC 2010). These lakes have physical barriers that prevent the movement of cod; however, all three of them receive intermittent tidal intrusions of salt water (COSEWIC 2010). Atlantic cod of the Newfoundland and Labrador population are listed as Endangered by COSEWIC but are not listed under SARA (COSEWIC 2010).

Atlantic cod are an epibenthic-pelagic species that occurs from the shallows down to 2,000 m water depth (Coad and Reist 2004b). Atlantic cod prey upon crustaceans and other fish (Coad and Reist 2004b).

Atlantic cod typically spawn over a period of less than three months in water that may vary in depth from tens to hundreds of metres (COSEWIC 2010). Atlantic cod are considered batch spawners, as females release only 5–25% of their egg complement at any given time and are known to release eggs every two to six days during a three to six-week spawning period (COSEWIC 2010).

4.5.1.2 Atlantic Wolffish

Atlantic wolffish are uncommon in the Area of Focus (Coad and Reist 2004b), but may occur in the Hudson Strait, Labrador Sea, and the Baffin Bay and Davis Strait offshore (Coad and Reist 2004b). Atlantic wolffish are listed as Species of Special Concern under Schedule 1 SARA and by COSEWIC (see Table 4.1 in Section 4.1) (COSEWIC 2012b). Atlantic wolffish have little-known economic value (Nunami Stantec 2012).

Atlantic wolffish are a benthic species that prefer the cold, deep waters of the continental shelf and occur from the shallows down to 600 m water depth (Coad and Reist 2004b; Kulka et al. 2007). Atlantic wolffish prefer rocky or hard clay bottoms (Kulka et al. 2007). They prey upon echinoderms, molluscs, crustaceans, and other fishes (Coad and Reist 2004b).

Atlantic wolffish are solitary, slow growing and have low fecundity (Kulka et al. 2007). Atlantic wolffish lay their eggs in nests that are then guarded (Kulka et al. 2007).

4.5.1.3 Arctic Char

Arctic char is a very abundant salmonid found throughout the Area of Focus that may occur in Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait Nearshore and Offshore, Lancaster Sound and the High Arctic Archipelago (Coad and Reist 2004b). Areas of abundance for Arctic char in the Area of Focus are shown above in Figure 4.5.

Arctic char is a culturally, nutritionally, and economically important species to northern communities (Nunami Stantec Ltd. 2010). Inuit from Arctic Bay, Clyde River, Grise Fiord, Iqaluit, Kimmirut, Pangnirtung, Pond Inlet, Qikiqtarjuaq and Resolute Bay report harvesting Arctic char as a main staple of their diet year-round (Priest and Usher 2004). Throughout its range, Arctic char are also important to commercial and sport fisheries (Coad and Reist 2004b).

Arctic char are anadromous and inhabit the shallow coastal waters of continental shelves (Coad and Reist 2004b). In the eastern Arctic, Arctic char are associated with most river mouths and nearshore areas along the eastern coast of Baffin Island and Lancaster Sound (Nunami Stantec Ltd. 2010). Arctic char are well adapted to Arctic lakes and rivers and, in many cases, are the only fish species that can inhabit the more northern aquatic ecosystems (Nunami Stantec Ltd. 2010). Some Arctic char only occur in lakes and do not enter marine waters (Coad and Reist 2004b).

The largest recorded run of Arctic char occurs in the Iqaluit River on Baffin Island, where 282,500 individuals were reported (Nunami Stantec Ltd. 2010).

Arctic char eat crustaceans and other fishes (Coad and Reist 2004b).

During the NCRI in Qikiqtarjuaq, it was noted by interviewees that the abundance of char in the Qikiqtarjuaq area varies year by year (Nunavut Department of Environment 2010); this could be due to a large winter harvest, or insufficient rain to permit char migration back to spawning areas in nearby lakes (Nunavut Department of Environment 2010). During the NCRI in Grise Fiord, some interviewees noted that there is more char in the area, while others thought that char numbers have decreased near town

(Nunavut Department of Environment n.d.). Char with very thick skin have been harvested at Pond Inlet. Community members indicate that these are a different type of char or salmon (Kilukishuk 2001, as cited in Nunavut Tunngavik Inc. 2001).

4.5.1.4 Arctic Cod

Arctic cod are abundant in the Area of Focus and may occur in the Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait nearshore and offshore, Lancaster Sound, and the High Arctic Archipelago (Coad and Reist 2004b).

There are very few fisheries for Arctic cod and this species is of little commercial and subsistence use but are a critical component of the Arctic marine food web. Arctic cod regularly occur in open waters but are also associated with the underside of sea ice and occur from the shallows down to 1,383 m water depth (Coad and Reist 2004b). Arctic cod are mainly found in the upper part of the water column and are often associated with drifting pack ice (Scott and Scott 1988).

Arctic cod prey upon plankton, crustaceans, and other fishes, including fish eggs and fry (Coad and Reist 2004b; Cosens et al. 1990). Arctic cod spawn under the ice during winter months (Bradstreet et al. 1986; Craig et al. 1982).

Arctic cod occasionally form very large and dense schools in the Canadian Arctic during the open-water season, sometimes approaching shore and becoming visible to people on land, in boats or in aircraft (Crawford and Jorgenson 1993; Welch et al. 1993). Arctic cod are an important prey species for many marine organisms, and large schools attract predators including seabirds, whales, and other fish species (Bradstreet et al. 1986; Coad and Reist 2004b).

It was noted in (NWMB 1998), that near Kimmirut, beluga whales feed on Arctic cod at the floe edge in spring, and when following the direction of the currents in the summer. Some of the hunters in Kimmirut think there has been a decline in Arctic cod in the area, or that the fish have moved to another area (NWMB 1998). It was noted by Inuit in Iqaluit that no large schools of Arctic cod have been observed in Frobisher Bay, as they were in the past (Nunavut Department of Environment 2005).

4.5.1.5 Arctic Skate

Arctic skate are common in the Area of Focus and may occur in the Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait nearshore and offshore, and Lancaster Sound (Coad and Reist 2004b).

Arctic skate are caught as bycatch in longline and trawl fisheries for Greenland halibut (Coad and Reist 2004b).

Arctic skate are a benthic species that prefers cold, deep waters up to 2,500 m (Coad and Reist 2004b; Jørgensen et al. 2005a). The biology of Arctic skate is poorly understood; however, it is known that they prey upon crustaceans and other fishes (Coad and Reist 2004b).

4.5.1.6 Capelin

Capelin are abundant in the Area of Focus and may occur in Hudson Strait, Baffin Bay and Davis Strait Nearshore and Offshore, and Lancaster Sound (Coad and Reist 2004b). They are found from the shallows up to 725 m water depth (Coad and Reist 2004b).

Within the Area of Focus, capelin represents a local food source, and are important to commercial fisheries outside the Area of Focus (i.e., northeast coast of Newfoundland) (Coad and Reist 2004b).

Capelin are an important forage fish species and food source for other fish species, marine mammals and seabirds (Scott and Scott 1988). As a result, capelin are an important link between primary producers (plankton is described above in Section 5.3) and higher trophic levels (Burton and Flynn 1998).

Capelin require cold, deep waters, but move inshore to spawn in areas with coarse sand and/or gravel (Scott and Scott 1988). Coastal spawning and staging areas are critical to the sustainability of capelin and represent key foraging areas for top predators (Davoren et al. 2006). Due to their ecological importance, coastal spawning and staging areas are critical to the sustainability of capelin stocks, and therefore critical areas for conservation (Davoren et al. 2006).

Capelin are considered planktivores, but will also eat marine worms, and small fishes (Coad and Reist 2004b).

4.5.1.7 Fourhorn Sculpin

Fourhorn sculpin are very abundant in the Area of Focus and the marine form may occur in Hudson Strait, Baffin Bay and Davis Strait Nearshore, Lancaster Sound, and the High Arctic Archipelago (Coad and Reist 2004b).

Fourhorn sculpin is occasionally caught as food fish throughout coastal Nunavut (Nunami Stantec 2012).

Fourhorn sculpin is a benthic species that inhabit shallow water up to 45 m in depth (Coad and Reist 2004b). This species is often associated with shallow brackish waters such as those found in estuaries (Scott and Scott 1988).

Fourhorn sculpin eat crustaceans, molluscs, and other fish (Coad and Reist 2004b).

4.5.1.8 Greenland Cod

Greenland cod are abundant in the Area of Focus and may occur in the Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait nearshore, and Lancaster Sound (Coad and Reist 2004b). They are of little commercial importance within the Area of Focus (Coad and Reist 2004b).

Greenland cod are a benthic species that occurs in the shallows down to 400 m water depth (Coad and Reist 2004b). Greenland cod prey upon crustaceans, molluscs, starfish, marine worms, and other fish (Coad and Reist 2004b).

4.5.1.9 Greenland Halibut

Greenland halibut are very abundant in the Area of Focus and may occur in the Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait nearshore and offshore, Lancaster Sound, and the High Arctic Archipelago (Coad and Reist 2004b). Greenland halibut are most abundant in Cumberland Sound and north through Davis Strait (Parks Canada 1995). Areas of abundance for Greenland halibut in the Area of Focus are shown above in Figure 4.5.

Greenland halibut are becoming increasingly important in the development of commercial fisheries in the eastern Arctic (Coad and Reist 2004b). There has been a winter fishery for Greenland halibut in Cumberland Sound (near Pangnirtung) since 1986 (Nunami Stantec 2012). Greenland halibut is a valuable resource for communities in the Area of Focus, in terms of traditional and commercial importance through, for example, the Inuit-owned Cumberland Sound Fisheries Ltd. in Pangnirtung. There has been interest in extending the Cumberland Sound Greenland halibut fishery boundary line to develop a summer fishery (Nunavut Department of Environment n.d.).

Greenland halibut are an epibenthic flatfish that typically occur along continental slopes from surface water down to 2,000 m water depth (Boertmann and Mosbech 2011; Coad and Reist 2004b). In Baffin Bay and Davis Strait, Greenland halibut are most abundant between 800–1,200 m (Coad and Reist 2004b). While Greenland halibut spend most of their time on the bottom, they make frequent migrations into the water column to feed (Boertmann and Mosbech 2011). It has also been noted that larger fish are generally found at deeper depths (Scott and Scott 1988).

Greenland halibut are believed to spawn in Davis Strait in winter or early spring at depths of 650-1,000 m (Scott and Scott 1988). Greenland halibut prey upon crustaceans, squid, and other fishes (Coad and Reist 2004b).

An NCRI was conducted in the community of Pangnirtung in 2013 (Nunavut Department of Environment n.d.). During this exercise, IQ on Greenland halibut in Cumberland Sound was gathered. Areas of occurrence were noted in the inner parts of Cumberland Sound and extending to near the mouth of the Sound. In these areas, Greenland halibut were present from January to April. During the gathering of IQ, it was also noted that during the 1990s, there were less Greenland halibut and more Greenland sharks early in the winter (Nunavut Department of Environment n.d.).

In addition to observations on the presence of Greenland halibut, concerns were raised during the gathering of IQ that changes in sea ice patterns are affecting the winter fishing seasons (Nunavut Department of Environment n.d.). It has been observed that ice is more inconsistent and dangerous, with ice break up occurring earlier in the year. It was suggested that a road be built around the mouth of the fiord to allow for fish harvesters to get around the unsafe ice (Nunavut Department of Environment n.d.).

4.5.1.10 Greenland Shark

Greenland shark are common in the Area of Focus and may occur in the Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait nearshore and offshore, and Lancaster Sound (Coad and Reist 2004b). In the North Atlantic, Greenland sharks are found from Baffin Island south to the Scotian Shelf, and occasionally further south in the Gulf of Maine (DFO 2018c). Areas of abundance for Greenland shark in the Area of Focus are shown above in Figure 4.5.

Greenland shark are caught as substantive bycatch in longline commercial fisheries for Greenland halibut (Coad and Reist 2004b). This species was once used as dog food and is commercially important elsewhere (Coad and Reist 2004b).

Greenland shark are a large epibenthic-pelagic species that occurs from the shallows down to 1,067 m water depth (Coad and Reist 2004b). Greenland shark are scavengers that feed on marine mammals, fishes, and invertebrates (Coad and Reist 2004b; DFO 2018c). Greenland shark are ovoviviparous and can have litters of up to 10 pups (DFO 2018c).

4.5.1.11 Northern Wolffish

While northern wolffish are common in the Area of Focus, the Arctic and Atlantic populations of this species are listed as Threatened under Schedule 1 of SARA and by COSEWIC (see Table 4.1 in Section 4.1) (COSEWIC 2012d). There have been significant declines in the abundance of northern wolfish; in the core range off northeast Newfoundland, there was a 98% decrease in abundance between 1978 and 1994 (COSEWIC 2012d). Within the Area of Focus, northern wolffish may occur in the Hudson Strait, Labrador Sea, and Baffin Bay and Davis Strait offshore (Coad and Reist 2004b).

Northern wolffish are caught as bycatch in fisheries for Greenland halibut and snow crab (DFO 2004; Kulka and Simpson 2004).

Northern wolffish are an epibenthic species that occurs from the shallows down to 1,700 m water depth (Coad and Reist 2004b). Generally, northern wolffish are found at depths greater than 100 m and are most common between 150 and 900 m (COSEWIC 2012d). Northern wolffish prefer areas with soft bottoms in proximity to boulders, and with water temperatures less than 5°C (Scott and Scott 1988).

Fecundity is low in northern wolffish, and spawning is thought to occur over an extended period from April to October (Scott and Scott 1988). Northern wolffish prey upon crustaceans, echinoderms, molluscs, comb jellies, jellyfish, and other fish (Coad and Reist 2004b).

4.5.1.12 Polar Cod

Polar cod are common in the Area of Focus and may occur in the Hudson Strait, Labrador Sea, Baffin Bay and Davis Strait nearshore and offshore, Lancaster Sound, and the High Arctic Archipelago (Coad and Reist 2004b).

Arctic cod are fished locally in subsistence fisheries (Coad and Reist 2004b).

Arctic cod regularly occur in open waters but are also associated with the underside of sea ice and occur in from the shallows down to 930 m water depth (Coad and Reist 2004b). Arctic cod prey on crustaceans and other fishes (Coad and Reist 2004b).

4.5.1.13 Roughhead Grenadier

While roughhead grenadier are abundant in the Area of Focus, the Atlantic population of roughhead grenadier is listed as Special Concern by COSEWIC (no listing under SARA) (see Table 4.1 in Section 4.1) (COSEWIC 2007a). Within the Area of Focus, roughhead grenadier may occur in the Hudson Strait, Labrador Sea, and Baffin Bay and Davis Strait nearshore and offshore (Coad and Reist 2004b).

There are no commercial fisheries for roughhead grenadier in the Area of Focus, but this an important commercial species elsewhere in Atlantic Canada (Coad and Reist 2004b). Roughhead grenadier are occasionally caught as bycatch in Greenland halibut fisheries in Cumberland Sound and Davis Strait (Nunami Stantec 2012).

Roughhead grenadier are an epibenthic species that occur in deep waters down to 2,740 m (Coad and Reist 2004b) but are most abundant between 200–600 m (Scott and Scott 1988). This species is slow growing, late maturing, and has low fecundity (COSEWIC 2007a). Roughhead grenadier prey upon marine worms, molluscs, crustaceans, squid, brittle stars and other fishes (Coad and Reist 2004b).

4.5.1.14 Spotted Wolffish

Spotted wolffish are common in the Area of Focus and may occur in the Hudson Strait, Labrador Sea, and Baffin Bay and Davis Strait offshore (Coad and Reist 2004b). Spotted wolffish are listed as Threatened under Schedule 1 of SARA and by COSEWIC (see Table 4.1 in Section 4.1) (COSEWIC 2012a).

Spotted wolffish are caught mainly as bycatch in commercial fisheries for Greenland halibut and snow crab (DFO 2004; Kulka and Simpson 2004). Bottom trawling in the region may disrupt or destroy spawning habitat, and oil and gas exploration and development could also pose a threat to wolffish habitat (Jennings and Kaiser 1998; Kulka et al. 2007).

Spotted wolffish are a benthic species that occurs from the shallows down to 600 m water depth (Coad and Reist 2004b). Spotted wolffish prey upon echinoderms, crustaceans, molluscs, worms, and fishes (Coad and Reist 2004b), but mainly feed on molluscs and echinoderms (Kulka and Simpson 2004). Fecundity is low in spotted wolfish, and they are thought to spawn late in the year (DFO 2004).

4.5.1.15 Thorny Skate

Thorny skate are common in the Area of Focus; however, they are listed as species of Special Concern by COSEWIC but not listed under SARA (see Table 4.1 in Section 4.1) (COSEWIC 2012c). Within the Area of Focus, thorny skate may occur in the Hudson Strait, Labrador Sea, and Baffin Bay and Davis Strait nearshore and offshore (Coad and Reist 2004b).

Thorny skate are caught as bycatch in longline and trawl commercial fisheries for Greenland halibut, and are a commercially important species elsewhere in Atlantic Canada (Coad and Reist 2004b).

Thorny skate are a benthic species that occurs from the shallows to 996 m water depth on both hard and soft bottoms (Coad and Reist 2004b; Scott and Scott 1988). Thorny skate prey upon marine worms, crustaceans, and other fishes (Coad and Reist 2004b). Thorny skate are long lived and, while fecundity is low for this species, they may spawn in any month of the year (Scott and Scott 1988; Sulikowski et al. 2005).

4.5.1.16 Northern Shrimp

Northern shrimp are most abundant north of 46ºN, and within the Area of Focus, are found in Cumberland Sound, Davis Strait and Hudson Strait (Koeller 2000; Stephenson and Hartwig 2010). Areas of abundance for northern shrimp in the Area of Focus are shown above in Figure 4.5.

There is a year-round fishery for northern shrimp off the east coast of Baffin Island and in Hudson Strait (Orr et al. 2006). This fishery includes striped pink shrimp (*Pandalus montagui*) (Orr et al. 2006).

Northern shrimp are most abundant at depths greater than 200 m, generally occur on soft substrates (mud, sand, and clay), and prefer temperatures of 1–6ºC (Koeller 2000). They prey upon marine worms, small crustaceans, detritus and marine plants during the day, and then migrate vertically in the water column to prey upon copepods and euphausiids at night (DFO 2006).

In the North Atlantic, northern shrimp are preyed upon by 26 species of marine fish, marine mammals, and invertebrates including seals, Greenland halibut, and Arctic cod (DFO 2006; Parsons 2005).

4.5.1.17 Squid

Gonatus fabricii is the most abundant squid in Arctic and sub-Arctic marine waters (Bjørke 2001).

Squid are sometimes used as bait in fisheries for Greenland halibut and snow crab (Frandsen and Wieland 2004).

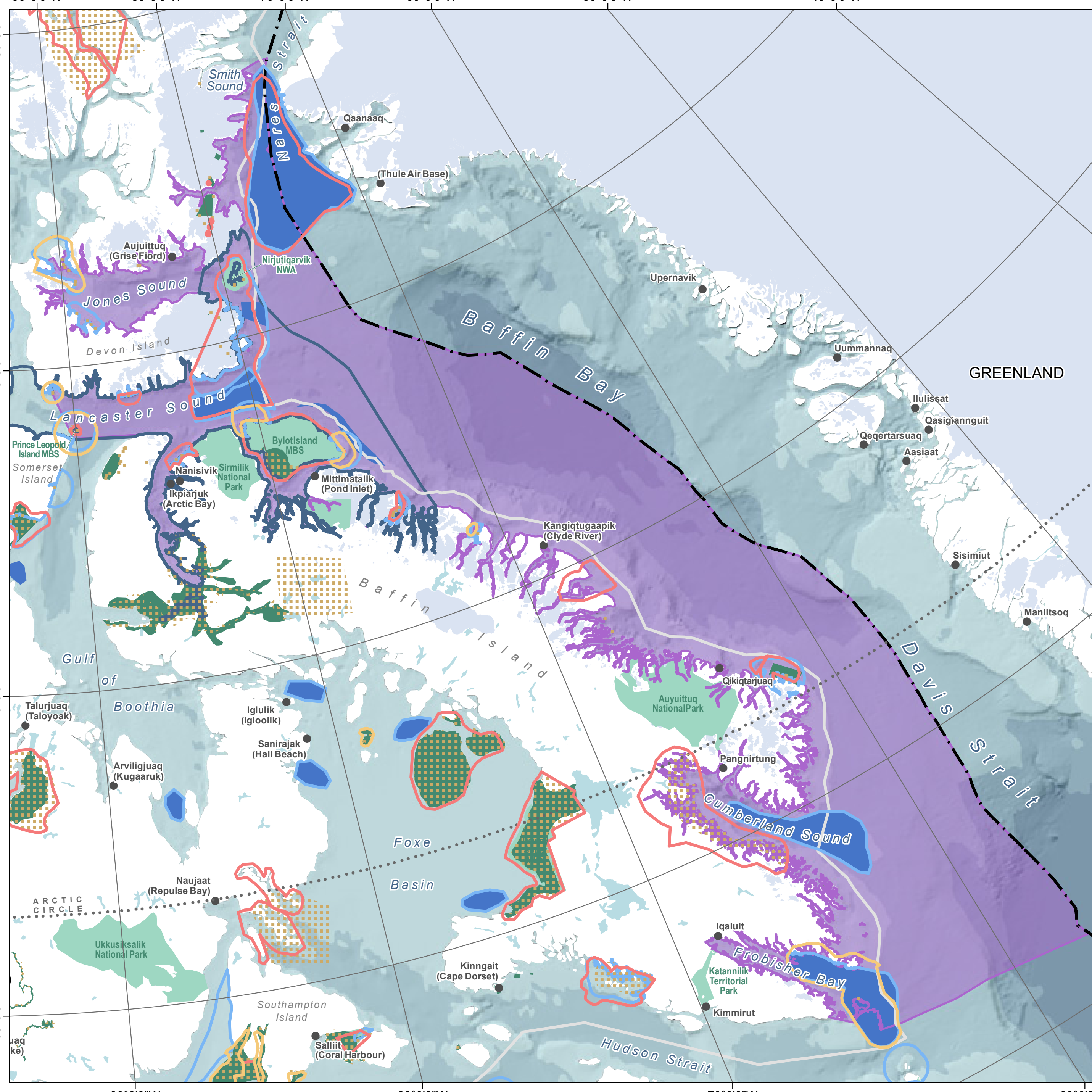
Young squid occur most often in the upper 60 m of the water column, but upon reaching adult length, they descend to depths of 400–1,000 m (Bjørke 2001; Frandsen and Wieland 2004).

Squid are an important prey species for a variety of fish and marine mammal species, including narwhals and seals, and potentially beluga whales (Bjørke 2001; Finley and Gibb 1982b; Richard et al. 1998; Sergeant 1991). Dawe et al. (1998) analyzed the stomach contents of Greenland halibut on the northeast Newfoundland continental shelf in 1,000–1,250 m of water, and results showed that squid were the predominant prey source.

4.6 Waterbirds

Western Baffin Bay and Davis Strait provide a variety of coastal and offshore habitats for waterbirds, including sheltered inlets and bays, estuaries, exposed waters, sounds, islands, islets, and cliffs (see Figure 4.6). While several species will use coastal and offshore areas in Baffin Bay and Davis Strait year-round, this region serves as important breeding grounds and staging area for millions of waterfowl, seabirds, and shorebirds on their way to and from arctic breeding grounds (see Figure 4.7) The Area of Focus is located along the Atlantic Flyway, which extends to Nunavut and parts of the Northwest Territories south through eastern Canada and the US, across the Caribbean Sea (Atlantic Flyway Shorebird Initiative 2016). Approximately 500 species, including many species of waterfowl, seabirds, and shorebirds in North America migrate along this flyway. Many waterbirds that migrate as far north as the arctic tend to form extremely large aggregations near foraging or breeding sites.

Approximately 40 waterbird species are known to regularly use habitats in the Area of Focus during breeding, wintering, or migratory periods (Table 4.8) (Birds of North America Online 2017; Mallory and Fontaine 2004). Most waterbirds occurring in the Area of Focus have secure populations; however, four species have been designated as at risk by COSEWIC and/or are listed on Schedule 1 of SARA (Table 4.8). Many waterbird species are used traditionally by local Inuit groups, as identified through oral and written evidence provided in IQ and TK studies.



Base

- Community
- Limit of Exclusive Economic Zone[4]
- Nunavut Settlement Area[3]
- Tallurutiup Imanga / Lancaster Sound NMCA[2]
- Protected Area or National Park[4]

Bathymetry[5] Depth (m)

< 200 | 200 - 1000 | 1000 - 2000 | 2000 - 3000 | > 3000

Project Features

- Area of Focus[2]
- Key Migratory Bird Habitat[6]
- Polynyas[7]
- Key Marine Habitat Site[8]
- Key Terrestrial Habitat Site[7, 9]

Key Habitat Site[10]

- Highly Risk Intolerant
- Moderately Risk Intolerant

1:10,000,000

0 50 100 200 300

Kilometres

Nunavut Impact Review Board Strategic Environmental Assessment

Figure 4.6 Important Habitats for Waterbirds

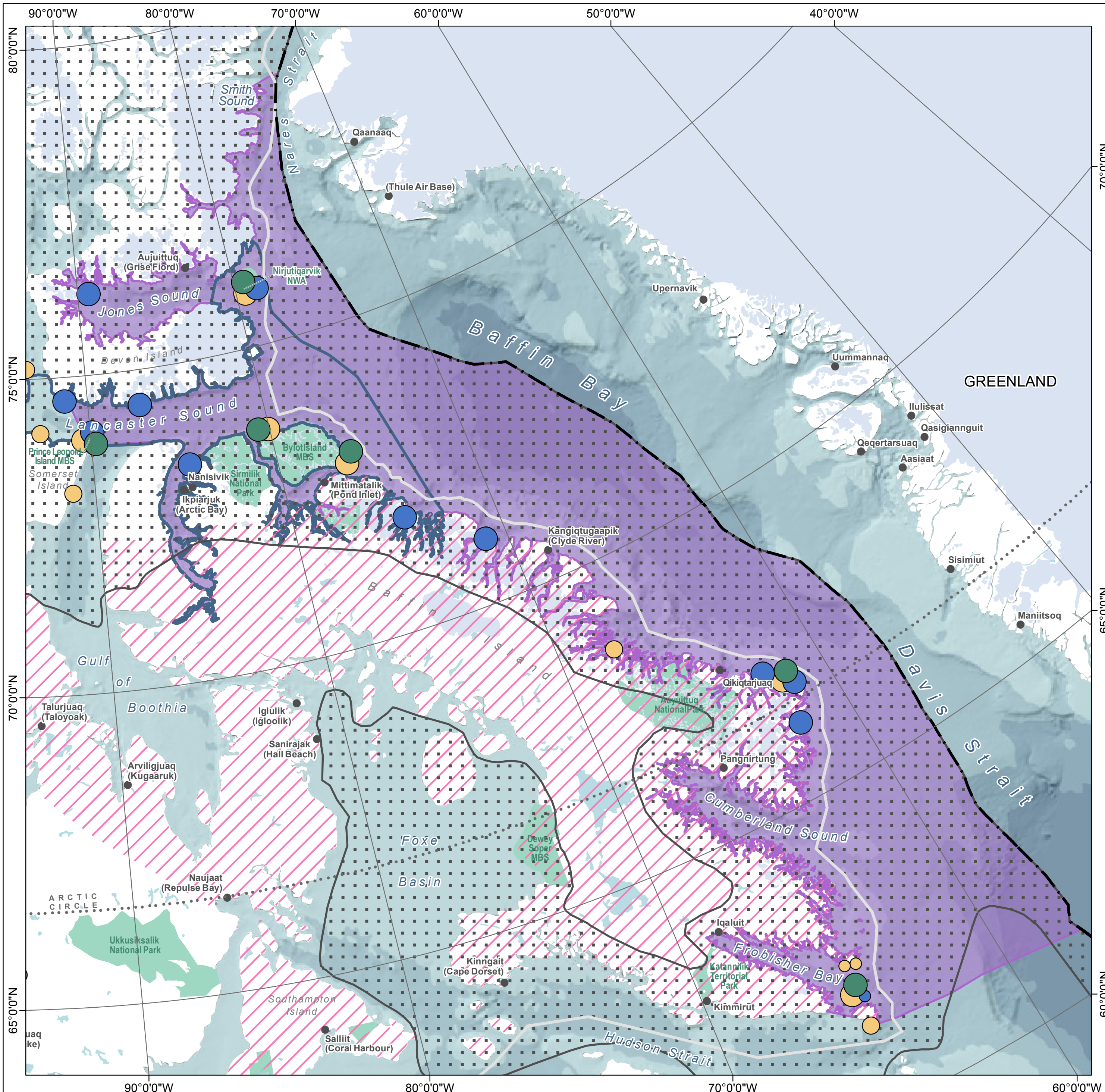
NUNAMI STANTEC LIMITED

N.I.R.B.

Prepared By: Nunami Stantec Limited
Projection: Canada Lambert Conformal Conic, North American 1983
Date: Apr 13, 2018
Project Number: 12322100
Produced By: L. Trudell
Verified By: J. Beckett
Revision: 01

References:
[1]Atlas of Canada Base Maps, 2017
[2]NIRB, 2017
[3]Nunavut Planning Commission, 2010
[4]National Framework Canada, 2017
[5]Natural Earth, 2016
[6]Government of Nunavut, 1991
[7]Mallory, M.L. and Fontaine A.J., 2004
[8]Canadian Wildlife Service, 2004
[9]Canadian Wildlife Service. 2008
[10]Environment and Climate Change Canada, 2016

Filepath: S:\1232\projects\123221001\figures\report\SEA\fig_123221001_NIRB_SEA_04.6_Important_Habitats_for_Waterbirds_in_the_Area_of_Focus.mxd



Base

- Community
- Limit of Exclusive Economic Zone[4]
- Nunavut Settlement Area[3]
- Tallurutiup Imanga / Lancaster Sound NMCA[2]
- Protected Area or National Park[4]

Bathymetry[5] Depth (m)

< 200 | 200 - 1000 | 1000 - 2000 | 2000 - 3000 | > 3000

Project Features

- Area of Focus[2]
- Red Knot, *Rufa* Subspecies Breeding Range[6]
- Ivory Gull Breeding Range[7]

1:10,000,000

0 50 100 200 300

Kilometres

Marine Bird Colony Size and Species[8]

- > 1000
- 50 - 999
- 1 - 49

- Black-legged Kittiwake
- Northern Fulmar
- Thick-billed Murre

Nunavut Impact Review Board Strategic Environmental Assessment

Figure 4.7 Seabird and Shorebird Distribution

NUNAMI STANTEC LIMITED

N.I.R.B.

Prepared By: Nunami Stantec Limited
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[2]NIRB, 2017
[3]Nunavut Planning Commission, 2010
[4]National Framework Canada, 2017
[5]Natural Earth, 2016
[6]Environment Canada, 2012
[7]Environment Canada, 2017
[8]Mallory, M.L. and Fontaine, A.J., 2004

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Table 4.8 Overview of Waterbird Species Associated with Marine Environments in the Area of Focus

Species	Scientific Name	NatureServe Status[1,2]	COSEWIC or SARA Designation	Occurrence in the Area of Focus[2]
Coastal Waterfowl				
Yellow-billed Loon	*Gavia adamsii*	S4B, S4M	NAR (COSEWIC)	B, M
Common Loon	*Gavia immer*	S5B, S5M	NAR (COSEWIC)	B, M
Pacific Loon	*Gavia pacifica*	SUB, SUM	–	B, M
Red-throated Loon	*Gavia stellata*	S4B, S4M	–	B, M
Canada Goose	*Branta canadensis*	S5B, S5M	–	B, M
Cackling Goose	*Branta hutchinsii*	S5B, S5M	–	B, M
Greater White-fronted Goose	*Anser albifrons*	S5B, S5M	–	M
Snow Goose	*Chen caerulescens*	S5B, S5M	–	B, M
Ross's Goose	*Chen rossii*	S5B, S5M	–	B, M
Brant	*Branta bernicla*	S5B, S5M	–	B
Tundra Swan	*Cygnus colombianus*	S5B, S5M	–	B, M
Red-breasted Merganser	*Mergus serrator*	S5B, S5M	–	B, M
King Eider	*Somateria spectabilis*	S3B, SUN, S3M	–	B, M, W
Common Eider	*Somateria mollissima*	S3B, S3N, S3M	–	B
Harlequin Duck	*Histrionicus histrionicus*	S3B, S3M	–	B, M, W
Long-tailed Duck	*Clangula hyemalis*	S4B, SUN, S4M	–	B, M, W
Seabirds				
Black Guillemot	*Cepphus grylle*	S5B, S5N, S5M	–	B, M, W
Dovekie	*Alle alle*	S3B, S3M	–	B, M, W
Thick-billed Murre	*Uria lomvia*	S5B, S5N, S5M	–	B, M, W
Atlantic Puffin	*Fratercula arctica*	S3B, S3M	–	W
Glaucous Gull	*Larus hyperboreus*	S4B, SUN, S4M	–	B, M, W
Iceland Gull	*Larus glaucoides*	S5B, SUN, S5M	–	B, M, W
Thayer's Gull	Larus thayeri	S4S5B, S4S5M	–	B
Ivory Gull	Pagophila eburnea	S1B, S1N, S1M	SC (COSEWIC) E (SARA)	B, M, W
Sabine's Gull	*Xema sabini*	S4S5B, S4S5M	–	B
Arctic Tern	*Sterna paradisaea*	S4B, S4M	–	B, M

Table 4.8 Overview of Waterbird Species Associated with Marine Environments in the Area of Focus

Species	Scientific Name	NatureServe Status[1,2]	COSEWIC or SARA Designation	Occurrence in the Area of Focus[2]
Northern Fulmar	*Fulmarus glacialis*	S5B, S5M	–	B
Parasitic Jaeger	*Stercorarius parasiticus*	S4S5B, S4S5M	–	B, M
Long-tailed Jaeger	*Stercorarius longicaudus*	S5B, S5M	–	B
Shorebirds				
Ruddy Turnstone	*Arenaria interpres*	S3B, S3M	–	B
Sanderling	*Calidris alba*	S3B, S3M	–	B
Baird's Sandpiper	*Calidris bairdii*	S5B, S5M	–	B
Red Knot	*Calidris canutus*	S2B, S2M	E (SARA, rufa ssp.) SC (SARA, islandica ssp.)	B, M
White-rumped Sandpiper	*Calidris fuscicollis*	S5B, S5M	–	B
Purple Sandpiper	*Calidris maritima*	S3B, S3M	–	B
Pectoral Sandpiper	*Calidris melanotos*	S4B, S4M	–	B
Semipalmated Sandpiper	*Calidris pusilla*	S3B, S3M	–	B
Buff-breasted Sandpiper	*Calidris subruficollis*	S3B, S3M	SC (SARA)	B
Common Ringed Plover	*Charadrius hiaticula*	S4B, S4M	–	B
Semipalmated Plover	*Charadrius semipalmatus*	S4B, S4M	–	B
American Golden Plover	*Pluvialis dominica*	S3B, S3M	–	B
Black-bellied Plover	*Pluvialis squatarola*	S3B, S3M	–	B
Red Phalarope	*Phalaropus fulicarius*	S4B, S4M	–	B, M
Red-necked Phalarope	*Phalaropus lobatus*	S3B, S3M	SC (COSEWIC)	B, M

NOTES:
[1] NatureServe Rankings are based on CESCC (2016) and are defined as:
- Geographic Scale: N = National, S = Subnational
- Conservation Status: X = Presumed Extirpated, H = Possibly Extirpated, 1 = Critically Imperiled, 2 = Imperiled, 3 = Vulnerable, 4 = Apparently Secure, 5 = Secure, U = Unrankable, NR = Not Rankable, NA = Not Applicable

[2] B = Breeding, M = Migration, W = Wintering
[3] E = Endangered, NAR = Not at Risk, SC = Special Concern,

4.6.1 Coastal Waterfowl

The Area of Focus provides seasonal or year-round habitat for loons, swans, geese, and diving ducks. Species occurrence and conservation status for select species are described in Table 4.8.

4.6.1.1 Distribution

Loons, swans, and geese occurring in Nunavut typically use coastal areas, tundra, and inland lakes for breeding. Species within these guilds generally occur in the Area of Focus during migration to and from arctic breeding grounds and wintering along the Atlantic or Pacific coasts, Great Lakes, Gulf of Mexico, or inland areas of North or Central America (Mallory and Fontaine 2004). Dabbling ducks are uncommon along the western portion of Baffin Bay and Davis Strait.

Diving ducks whose ranges extend into Nunavut include: ring-necked duck, black scoter, surf scoter, white-winged scoter, harlequin duck, long-tailed duck, common eider, king eider, common goldeneye, bufflehead, hooded merganser, common merganser and red-breasted merganser. Most of these species reach the northern limit of their range in southwestern Nunavut, except the long-tailed duck, red-breasted merganser, and both eider species which breed throughout Nunavut. Coastal waterfowl will aggregate in large numbers on polynyas during winter and migration periods, as productive foraging sites (Stirling 1997). Polynyas located adjacent to breeding colonies also support improved breeding success. Within the Area of Focus, Eastern Jones Sound, Eastern Lancaster Sound, and Frobisher Bay provide important habitats for eiders and long-tailed duck. Most species of diving ducks winter in southern Canada, the United States, Mexico and Central America (Mallory and Fontaine 2004). However, king eider, common eider, and harlequin duck can occur in the Area of Focus year-round. See Section 4.6.1.4 for full species accounts for king eider, common eider, and harlequin duck.

4.6.1.2 Ecology

Diving ducks occur in a variety of coastal waters, including deeper areas as well as estuaries, mudflats, and large lakes and rivers. Diving ducks forage underwater on aquatic plants, gastropods, amphipods, molluscs, crustaceans, and fish in intertidal, subtidal or offshore coastal areas (Birds of North America Online 2017).

In Nunavut, loons spend most their time on open water and come to land mainly to nest. In the Area of Focus, loons are expected to stage in marine environments during migration to southern wintering locations. Small groups of loons may be found group feeding for fish on lakes in the late summer and during fall migration (National Audubon Society (NAS) 2008).

Geese and swans breed primarily on marshy tundra, marshy lakes and bays. Most nests are located near water and often on islands. Frobisher Bay has been identified as an important feeding, staging, and breeding area for several waterfowl species including Canada goose, Harlequin duck, and long-tailed duck (Latour et al. 2008; Mallory and Fontaine 2004). Canada geese have also been reported to breed more frequently in the vicinity of Pangnirtung in recent years (Qarpik 2001 as cited in Nunavut Tunngavik

Inc. 2001). Grise Fiord has been identified as an important area for cackling geese since the late 1980's (Nunavut Department of Environment n.d.).

In late spring and late summer, eiders aggregate along the ice edge in Lancaster sound and on the eastern side of Baffin Island. Eiders stage close to inland breeding sites to or from migration to wintering habitat. Upwards of 25,000 migrating eiders have been recorded on the east side of Bylot Island with other large aggregations in Cumberland Sound (Latour et al. 2008; Mallory and Fontaine 2004).

Long-tailed ducks breed throughout Baffin Island and birds will overwinter in ice-free areas around Hantszch Island and the eastern edge of Davis Strait (Birds of North America Online 2017). Molting sites for long-tailed ducks are reported near Coburg Island (Mallory and Fontaine 2004).

4.6.1.3 Ecological or Economic Importance

Coastal waterfowl are of high socio-economic value in Nunavut and are sensitive because they nest in colonies and occur in large aggregations during the flightless molt period or staging on their way to and from breeding sites. They are used for subsistence (meat, eggs, and feathers) during the spring and summer. Large numbers of eiders, snow geese, geese and ducks are hunted or eggs collected by Inuit in Pond Inlet, Clyde River, and Pangnirtung (Priest and Usher 2004). Waterfowl have strong cultural significance and are often featured in carvings.

4.6.1.4 Selected Species Occurring within the Area of Focus

The following section provides a detailed description of the conservation status, distribution, and ecology of select coastal waterfowl within the Area of Focus. Focal species include those that occur throughout the Area of Focus, have a strong association with habitats within the Area of Focus or rely on it for multiple seasons of use, and/or are species of conservation concern or traditional importance.

KING EIDER

CONSERVATION STATUS

Special protection for hunting, and the establishment of refuges is afforded king eider under Article IV of the *Migratory Birds Convention Act*. King eider has not been assessed by COSEWIC. The Nunavut population of king eider is unknown but estimated to be more than 10,000 birds (ECCC 2015). The species is ranked as Vulnerable in Nunavut due to national declines in numbers (CESCC 2016). Available data from Greenland and Nunavut suggest that the eastern arctic population is showing substantial declines, due in part, to annual harvest (ECCC 2015). Subsistence harvest of both common and king eiders in Nunavut is estimated around 6,000 birds annually (Sea Duck Joint Venture 2015a).

Distribution and Ecology

King eiders occur in arctic and subarctic coastal habitats and have a circumpolar distribution that includes Russia, Alaska, Canada and Greenland (Sea Duck Joint Venture 2004). King eiders breed in coastal areas of the arctic, typically nesting in low marshy areas or near freshwater ponds on tundra. Eiders arrive on their breeding grounds around mid-June (Cotter et al. 1997; Sea Duck Joint Venture 2004). Migratory patterns of eastern king eiders are largely unknown, but they are thought to stage on polynyas prior to nesting (Abraham and Finney 1986a; Sea Duck Joint Venture 2015a).

They primarily winter in marine waters along both the northern Pacific and Atlantic coasts, including along southwestern Greenland, typically within 15 km of polynyas (Powell and Suydam 2012; Sea Duck Joint Venture 2004). In the eastern arctic, wintering eiders form large aggregations and will travel as far north as open water is available, near the edge of sea ice and within polynyas (Powell and Suydam 2012). Large numbers of king eider have been recorded at the southern tip of Baffin Island with smaller numbers in Frobisher Bay but that quickly redistribute (ECCC 2015; Powell and Suydam 2012). The distribution of king eider along the east side of Baffin Island remains largely unknown. Telemetry data indicate that wintering eiders travel large distances over the course of the season and movements are likely influenced by sea ice conditions and food accessibility (Sea Duck Joint Venture 2015a). Approximately one third of the population remains at one location all winter. Compared to common eiders, king eiders will stage in deeper waters (i.e., 30 m) further from shore (i.e., 48 km); benthic food availability affects offshore distribution.

Common Eider

Conservation Status

Special protection for hunting, and the establishment of refuges is afforded the common eider under Article IV of the *Migratory Birds Convention Act*. Common eider has not been assessed by COSEWIC. It is considered Vulnerable in Nunavut based on recent declines in some areas and a lack of detailed knowledge about the status of most of the population in Nunavut (CESCC 2016; ECCC 2015; Robertson and Gilchrist 1998). Recent surveys from Nunavut show large increases in nesting eiders in Ungava Bay and Queens Channel, while other historical nesting sites have decreased in recent decades (Sea Duck Joint Venture 2017). Total population estimates are unreliable because changes in nesting activity are thought to be caused, to some extent, by changes in distribution of breeding birds. Recent surveys estimate more than 32,000 nesting pairs along Hudson Strait (Sea Duck Joint Venture 2017). Common eiders are the most typically harvested marine bird in the Canadian arctic (Sea Duck Joint Venture 2017). Both birds and eggs are harvested for subsistence; birds are also hunted recreationally and commercially (Sea Duck Joint Venture 2017). Recent harvest levels in Greenland and Canada are considered not sustainable (ECCC 2015).

Distribution and Ecology

Similar to king eiders, common eiders are located in arctic and subarctic coastal waters and have a circumpolar distribution that includes Russia, Alaska, Canada, and Greenland (Canadian Wildlife Service Waterfowl Committee 2015). The Area of Focus overlaps with range of the northern race (*S. m. borealis),* which breeds throughout coastal areas of the eastern Canadian arctic, from south-central Labrador north to Ellesmere Island, including eastern Baffin Island (Goudie et al. 2000). They often breed and nest in colonies along marine coasts, mostly on islands and islets and occasionally on islands in freshwater free of mammalian predators (Latour et al. 2008; Sea Duck Joint Venture 2017). Most of the population nests along the coasts of Hudson Strait and southeast Baffin Island (Abraham and Finney 1986a), with key breeding areas including northern Labrador (north of 54°N), Ungava Bay, Frobisher Bay, Cumberland Sound in southeast Baffin Island, Southampton Island, the western part of Foxe Basin, and a few High Arctic islands in Jones Sound located between Devon and Ellesmere Islands (Latour et al. 2008; Sea Duck Joint Venture 2017). Although previously uncommon to the area, common eiders have been observed breeding near Pangnirtung in recent years (Qarpik 2001 as cited in Nunavut Tunngavik Inc. 2001).

The northern race winters in the Gulf of St. Lawrence and on the coasts of Labrador, Newfoundland, and southwest Greenland, although some birds remain in Hudson Strait for the winter (Goudie et al. 2000; Sea Duck Joint Venture 2017). Common eiders overwinter and molt in open water leads in pack ice and along leeward sides of islands, as well as ice-free waters. During spring migration (March to mid-June), large aggregations may occur immediately south of heavy arctic ice and in open leads (Mallory and Fontaine 2004; Sea Duck Joint Venture 2017). The north shore of Ungava Bay is a major molt-migration location for the *borealis* subspecies (Goudie et al. 2000).

Harlequin Duck

Conservation Status

The eastern population of harlequin duck is estimated to be approximately 1,500 birds and is designated as Special Concern on Schedule 1 of SARA (COSEWIC 2013). While no accurate population estimates are known for Nunavut, less than 100 pairs are expected to breed in Nunavut; therefore, this species is ranked as Vulnerable within the territory (CESCC 2016; COSEWIC 2013; Sea Duck Joint Venture 2015b). Historically, overhunting was the primary threat to eastern population of harlequin duck (COSEWIC 2013). Hunting bans have been implemented throughout eastern Canada since 1990 except for Nunavut, where small numbers of birds continue to be harvested annually by subsistence hunters (Sea Duck Joint Venture 2015b).

DISTRIBUTION AND ECOLOGY

The eastern population of harlequin duck is separated into the Eastern Wintering Population and the Greenland Wintering Population. Only members of the Greenland Wintering Population occur in Nunavut and are known to breed on southern Baffin Island and winter along Greenland's southwest coast (COSEWIC 2013).

Harlequin ducks spend most of the year in coastal marine environments on turbulent seas and the rocky parts of coastal areas (Robertson and Goudie 1999). During the molting, migration, and winter periods, harlequin ducks are often associated with offshore islands, headlands, and rocky coastline where the surf breaks against coastal rocks and ice build-up is minimal (COSEWIC 2013). Birds feed over subtidal ledges, locating their food by diving in shallow waters over wave-pounded rocks and ledges to find prey among crevices (Robertson and Goudie 1999). Large aggregations can occur in areas where there is abundant food availability (COSEWIC 2013). Each spring they move inland to nest on the ground along shallow, fast-flowing rivers with concentrations of aquatic invertebrates.

4.6.2 Seabirds

The Area of Focus provides seasonal or year-round habitat for alcids, gulls, terns, fulmars, and jaegers. Species occurrence and conservation status for select species are described in Table 4.8.

4.6.2.1 Distribution

Seabirds are defined as those bird species that only come to land to breed and spend the rest of their time almost exclusively at sea, including alcids, gulls, terns, fulmars, and jaegers. Seabirds breed, winter, and migrate through the Area of Focus, but their seasonal distribution is heavily influenced by ice coverage. Seabirds migrate to the region between mid-May through late June and will form large aggregations along ice edges or ice-free coastlines, depending on food availability.

Most seabird species breed colonially, and colonies are found throughout the Area of Focus (see Figure 4.7) For many species, the extensive rocky coasts and islands in the Canadian arctic represent a substantial portion of their breeding range. Colonies range in size from a few to several million nesting pairs, forming single or multi-species colonies (Latour et al. 2008). Seabirds typically initiate fall migration between late August and late October as ice freeze progresses. Although most of these seabirds winter further south along the Atlantic or Pacific coasts, several species chose to winter in ice free portions of the Area of Focus (Birds of North America Online 2017). See Section 4.6.2.4 for full species accounts for dovekie, thick-billed murre, Atlantic puffin, ivory gull, and northern fulmar.

4.6.2.2 Ecology

Large aggregations of seabirds will form at breeding, foraging, and migratory staging areas throughout the Area of Focus. Seabirds occurring within the Area of Focus are generally piscivorous, feeding primarily on schooling fish species including capelin, sand eel, and polar cod; however, fulmars, dovekies, and thick-billed murres will also consume large quantities of zooplankton and benthic invertebrates.

Waters within several kilometres of breeding colonies are important for foraging and post-fledgling periods.

Alcids breed colonially and form large aggregations at breeding locations, nesting on the ground on cliffs, often favouring protective crevices. Colonial sites at Cape Hay, Cape Graham Moore, Cumberland Sound, Reid Bay, Coburg Island, and Cambridge Point serve as important breeding sites (IBA Canada 2017; Latour et al. 2008; Mallory and Fontaine 2004). Up to 350,000 nesting pairs of thick-billed murres and 30 million dovekies nest near the North Water Polynya (Mallory and Fontaine 2004). An additional 160,000 thick-billed murres breed on Coburg Island. Sizeable northern fulmar breeding colonies are located at Cape Searle, Reid Bay, Hobhouse Inlet, Baillarge Bay, and Coburg Island (Latour et al. 2008). They may feed far from breeding colonies and forage by diving from the surface and swimming underwater. Their diet consists of small fish and planktonic crustaceans (Gaston and Hipfner 2000).

Gulls and terns nest alone or in colonies on lakes, rivers, marshes, tidal estuaries, or coastal cliffs, preying on fish, smaller birds, eggs, and occasionally small mammals, as well as scavenging opportunistically (Birds of North America Online 2017). Most species winter in southern parts of Canada or the United States; however, glaucous, Iceland, and ivory gulls may remain in the Area of Focus throughout the year (Birds of North America Online 2017).

Jaegers and fulmars typically use offshore habitats except when breeding. Nests are colonial and made in a shallow ground depression lined with grass, moss, and leaves. Several large northern fulmar breeding colonies are located on the east side of Baffin Island. Generally, jaegers spend winter on tropical oceans of the southern hemisphere, while northern fulmars remain along North American coasts (Birds of North America Online 2017; Mallory and Fontaine 2004).

Lancaster Sound and Cape Hay serve as important spring and fall staging areas for several seabirds, including dovekie, black guillemot, thick-billed murre, and northern fulmar (IBA Canada 2017; Latour et al. 2008; Mallory and Fontaine 2004).

4.6.2.3 Ecological or Economic Importance

Seabirds are of high socio-economic value in Nunavut; these species are hunted and used for egg gathering. Large numbers of duck, tern, and gull eggs are gathered in the Qikiqtarjuaq region (Priest and Usher 2004). They can be sensitive because they nest in colonies and occur in large congregations. Seabirds have strong cultural significance and are often featured in carvings.

4.6.2.4 Selected Species Occurring within the Area of Focus

The following section provides a detailed description of the conservation status, distribution, and ecology of select seabirds within the Area of Focus. Focal species include those that occur throughout the Area of Focus, have a strong association with habitats within the Area of Focus or rely on it for multiple seasons of use, and/or are species of conservation concern or traditional importance.

DOVEKIE

CONSERVATION STATUS

Dovekie has not been assessed by COSEWIC but is considered Vulnerable in Nunavut (CESCC 2016). The only known breeding colony in the Canadian arctic is located on eastern Baffin Island and supports fewer than 1,000 pairs (Montevecchi and Stenhouse 2002). Nest survivorship is thought to be influenced by predation in coastal areas (Finley and Evans 1984).

DISTRIBUTION AND ECOLOGY

Dovekie breed primarily along the coast of Greenland, along the North Water Polynya (Mallory and Fontaine 2004). The one documented breeding colony in the Canadian Arctic is located in Home Bay on East Baffin Island; a second potential colony has been reported on Ellesmere Island (Montevecchi and Stenhouse 2002). Dovekie will breed in large colonies on steep coastal slopes, where they lay one egg in crevices or beneath large rocks (Montevecchi and Stenhouse 2002).

In early May, large aggregations of migrating dovekies can be found in offshore marine waters within the Area of Focus, foraging along ice edges in open water, as they travel to breeding sites in western Greenland. Up to 14 million birds have been observed historically in the Lancaster Sound Polynya with several thousand located in bays along eastern Baffin Island (IBA Canada 2017; Latour et al. 2008; Mallory and Fontaine 2004). In August, several thousand dovekies have been reported staging in Cumberland Sound and Frobisher Bay (Mallory and Fontaine 2004). While most birds winter in the north Atlantic, the winter range for dovekie extends as far north as southern Baffin Bay. Wintering dovekie are distributed offshore in areas where shelf edges and oceanographic currents combine to create vertical mixing and concentrate prey (Montevecchi and Stenhouse 2002).

THICK-BILLED MURRE

CONSERVATION STATUS

The thick-billed murre has not been assessed by COSEWIC and is considered Secure in Nunavut (CESCC 2016). Thick-billed murre is one of the more common seabird species occurring in the Area of Focus and the most common seabird breeding in the Canadian Arctic (Gaston and Robertson 2014). Hunting of wintering birds in Newfoundland, Labrador, and western Greenland is suspected to be a key consideration in the long-term sustainability of Canadian populations in combination with contaminant exposure, disturbance to breeding colonies, and climatic conditions (Frederiksen et al. 2016; Gaston and Robertson 2014; Wiese et al. 2004). As bird use of breeding and wintering regions are highly correlated, management of populations in the Canadian arctic will deviate from that in Iceland and Greenland to some degree (Frederiksen et al. 2016). Eggs are gathered by local communities in Pond Inlet (Priest and Usher 2004).

DISTRIBUTION AND ECOLOGY

Thick-billed murre is one of the most numerous seabirds to breed along eastern Baffin Bay, Davis Strait, and eastern Lancaster Sound (Gaston and Hipfner 2000; Indigenous and Northern Affairs Canada (INAC) 2012; Mallory and Fontaine 2004). Some of the largest breeding colonies are in eastern Jones Sound, eastern Lancaster Sound, Cape Hay, Cape Graham Moore, Cape Searle and Reid Bay, Cumberland Sound as well as Hantzsch Island (IBA Canada 2017; Indigenous and Northern Affairs Canada (INAC) 2012; Wiese et al. 2004) (see Figure 4.7). Approximately 350,000 breeding pairs nest near the North Water Polynya and another 386,000 pairs within eastern Lancaster Sound. Individuals nest along bare cliff ledges, occasionally using crevices or caves formed in the rock. Murres breed in proximity to deep ocean waters along coastlines and the continental shelf; densities of birds are generally higher where ice cover is abundant compared to locations where it is absent (Gaston and Hipfner 2000). Marine waters within 30 km of breeding colonies are particularly important for foraging and fledgling birds (Mallory and Fontaine 2004).

A portion of the Canadian arctic population occurs along southeast Baffin Island, including Frobisher Bay year-round; however, most birds migrate to wintering grounds primarily in southwest Greenland, eastern Quebec, and Newfoundland in early September, returning to breeding grounds in early or mid-May. During winter months, birds distribute along the continental shelf and continental slope waters (Gaston and Hipfner 2000; Wiese et al. 2004).

ATLANTIC PUFFIN

CONSERVATION STATUS

Atlantic puffin has not been assessed by COSEWIC, but is considered Vulnerable in Nunavut, based on previous pressure from egg gathering and hunting and uncertainty about the current size and distribution of the population (CESCC 2016). The estimated breeding population is expected to be fewer than 30 pairs (Mallory and Fontaine 2004).

DISTRIBUTION AND ECOLOGY

Atlantic puffin breeds along coastal areas of North America and northern European coastlines. Overall, the North American population is between 350,000 and 400,000 breeding pairs, with approximately 70,000 to 90,000 of these breeding in Labrador. Most puffins nest in colonies on small, rugged islands. Atlantic puffins nest on grassy slopes in burrows 50 to 200 cm long, which they dig with their bills and the sharp claws on their feet. Some birds may also nest in cracks under boulders or in crevices on cliff faces, especially in arctic colonies where there is little soil or where the soil remains frozen for much of the summer. Nunavut represents the northern limit of the Atlantic puffin’s range, with breeding records known from Prince Charlotte Monument at the entrance to Jones Sound, on a small island off the southeast cost of Resolution Island, and on two small islands in Digges Sound off the northwest tip of the Ungava Peninsula (Latour et al. 2008; Lowther et al. 2002b). Pijamini (2001 as cited in Nunavut Tunngavik Inc. 2001) reported seeing puffins move increasingly northward and becoming more common in the

Pangnirtung area. Puffins spend most of their time swimming, diving, and feeding on small fish at sea (Lowther et al. 2002b). Most birds feed within 10 km of their breeding colony, although feeding trips of 1,000 km have been reported. While specific migration routes and behaviour for Eastern Canadian Arctic puffins are not well known, the winter distribution of puffins is largely offshore, generally south of their breeding range, and ranges from southern Greenland to Virginia (Lowther et al. 2002b).

IVORY GULL

CONSERVATION STATUS

Ivory gull was most recently assessed by COSEWIC in 2006 and is designated as Endangered on Schedule 1 of SARA (Environment Canada 2014e). It is considered Critically Imperiled in Nunavut based on restricted distribution, nest predation, hunting practices in Greenland, and potential sensitivity to disturbance, industrial activity, and environmental contaminants (CESCC 2016). Climate change influences on timing of ice formation and breakup in Baffin Bay is expected to influence nesting success (Environment Canada 2014e).

DISTRIBUTION AND ECOLOGY

Ivory gull has a circumpolar distribution that includes the central Canadian Arctic and western Russia; breeding sites in Canada are located only in Nunavut (Environment Canada 2014e). There are approximately 400 breeding pairs in Canada. Its breeding range includes southeastern Ellesmere Island, eastern Devon Island, northern Baffin Island, and Seymour Island along the Penny Strait polynya (COSEWIC 2006b; Mallory et al. 2008) (see Figure 4.7). The Inglefield Mountains of Ellesmere Island have consistently supported 30 to 40% of the Canadian ivory gull population over the past two decades (IBA Canada 2017; Latour et al. 2008), while the importance of the Seymour Island colony has increased over time to a similar level (Gilchrist and Mallory 2005). Most of the remaining individuals are on the Brodeur Peninsula of Baffin Island; however, within the past decade 10 colonies near the coast have been abandoned, while only three new ones further inland have been documented (COSEWIC 2006b). The Sydkap Ice Field on southern Ellesmere Island was formerly home to a large colony of up to 300 ivory gulls, but was found abandoned during surveys in 2002 and 2003 (Latour et al. 2008). The colonies on eastern Devon Island were always relatively small, and also have been largely abandoned (Latour et al. 2008).

Ivory gulls have restrictive requirements for breeding sites: primarily isolation from terrestrial predators (e.g., arctic fox) but within 100 to 200 km of open water in May and early June (COSEWIC 2006b). Most colonies are located within 100 km of polynyas, where gulls have access to opportunistic feeding on fish or invertebrates, or scavenging carcasses (Mallory et al. 2008). Colonies are typically located on steep rocky cliffs providing limited access for mammalian predators (COSEWIC 2006b; IBA Canada 2017). Most nest sites on Ellesmere and southeast Devon Island are on granite nunataks 20 to 50 km inland, while on west Devon, Baffin, Cornwallis, and Somerset Islands, the colonies are 20 to 40 km inland on large barren limestone plateaus where the lack of vegetation, in turn, results in an absence of lemmings and foxes (COSEWIC 2006b; Gilchrist and Mallory 2005).

Depending on ice coverage, gulls will migrate to northern Lancaster Sound in early October, moving eastward to Baffin Bay until freeze-up (Mallory et al. 2008). Gulls winter along ice pack and polynyas between Greenland and Nunavut or Newfoundland, but annual locations vary based on sea ice distribution (Environment Canada 2014e). Groups of 100 birds have been observed staging in Frobisher Bay, as well as along ice edges of Cape Graham Moore and Buchan Gulf (Mallory and Fontaine 2004). Between 50 and 75% of the global population is estimated to regularly winter in Canadian waters.

Several regions in the Area of Focus have been identified as IBAs for ivory gull, including Eastern Devon Island Nunataks, Inglefield Mountains, Cape Hay, Southwest Bylot, and Cape Graham Moore (IBA Canada 2017).

NORTHERN FULMAR

CONSERVATION STATUS

Northern fulmars are not traditionally harvested in Nunavut; the species is considered Secure in Nunavut (CESCC 2016). They are among the longest-lived seabirds with lifespans that can extend up to 40 years (Mallory et al. 2012). However, because most birds initiate breeding at eight years old, and produce a single egg per year, low reproductive output can make them sensitive to factors that influence breeding success (Mallory et al. 2012).

DISTRIBUTION AND ECOLOGY

Northern fulmars breed throughout Baffin Bay and Davis Strait, with notable colonies located along northern Baffin Island and eastern Devon Island, arriving in late April or early May (Mallory et al. 2012) (see Figure 4.7). Fulmars breed in steep cliffs on small or large islands, often in mixed colonies with other cliff-breeding species (Mallory et al. 2012). However, compared to other species, fulmars more typically select for vegetated nesting sites that are inaccessible to predators due to the steepness of the cliff face (IBA Canada 2017; Mallory et al. 2012). Foraging around breeding colonies is varied and extensive, sometimes upwards of 400 km from the colony site (Mallory and Fontaine 2004). Breeding locations include Coburg Island, eastern Jones Sound, eastern Lancaster Sound, Hobhouse Inlet, Buchan Bay, and Cumberland Sound (Latour et al. 2008; Mallory and Fontaine 2004). The largest Canadian colony (greater than 100,000 pairs) is located at Cape Searle and Reid Bay (IBA Canada 2017; Mallory and Fontaine 2004). The Buchan Gulf, Scott Inlet, Reid Bay, and Cape Searle Important Bird Areas are globally and nationally significant Important Bird Areas of the species (IBA Canada 2017).

Fulmars are distributed throughout offshore habitats where open water is present, avoiding coastal areas or those with an abundant buildup of sea ice. Aggregations of birds are associated with upwellings, where zooplankton, fish, and squid are abundant (Mallory et al. 2012). Birds on migration from the Canadian arctic may travel north towards Ellesmere Island. Staging birds are regularly observed along Cape Hay and Cape Graham Moore. Wintering birds congregate along offshore regions of the northeast Atlantic coastline.

4.6.3 Shorebirds

The Area of Focus provides seasonal or year-round habitat for phalaropes, turnstones, sandpipers, and plovers. Species occurrence and conservation status for select species are described in Table 4.8.

4.6.3.1 Distribution

Turnstones, sandpipers, plovers and phalaropes in Nunavut occur in the Area of Focus primarily during breeding but may use coastal or offshore habitats for staging during migration along the Pacific or Atlantic coasts, as well as to Greenland and Europe (Birds of North America Online 2017). A list of potentially occurring shorebird species is provided in Table 4.8; however, many of these species only use habitats on the periphery of the Area of Focus (e.g., Ellesmere and Devon Islands). Species that occur more extensively throughout the Area of Focus include ruddy turnstone, Baird’s sandpiper, purple sandpiper, semipalmated sandpiper, common ringed plover, semipalmated plover, red phalarope, and red-necked phalarope (Birds of North America Online 2017). See Section 4.6.3.4 for full species accounts for ruddy turnstone, red knot, purple sandpiper, and red phalarope.

4.6.3.2 Ecology

In Nunavut, shorebirds spend most of their time on inland breeding habitats, including tundra, rivers, and lakes, coastal beaches, and cliffs but may travel to adjacent coastal shorelines for foraging. During the breeding period, most species forage on freshwater invertebrates, although marine crustaceans, amphipods, and molluscs may make up a portion of their diet. There are no especially large aggregations of breeding shorebirds, and no Important Bird Areas have been identified within the Area of Focus as supporting globally or nationally signification habitat for shorebird species (IBA Canada 2017).

Most shorebird species undertake long-distance migrations between wintering grounds in South and Central America, southern regions of North America, Greenland, or Europe and breeding habitat in Nunavut (IBA Canada 2017). Breeding habitat within the Area of Focus is the northernmost extent for shorebirds migrating along the Atlantic Flyway, from wintering grounds in temperate regions of South America and sub-tropical areas of the US and Mexico (Atlantic Flyway Shorebird Initiative 2016). Accordingly, birds generally arrive late in the season (e.g., May through early June), and initiate fall migration as early as late July or August (Birds of North America Online 2017). The integrity of staging habitat during migration is a key element in maintaining the viability of global populations (Atlantic Flyway Shorebird Initiative 2016).

Shorebirds can travel long distances between stopovers during migration, with many species using regions of James Bay, Hudson’s Bay, the Atlantic coast, and eastern Greenland. Shorebird species rely more heavily on coastal habitats during migration; here, habitat quality and prey availability are essential components to supporting viable shorebird populations (IBA Canada 2017). Phalaropes are the only shorebird species occurring within the Area of Focus that use offshore marine environments during migration and winter and will congregate near ocean upwellings that support higher zooplankton productivity and availability. Existing literature does not indicate that the Area of Focus support key migratory staging or wintering habitat for shorebirds (Latour et al. 2008).

4.6.3.3 Ecological or Economic Importance

Shorebirds are not typically harvested for meat or eggs on their breeding grounds but have been hunted historically in parts of their winter range. Most shorebird species do not have strong cultural significance.

4.6.3.4 Selected Species Occurring within the Area of Focus

The following section provides a detailed description of the conservation status, distribution, and ecology of select shorebirds within the Area of Focus. Focal species include those that occur throughout the Area of Focus, have a strong association with habitats within the Area of Focus or rely on it for multiple seasons of use, and/or are species of conservation concern or traditional importance.

RUDDY TURNSTONE

CONSERVATION STATUS

The Canadian population is estimated at 235,000 (Morrison et al. 2000), most of which breed in Nunavut. In 2017, the *morinella* subspecies of ruddy turnstone was identified as a candidate species for assessment by COSEWIC due to an observed 74% population decline between 1974 and 2014, due in part to overgrazing by geese on breeding grounds (COSEWIC 2015). The species is considered Vulnerable in Nunavut due to rapid declines observed on Quebec migration surveys and in the United States (CESCC 2016).

DISTRIBUTION AND ECOLOGY

Ruddy turnstone arrives at breeding habitat in tundra regions of northern North America in early June. Within the Area of Focus, turnstones breed on south Baffin Island, Devon Island, and Ellesmere Island (Nettleship 2000). Ruddy turnstones will use rocky arctic coasts, building nests in dry or wet tundra flats, hummocks, and slopes near ponds, lakes, and streams. The nest is made in a scrape or depression on the ground or in vegetation. Ruddy turnstones are monogamous and territorial, and display high site and mate fidelity (Nettleship 2000). On their breeding grounds, ruddy turnstones feed predominantly on flies, but on migration and during the winter their diet is diverse, ranging from coastal invertebrates to small fish, carrion, human garbage, and unattended eggs of other birds (Nettleship 2000). Fall migration extends from August through October. On migration, turnstones rely on coastal rocky shorelines, sand or pebble beaches, and mudflats that provide abundant crustacean or mollusk forage (Nettleship 2000). Staging area are a critical part of the species' migration.

RED KNOT

CONSERVATION STATUS

There are two subspecies of red knot that breed in Nunavut. The *rufa* subspecies has been designated Endangered by COSEWIC and is listed on Schedule 1 of SARA due to observed breeding population declines of 70% within the past 15 years (ECCC 2017e). Current estimates suggest there are less than 20,000 birds, including 15,000 adults as of 2007 (COSEWIC 2007b). The *islandica* subspecies has been assigned a status of Special Concern by COSEWIC due to an observed decline of 17% of the breeding population within the last 15 years. Population estimates assume the subspecies supports 270,000 birds, including 81,000 breeding individuals in Canada (COSEWIC 2007b). The subspecies is not listed on Schedule 1 of SARA (Government of Canada 2017). Red knot is considered Imperiled in Nunavut (CESCC 2016). Habitat on the Canadian breeding grounds is considered stable; however, migratory stopover sites along both the Pacific and Atlantic coasts of North America have experienced declines in habitat quality and quantity. Depleted horseshoe crab prey resources (for the *rufa* subspecies) and shellfish harvesting on the wintering grounds in Europe (for the *islandica* subspecies) present ongoing threats for migrating birds (COSEWIC 2007b; ECCC 2017e).

DISTRIBUTION AND ECOLOGY

Red knot breeds in northern Alaska and Canada, as well as in northern Greenland and Russia. The species' breeding range in the Area of Focus includes Ellesmere and Devon Islands (Baker et al. 2013; ECCC 2017e) (see Figure 4.7). Breeders from Greenland and northeastern Canada stage along shorelines of Baffin Island as they migrate across the Atlantic to winter in western Europe, via the eastern Atlantic Flyway. Most of the remaining North American breeders undertake a long-distance migration to South America along the Atlantic Flyway (Atlantic Flyway Shorebird Initiative 2016), though small numbers winter along the Atlantic and Pacific coasts of North America (Baker et al. 2013). Within the Area of Focus, the *rufa* subspecies breeds across Baffin Island, while the *islandica* subspecies breeds on Ellesmere and Devon Islands. The breeding range for the two subspecies overlaps on northern Baffin Island and Bylot Island (ECCC 2017e).

Red knots use different habitats for breeding than for wintering or migration. In the Arctic, red knots nest in dry tundra or along sparsely vegetated gravel ridges, plateaus, or slopes (Baker et al. 2013). Red knots often return to the same general breeding area from year to year. Foraging habitats can be considerable distances (up to 10 km) from the nest, and are usually in damp or barren areas, where molluscs, crustaceans, and other invertebrates are present (Baker et al. 2013; COSEWIC 2007b; ECCC 2017e). During migration and on wintering grounds, red knots gather in large flocks, feeding in coastal intertidal areas and roosting on nearby beaches, marshes or fields, where open undisturbed habitat is available (Baker et al. 2013; ECCC 2017e).

Purple Sandpiper

Conservation Status

The purple sandpiper has not been assessed by COSEWIC and is considered Vulnerable in Nunavut (CESCC 2016). The Canadian population of purple sandpiper is estimated at 15,000 birds (Payne and Pierce 2002). Approximately 85% of the Canadian population (or less than 13,000 birds) is estimated to breed in Nunavut. Substantial declines have been reported between 1975 and 1995 in the Rasmussen Lowlands (Gratto-Trevor et al. 2001; Johnston et al. 2000).

Distribution and Ecology

Purple sandpiper breed throughout the Canadian arctic, including Devon, Bylot, and Baffin Islands within the Area of Focus. The species will breed on low tundra near coastlines and along gravel or sand beaches on inland rivers (Payne and Pierce 2002).

Purple sandpipers arrive at breeding grounds in late May or early June and initiate fall migration between September and November. Birds migrate between breeding grounds and ice-free coastlines for wintering; individuals breeding in the low arctic may only migrate short distances (less than 100 km) to wintering habitat (Payne and Pierce 2002). On migration, purple sandpipers use exposed rocky shorelines that experience considerable wave activity but are occasionally also found along tidal flats and pools. The species' feeds primarily on marine invertebrates and molluscs throughout its annual cycle (Payne and Pierce 2002).

Red Phalarope

Conservation Status

Red phalarope has not been assessed by COSEWIC and is considered Apparently Secure in Nunavut (CESCC 2016). Population estimates for red phalarope are crude; however, it includes less than 500,000 birds in Canada, including 300,000 that migrate through Davis Strait in late June (Tracy et al. 2002).

Distribution and Ecology

The breeding range of red phalarope extends along the extreme northern edge and islands of North America's Arctic, from Alaska to Greenland (Tracy et al. 2002). In the Area of Focus, breeding range is located on Ellesmere Island, Devon Island, Bylot Island, and southern Baffin Island (Tracy et al. 2002). Recent reports from the Pangnirtung area suggest that breeding activity in this region has declined in recent years (Qarpik 2001 as cited in Nunavut Tunngavik Inc. 2001). Red phalaropes prefer to nest on hummocks on poorly drained coastal tundra in proximity to marine habitats, often selecting areas where snow melt is earlier than average (Tracy et al. 2002). Nests are usually located under vegetation that is sufficiently tall to provide some overhead shelter from weather and predation (Tracy et al. 2002). Foraging by red phalaropes during the breeding season focuses primarily on adult and larval insects, and crustaceans in shallow, wading-depth water (less than 5 cm) at edges of shallow ponds.

Compared to other phalarope species, red phalaropes are the most pelagic, spending up to 11 months of the year in marine habitats (Tracy et al. 2002). Migratory and wintering areas, including Davis Strait, is entirely pelagic (Tracy et al. 2002). Red phalaropes migrate along lead edges of sea ice, waiting for suitable breeding habitat to become available during spring snow melt. Birds will stage offshore along oceanic fronts that support larger prey concentrations; large aggregations are commonly associated with grey whale (near Alaska) or bowhead whales (Tracy et al. 2002).

4.7 Marine Mammals

Baffin Bay and Davis Strait provide a variety of seasonal habitats for various marine mammals including pinnipeds (e.g., ringed, harp and bearded seals and walrus), baleen whales (e.g., bowhead whale, humpback whale, fin whale), toothed whales (e.g., narwhal, killer whale, beluga whale, Northern bottlenose whale), and polar bear. Marine mammal species were selected for inclusion in this Strategic Environmental Assessment based on one or more of the following criteria:

- Recognized by COSEWIC and/or Schedule 1 of SARA as a Special Concern, Threatened, or Endangered species
- Known to be of cultural, economic or subsistence interest to Nunavut residents

Of the 12 marine mammal species occurring in the Area of Focus that meet the above criteria, 10 species have been designated as at risk by COSEWIC and/or are listed on Schedule 1 of SARA (Table 4.9). Several marine mammal species are of cultural, economic or subsistence interest to Nunavut residents, as identified through oral and written evidence provided in IQ and TK studies.

Table 4.9 Overview of Marine Mammal Species Associated with Environments in the Area of Focus

Species	Scientific Name	COSEWIC, SARA or IUCN Designation	Potential Species Occurrence in the Area of Focus[2]
Pinnipeds			
Ringed Seal	*Phoca hispida*	NAR (COSEWIC), but a high priority candidate for protection	B, W, S
Bearded Seal	*Erignathus barbatus*	Not assessed (COSEWIC) LC (IUCN)	B, W, S
Harp Seal	*Pagophilus groenlandicus*	Not assessed (COSEWIC) LC (IUCN)	B, W, S
Walrus	*Odobenus rosmarus rosmarus*	SC (COSEWIC) V (IUCN)	B, W, S
Toothed Whales			
Narwhal	*Monodon Monoceros*	SC (COSEWIC) LC (IUCN)	B, W, S
Beluga Whale	*Delphinapteus leucas*	T (COSEWIC) - Cumberland Sound Population	B, W, S

Table 4.9 Overview of Marine Mammal Species Associated with Environments in the Area of Focus

Species	Scientific Name	COSEWIC, SARA or IUCN Designation	Potential Species Occurrence in the Area of Focus[2]
		SC (COSEWIC) - Eastern High Arctic/Baffin Bay population LC (IUCN)	
Killer Whale	*Orcinus orca*	SC (COSEWIC) - Northwest Atlantic/Eastern Arctic population	S
Northern Bottlenose Whale	*Hyperoodon ampullatus*	SC (COSEWIC) - Davis Strait-Baffin Bay-Labrador Sea population	S
Baleen Whales			
Bowhead Whale	*Balaena mysticetus*	SC (COSEWIC) - Eastern Canada-West Greenland population LC (IUCN)	B, W, S
Humpback Whale	*Megaptera novaeangliae*	NAR (COSEWIC) - Western North Atlantic population	S
Fin Whale	*Balaenoptera physalus*	SC (COSEWIC) - Atlantic population E (IUCN)	S
Other			
Polar Bear	*Ursus maritimus*	SC (COSEWIC) V (IUCN)	B, W, S

NOTES:
1 E = Endangered, NAR = Not at Risk, LC – Least Concern, SC = Special Concern, T – Threatened, V- Vulnerable
2 B = Breeding, W = Wintering, S = Summering; Species presence and the timing of their occurrence within the Area of Focus are based on a literature review. Species occurrence may vary and rare sightings of species not listed are possible.

4.7.1 Ringed Seal

4.7.1.1 Conservation Status

Ringed seals have been identified by the COSEWIC Species Specialist Subcommittee as a “high priority candidate” for status report production, due to concerns that the species may be at risk of extinction or extirpation (Government of Canada 2017b). Ringed seals were previously assessed by COSEWIC, in 1989, as “Not at Risk” (Government of Canada 2018).

Population estimates for this species are difficult, given their wide range and difficulties in acquiring accurate counts (Kelly et al. 2010b). Currently, the estimates for Arctic subpopulation of ringed seals (e.g., those found in Greenland Sea, Baffin Bay, Hudson Bay, Beaufort and Chukchi Seas, and the White, Barents and Kara Seas) is unknown (Laidre et al. 2015a). The most recent estimate from 1998, for ringed seals in Baffin Bay and adjacent waters was approximately 1.2 million seals (Kingsley 1998). Inuit of

Grise Fiord have observed a decrease in the number of ringed seals, while an increase was noted by Inuit of Qikiqtarjuaq (Nunavut Department of Environment 2010, n.d.). During the NCRI, ringed seals were noted to be in abundance by Inuit of Qikiqtarjuaq, who also noted that historically populations were higher (Nunavut Department of Environment 2010).

Ringed seals are of particular importance to the Inuit of Nunavut. Ringed seals supported the cultural development of the coastal Inuit by providing a supply of heating oil, meat and skins (Hovelsrud et al. 2008). Seal harvesting provides the Inuit a mechanism to maintain traditional sharing customs, knowledge of natural resources and the environment, and the transfer of values and skills from generation to generation (Hovelsrud et al. 2008). The annual harvest estimate for all communities in Nunavut between June 1996 and May 1997 was 26,958 (± 1,112) (Priest and Usher 2004).

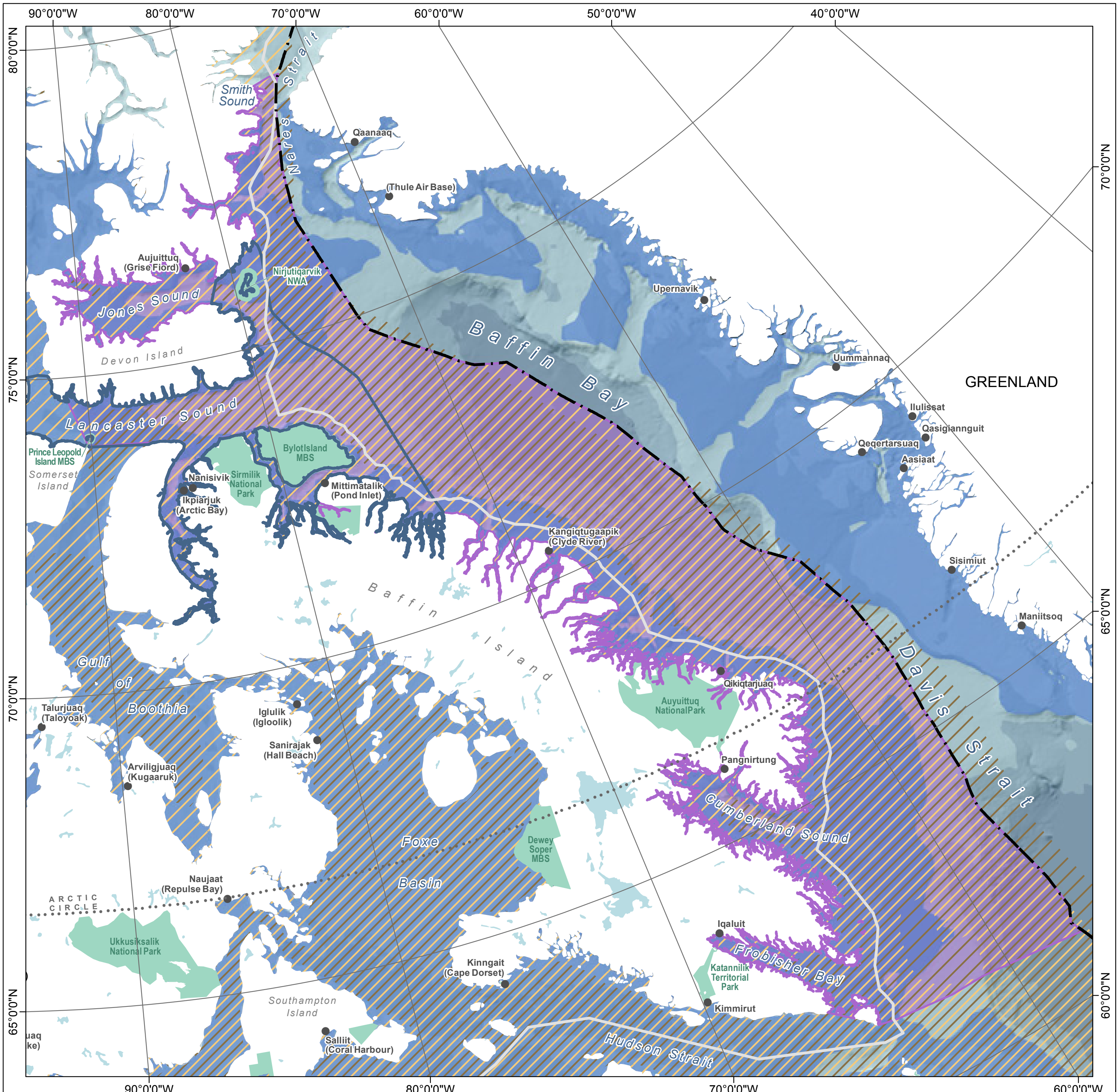
Risks to this species include effects from climate change. A longer ice-free season and reduced sea ice cover is predicted to affect the distribution and abundance of prey (Young and Ferguson 2013) and reduce body condition of ringed seals (Ferguson et al. 2017). Community members from Grise Fiord in 2012 noted a decrease in the numbers of ringed seals observed relative to previous years, and that the seals appeared to be becoming more variable in size and generally smaller (Government of Nunavut nd). Furthermore, a decrease in winter/spring snowfall is anticipated to reduce snow depth and snow drift formation, leading to reduced availability of suitable birthing lair habitat, and lower pup survival due to greater exposure to predation by polar bear (Ferguson et al. 2017; Iacozza and Ferguson 2014).

4.7.1.2 Distribution and Ecology

Ringed seals are circumpolar and distribution is largely associated with prey availability and sea ice (Kelly et al. 2010b; Yurkowski et al. 2016). Ringed seals are found throughout the Canadian Arctic (Harwood and Stirling 1992; Stirling and Smith 2004; Yurkowski et al. 2016). In the eastern Canadian Arctic, surveys conducted in 1978 in Lancaster Sound, Peel Sound, Barrow Strait and Melville Sound, indicated high densities of hauled-out ringed seals in the western portion of Lancaster Sound, Barrow Strait, and Peel Sound (Smith et al. 1978). Aerial surveys of the Baffin Bay pack ice conducted in 1978–1979, found even distributions of hauled out ringed seals, in the pack ice and in the coastal areas of Baffin Island from May to early July (Finley et al. 1983). Results from recent satellite tagging efforts have shown that ringed seals can be present in the Area of Focus year-round (Born et al. 2004; Teilmann et al. 1999; Yurkowski et al. 2016). The distribution of ringed seal in the Area of Focus and surrounding waters is shown in Figure 4.8.

Ringed seals can be found in ice-covered waters in winter and will maintain breathing holes in the ice (Smith and Sterling 1975). Movements during this time are typically limited (Harwood et al. 2015; Kelly et al. 2010a), although those seals with access to polynyas may travel farther to take advantage of increased production (Stirling 1997), as was the case with ringed seals and the North Water Polynya (Born et al. 2004). Through the winter, adults excavate subnivian lairs in pack ice and shore fast ice, and occupy them for whelping and nursing (Burns 1970; Finley et al. 1983). Whelping in the eastern Canadian Arctic typically occurs in March/April (Finley et al. 1983; Kelly et al. 2010a; Smith and Hammill 1981). In late spring/early summer, molting occurs, and ringed seals are found basking on the sea ice (Kelly et al. 2010a). In summer, movement patterns vary widely. Ringed seals tracked via satellite tags have indicated that some individuals will remain in Baffin Bay and the North Water Polynya (Born et al. 2004; Teilmann et al. 1999), while others that inhabit areas with shorter ice free duration may move farther distances throughout their range (Yurkowski et al. 2016). Satellite telemetry data indicates that ringed seals use the Area of Focus for foraging during the summer (Yurkowski et al. 2016), as well as for pupping and molting, earlier in the year (Finley et al. 1983).

Ringed seals eat a wide range of prey, including both benthic and pelagic species (McLaren 1958). In the Canadian Arctic, the diet of ringed seals is predominantly Arctic cod and zooplankton/shrimp (Yurkowski et al. 2016). Immature ringed seals sampled on the western side of the North Water Polynya were found feeding primarily on amphipods, while the adult diet comprised predominantly Arctic cod and polar cod (Holst et al. 2001).



Base Features

- Community[1]
- Limit of Exclusive Economic Zone[4]
- Nunavut Settlement Area[3]
- Tallurutiup Imanga / Lancaster Sound NMCA[2]
- Protected Area or National Park[4]

Bathymetry[5] Depth (m)

< 200 | 200 - 1000 | 1000 - 2000 | 2000 - 3000 | > 3000

Project Features

- Area of Focus[2]

Ringed Seal[6, 7]

- Summer/Winter

Bearded Seal[8]

- Common

Harp Seal[6]

- Common in Summer

1:10,000,000

0 50 100 200 300

Kilometres

Nunavut Impact Review Board Strategic Environmental Assessment

Figure 4.8 Phocid Seal Distribution and Important Habitats

NUNAMI STANTEC LIMITED

N.I.R.B.

Prepared By: Nunami Stantec Limited
Projection: Canada Lambert Conformal Conic, North American 1983
Date: Apr 13, 2018
Project Number: 12322100
Produced By: L. Trudell
Verified By: J. Beckett
Revision: 01

References:
[1]Atlas of Canada Base Maps, 2017
[2]NIRB, 2017
[3]Nunavut Planning Commission, 2010
[4]National Framework Canada, 2017
[5]Natural Earth, 2016
[6]Stephenson, S.A. and Hartwig, L., 2010
[7]Kelly et al., 2010
[8]Cameron et al., 2010

Filepath: S:\1232\projects\123221001\figures\report\SEA\fig_123221001_NIRB_SEA_04.8_Phocid_Seal_Distribution_in_AoF_and Nunavut_Waters.mxd

Ringed seals mature at approximately 7 years of age and can live to well past 40 years (McLaren 1958). The typical life span for ringed seals is 15–28 years (Frost and Lowry 1981). Natural predators of ringed seal include polar bear, killer whales, and Arctic foxes (Higdon et al. 2012; Smith and Hammill 1981).

4.7.1.3 Key Habitat

Ringed seals are associated with coastal areas of Baffin Bay, offshore regions, and the North Water Polynya (Born et al. 2004; Finley et al. 1983; Holst et al. 2001). They utilize many different types of habitat within the regions, ranging from pack ice to open water. During whelping and nursing, suitable ice and snow for pupping lairs is critical for pup survival (Kelly et al. 2010a; Stirling and Smith 2004).

4.7.2 Bearded Seal

4.7.2.1 Conservation Status

Bearded seals were subject to an assessment by IUCN in 2016, and due to a large population, broad distribution, and no evidence of population decline, were classified as “Least Concern” (Kovacs 2016). There has been no assessment of the bearded seal by COSEWIC or under SARA. Reassessment of the bearded seal has been recommended once new data becomes available regarding the potential effects of climate-change induced loss of sea ice on this species (Kovacs 2016). In 2012, members of the Grise Fiord community noted that numbers of bearded seals appeared to be on the increase (Nunavut Department of Environment n.d.). During the interviews for the NCRI, a decrease in bearded seal populations was noted by Inuit of Qikiqtarjuaq (Nunavut Department of Environment 2010).

The Inuit harvest bearded seals for sustenance and their tough, flexible hides, which can be used for kayak coverings, lines, traces, and kmaik (boot soles) (Hovelsrud et al. 2008). These important harvesting activities also support traditional sharing customs, help maintain knowledge of the environment (women preparing the meat or skins gain insights into the health of the animals), and allow transfer of values and skills between generations (Hovelsrud et al. 2008).

Losses of sea ice associated with climate change negatively affect bearded seal populations, causing a reduction in recruitment and body condition (Moore and Huntington 2008). These effects are, in part, based upon the species’ high dependency on productive benthic habitats that receive nutrient transfer from ice-associated production (i.e., habitats that benefit from tight pelagic-benthic coupling in the presence of sea ice cover) (Kovacs 2016; Moore and Huntington 2008).

4.7.2.2 Distribution and Ecology

Bearded seal have a patchy circumpolar distribution across the Arctic and sub-Arctic south of 85° N (Kovacs 2016). In eastern Canada, bearded seal range across the eastern Canadian Archipelago (including around Baffin Island), throughout Hudson Bay, and south to northern Newfoundland. In part due to the absence of commercial exploitation of the species and low numbers harvested by Inuit, there is a lack of information in the available literature regarding the distribution and seasonal movements of bearded seals in the eastern Canadian Arctic, with most literature pertaining to the Bering, Chukchi, and

Beaufort Seas. The species is not strictly migratory. There are variations between populations, with some seasonal movements associated with the advance and retreat of sea ice seen in the Bering-Chukchi region (Burns and Frost 1979), and more sedentary behaviour reported in the Sea of Okhotsk (Fedoseev 1973). Species distribution seems to be restricted by its dependence on habitats that provide high benthic productivity for feeding, as well as the presence of pack ice, which is used by bearded seals for reproduction, molting and resting (Moore and Huntington 2008). Bearded seals generally spend the winter in areas where ice cover is thin or broken (Finley and Renaud 1980). The North Water Polynya provides important winter habitat for bearded seal in the Area of Focus (Heide-Jørgensen et al. 2016). The common distribution of bearded seal in the Area of Focus is shown in Figure 4.8.

In the Canadian High Arctic, sculpins and Arctic cod made up the greatest proportions of the summer diet of bearded seal, followed by eelpout, polar cod, whelks, shrimp and other species of invertebrate (Finley and Evans 1983).

Bearded seals are a highly vocal species and use calls to indicate breeding condition and maintain territories (MacIntyre et al. 2015). The species may live to approximately 25 years old, with females and males reaching sexual maturity after 4 years and 6 to 8 years of age, respectively (Smith 1981). Breeding in the eastern Canadian Arctic, typically occurs in April-June, and molting occurs between May to July (Cameron et al. 2010). Bearded seals have an active gestation period of approximately 301 days, with a period of suspended development (or delayed implantation) of approximately 64 days (Smith 1981).

Natural predators of bearded seals include polar bears and killer whale (Cameron et al. 2010; Higdon et al. 2012).

4.7.2.3 Key Habitat

Studies have found that bearded seals show a general preference for shallower water habitats (greater than 75 m depth) (Finley and Renaud 1980). Dense annual pack ice provides a critical habitat for bearded seals (Laidre et al. 2008b). Access to open water and habitat near open water is also important for bearded seals (e.g., Burns and Frost 1979). A preference for pack ice habitats and reoccurring polynyas has been reported, although it is thought that proximity to areas of high benthic productivity is of primary importance over open water habitats (Smith 1981). This theory is supported by some bearded seals that overwinter around pressure ridges under fast ice and refrozen leads in other regions (e.g., in the Amundsen Gulf).

4.7.3 Harp Seal

4.7.3.1 Conservation Status

Harp seals have not been assessed by COSEWIC. Given their high population estimates, they are listed as a ‘Low priority candidate’ for a COSEWIC assessment by the COSEWIC Species Specialist Subcommittee (Committee on the Status of Endangered Wildlife in Canada (COSEWIC) 2017). Following an assessment by the IUCN in 2015, harp seal were listed as ‘Least Concern’ on the IUCN Red List of

Threatened Species, due in part to a large population size and increasing trend across major population groups (Kovacs 2015).

Harp seals are separated into three populations: White Sea/Barents Sea, Greenland Sea and Northwest Atlantic (Hammill et al. 2014). The estimated population of the Northwest Atlantic harp seal population is 7.4 million (DFO 2016). There are no estimates of harp seal numbers for Baffin Bay and surrounding waters. Inuit of Grise Fiord have observed fewer harp seal in recent years, while Inuit from Qikiqtarjuaq note both an increase and decrease in harp seals observed and Inuit from Kimmirut and Pond Inlet observed an increase (Nunavut Department of Environment n.d.; NWMB 1998).

Harp seals provide the Inuit of Nunavut with a source of food and clothing. Their harvesting helps maintain traditional sharing customs, environmental knowledge, and supports the transfer of values and skills from generations to generation (Hovelsrud et al. 2008).

Threats to this species include poor ice conditions in whelping areas (i.e., low ice coverage or thickness), which can have a large effect on pup mortality (Sergeant 1991; Stenson and Hammill 2014). Inuit from Clyde River have reported that polar bears are eating harp seals more often in recent years because of changes with sea ice (Government of Nunavut 2017g).

4.7.3.2 Distribution and Ecology

Harp seals are widespread through their range in the North Atlantic and Arctic Oceans. The Northwest Atlantic population distribution ranges from Hudson Basin, Foxe Basin, Baffin Bay, Davis Strait, and through the Gulf of Saint Lawrence and Newfoundland in the western North Atlantic (Hammill et al. 2014; Sergeant 1976). Movements of the Northwest Atlantic population are highly associated with the sea ice edge and reflect seasonal changes in ice extents (Sergeant 1976, 1991). In summer, seals migrate north with the retreating ice into Arctic waters, including Davis Strait, Baffin Bay and Lancaster Sound. In the fall, they migrate south to overwinter and whelp on the pack ice off northeastern Newfoundland or in the Gulf of St. Lawrence (Sergeant 1976, 1991). Whelping typically occurs in masses or “whelping patches” in February in the Gulf of St. Lawrence and in March off northeastern Newfoundland, (Sergeant 1991). Year one animals frequently conduct solitary northward migrations in the late spring and early summer to seek out the ice, where they eventually join adults to form large aggregations (Sergeant 1976, 1991). The common distribution of harp seal in the Area of Focus is shown in Figure 4.8

The diet of juvenile harp seals consists of pelagic fish and crustaceans, while adults also feed on benthic crustaceans, cephalopods, and fish (Sergeant 1991). Stomach content analysis of seals revealed the importance of amphipods, and differences in diet between regions and ages. Diets consist primarily of amphipods, Arctic cod, capelin, herring, sand lance, and redfish (Lawson and Stenson 1997; Potelov et al. 2000; Tucker et al. 2009). Stomach contents of pups less than six months old, caught on the Labrador Shelf and Grand Banks, contained invertebrates, capelin and sand lance, while subadults (six months to four years), in the northern part of their range, primarily fed on capelin and Arctic cod. Those on the Grand Banks fed on sand lance and capelin (Lawson and Stenson 1997).

Harp seals can live for over 30 years and mature between the ages of 4 and 8 years (Sergeant 1991). Natural predators of harp seal include polar bears and killer whales (Hammill et al. 2014; Higdon et al. 2012).

4.7.3.3 Key Habitat

Harp seals rely on sea ice for resting, whelping and nursing. When in the Arctic, the species feeds in the bays of Baffin Island and they have been shown to summer in areas such as Cumberland Sound and in the North Water Polynya in Lancaster Sound (Sergeant 1991). Large aggregations of harp seals have been observed in Admiralty Inlet in summer and Davis Strait is considered an important area (Stephenson and Hartwig 2010).

4.7.4 Walrus

4.7.4.1 Conservation Status

There are two walrus subspecies: the Pacific and Atlantic walrus. Atlantic walrus were assessed by COSEWIC in 2006, and are listed under SARA as “Special Concern” (COSEWIC 2006a). There are four distinct populations of the Atlantic walrus (total abundance likely greater than 25,000) that occur in the eastern Arctic (Lowry 2017). In 2016, the IUCN listed the Atlantic Walrus as “Vulnerable”, a change from the 2008 listing of “Data Deficient”, based on predicted future decline in their habitat quality and limitations of population abundance and trend data (Lowry 2017). The Baffin Bay (High Arctic) winter population of Atlantic walrus is believed to comprise approximately 1,500 individuals, and is thought to be increasing (Laidre et al. 2015b). Numbers and trends of the Northern Hudson Bay-Davis Strait population are unknown. Inuit of Grise Fiord have observed an increase in walrus along the south side of Jones Sound, with fewer sightings on the north side of this waterway (Nunavut Department of Environment n.d.).

Walruses strongly influence productivity and ecological function in marine ecosystems through predation on benthic invertebrates, and associated disturbances of bottom sediments that facilitate nutrient flow into the water column (Ray et al. 2006).

Atlantic walrus are an important component of the traditional subsistence economy of the Inuit; their meat provides a source of protein, and their ivory is harvested and sold (Hovelsrud et al. 2008). The annual mean number of walruses hunted and taken in a five-year period between 1996 to 2001 in Nunavut was 382 individuals (Priest and Usher 2004). Subsistence harvests of Atlantic walrus are regulated by quotas in Canada: allowable takes are conservative given a management objective of population recovery (Lowry 2017).

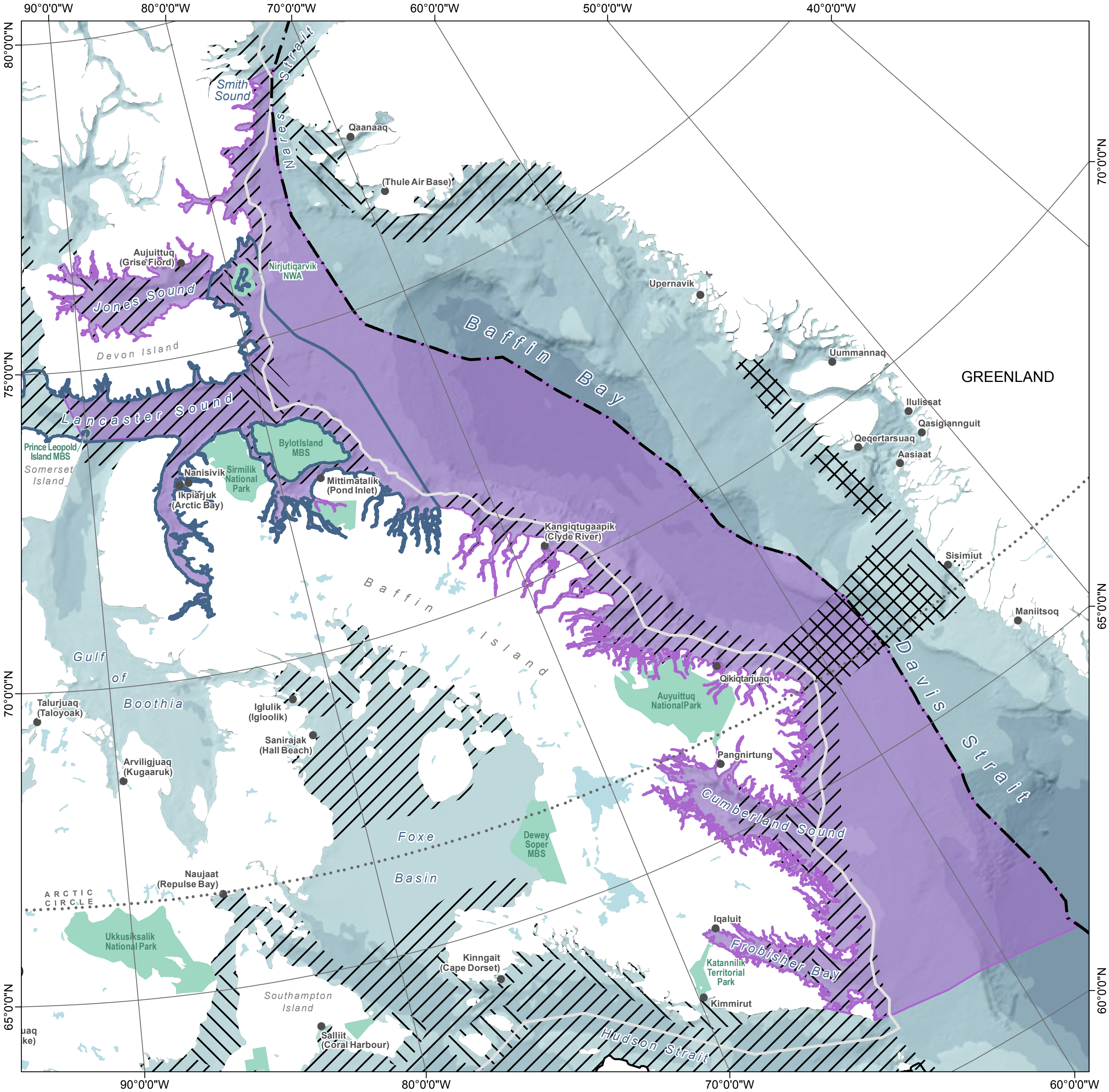
Threats to Atlantic walrus populations in Canada include hunting, noise disturbance, habitat loss, and environmental contamination. Following disturbance, walrus have been known to abandon haul outs (“*uglit*” in Inuktitut) in favour of less accessible islands and shorelines (COSEWIC 2006a). Their restricted seasonal distribution and narrow ecological niche make Atlantic walrus vulnerable to environmental change (e.g., declining sea ice), and an easy species to hunt relative to other marine mammals (COSEWIC 2006a; Huntington 2009; Moore and Huntington 2008). Inuit hunters and Elders from communities on Baffin Island report that on rare occasions, killer whales prey on walrus despite being fearful of the species (Westdal and Ferguson 2009). Walrus tusks have been reportedly dipped in the water by the Inuit of Arctic Bay to ward off killer whales during hunts (Westdal and Ferguson 2009).

4.7.4.2 Distribution and Ecology

Walrus have a discontinuous circumpolar distribution in the Arctic. Of the four populations identified in Canada, two overlap with the Area of Focus: the Northern Hudson Bay-Davis Strait population and the Baffin Bay (High Arctic) population (COSEWIC 2006a). The Northern Hudson Bay-Davis Strait population ranges from Arviat on the west coast of Hudson Bay east through Hudson Strait to Clyde River on the east Coast of Baffin Island. The Baffin Bay population ranges from Bathurst Island, north to Kane Basin and northwest to Greenland. A Grise Fiord community member reported fewer numbers of walrus on the north side of Jones Sound, Ellesmere Island (to the northwest of Baffin Bay) than on the south side of Jones Sound, Devon Island (Nunavut Department of Environment n.d.). The distribution, wintering areas, and transition areas for walruses in the Area of Focus is shown on Figure 4.9.

In winter, Atlantic walrus haul out onto ice floes and form large social groups. The North Water Polynya is important winter habitat for walrus in the Area of Focus (Heide-Jørgensen et al. 2016). At other times of the year, walrus tend to gather in large herds and become associated with drifting pack-ice (Richard 2001). In summer and fall, when ice is lacking, Atlantic walrus congregate on land in a few predictable haul-out locations, including along the southeast coast of Baffin Bay (COSEWIC 2006a). Atlantic walrus exhibit sex-specific distribution and movement. Female walrus with young tend to summer in different areas to males, although both sexes tend to occupy the same wintering areas (Laidre et al. 2008b). During times of strong onshore winds and heavy seas, walruses actively seek more sheltered areas (COSEWIC 2006a).

Walruses are known to travel long distances by swimming or by riding ice floes but until recently, little was known about their seasonal movements. The movements of Atlantic walruses have been found to be more complex than simply following the seasonal expansion and retraction of annual sea ice (Carla et al. 2009). Walruses in the High Arctic of Svalbard, for example, have been tracked moving far into the ice pack during the winter (up to 600 km from the nearest ice-free water), and far from coastal summering areas (Carla et al. 2009). The species feeds predominantly on bivalve molluscs and Arctic cod; however, stomach contents analyses have identified several other prey including gastropods, sea cucumbers, sea urchins, polychaetes, amphipods, isopods, and brachiopods (Fisher and Stewart 1997). Atlantic walruses are also known to eat fishes, and seabirds, and scavenge on dead ringed seals, bearded seals, and whales (COSEWIC 2006a).



Base Features

- Community[1]
- Limit of Exclusive Economic Zone[4]
- Nunavut Settlement Area[3]
- Tallurutiup Imanga / Lancaster Sound NMCA[2]
- Protected Area or National Park[4]

Bathymetry[5] Depth (m)

< 200; 200 - 1000; 1000 - 2000; 2000 - 3000; > 3000

Project Features

- Area of Focus[2]

Walrus[7]

- Known Range
- Transition Zone
- Common in Winter

1:10,000,000

0 50 100 200 300

Kilometres

Nunavut Impact Review Board Strategic Environmental Assessment

Figure 4.9 Walrus Distribution

NUNAMI STANTEC LIMITED

N.I.R.B.

Prepared By: Nunami Stantec Limited
Projection: Canada Lambert Conformal Conic, North American 1983
Date: Apr 13, 2018
Project Number: 12322100
Produced By: L. Trudell
Verified By: J. Beckett
Revision: 01

References:
[1]Atlas of Canada Base Maps, 2017
[2]NIRB, 2017
[3]Nunavut Planning Commission, 2010
[4]National Framework Canada, 2017
[5]Natural Earth, 2016
[6]Stephenson, S.A., and Hartwig, L., 2010

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Male walruses compete intensely to mate with multiple females between February and April, in ice or in the water (COSEWIC 2006a). The implantation of the embryo is delayed until late June or early July, and the duration of active gestation is approximately 11 months (COSEWIC 2006a). Walrus tend to give birth in late May and early June, and suckling continues for 25–27 months (Fisher and Stewart 1997). Female walruses mature between 5 and 10 years of age and give birth to a single pup about once every three years (COSEWIC 2006a). Walruses may live to over 35 years of age (COSEWIC 2006a; Richard 2001). Natural predators of walrus include polar bears, particularly in late winter and early spring in the Canadian high Arctic, and to a lesser extent killer whale (COSEWIC 2006a).

4.7.4.3 Key Habitat

Suitable land habitats for Atlantic walrus in the summer are characterized by low, rocky shores with steep or shelving subtidal zones that provide the species easy access to marine waters for feeding or predator avoidance (COSEWIC 2006a). In winter, large groups of Atlantic walrus use ice floes for haul out; sea ice stability and concentration are thought to be an important determinants of winter distribution and breeding behaviour (Carla et al. 2009; COSEWIC 2006a).

Walrus critical habitats include shallow water areas (less than 80 m in depth) with benthic substrates that support productive bivalve communities (with open water above these feeding areas), and dense annual pack ice or land upon which to haul-out (COSEWIC 2006a; Laidre et al. 2008b).

4.7.5 Narwhal

4.7.5.1 Conservation Status

Narwhals were designated as “Special Concern” following an assessment by COSEWIC in 2004 (COSEWIC 2004a), but to date there has been no assessment of the species under SARA. The species was re-assessed by the IUCN in 2017 and is listed as “Least Concern” on the IUCN Red List of Threatened Species. This was a change from the previous IUCN assessment for Narwhal, in 2012, which listed the species as ‘Near Threatened’ due to previous lower population estimates. The Baffin Bay narwhal population, c. 2004, appeared large (estimated at approximately 45,000 individuals), although there is uncertainty regarding that population estimate, population trends, and levels of sustainable hunting (COSEWIC 2004a).

The Inuit harvest narwhal from Davis Strait and Baffin Bay for their meat, using a combination of traditional and modern hunting equipment (Hovelsrud et al. 2008). Consumption of narwhal maktak is very important for vitamin C intake (Audlaluk as cited in The Association of Fishers and Hunters in Greenland 2013). Current community-based narwhal management initiatives are focused on promoting the integration of IQ into the resource management process. Inuit harvesters have frequently reported that narwhal stocks in Nunavut appeared to be healthy and growing, and that the previous community quota system was impractical and unresponsive to their knowledge (Armitage 2005). A pilot three-year, community-based narwhal management process was established in 1999 involving five Inuit communities: Arctic Bay, Qikiqtarjuaq (Broughton Island), Pond Inlet, Repulse Bay and Kugaaruk (Pelly

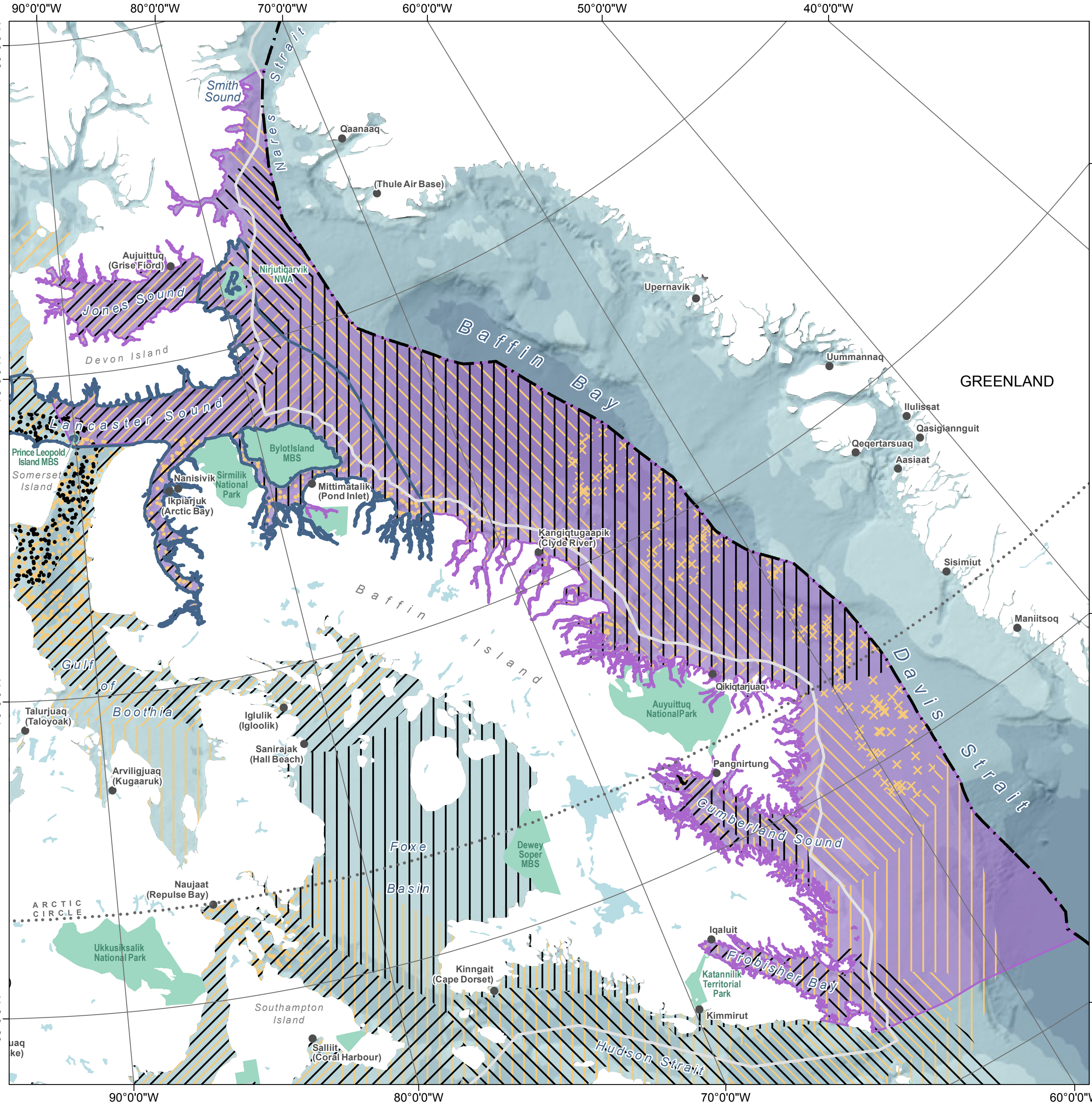
Bay), and involved the formal removal of annual community specific quotas for harvesting (Armitage 2005). Between 1998 and 2001, harvest and mortality rate exceeded that of the historic quotas for all communities, leading to sustainability concerns. The formal removal of annual community quotas was not synonymous with a commonly held understanding of "no quota" system". The total allowable harvest set by the NWMB was clarified to participants and outside observers to resolve misunderstanding, and a commitment to extend the program was made (Armitage 2005).

Threats to narwhals include ice entrapment (e.g., in artificially opened and natural channels that refreeze), predation by killer whales and polar bears, disease and parasites, changes in prey abundance and habitat alteration associated with climate change, environmental contaminants, underwater noise from offshore oil and gas activities, disturbance or strikes associated with shipping, hunting, and commercial fisheries that target prey species (COSEWIC 2004a; Huntington 2009, in press; Reeves et al. 2014).

4.7.5.2 Distribution and Ecology

Two of the three recognized populations of narwhal occur in Canadian waters: the Baffin Bay population, and the Hudson Bay population. The third recognized population of narwhal occurs off east Greenland and is not thought to enter Canadian waters (COSEWIC 2004a). The Baffin Bay narwhal population inhabits the area from the southern end of Baffin Island north to the waters of Hall Basin, between the west coast of Greenland and Ellesmere Island (Reeves et al. 2014).

Narwhal migration patterns follow the seasonal freeze up and retreat of the ice edge. Inuit harvesters describe behaviour and distribution patterns of narwhal across six Inuit seasons (characterized by environmental conditions such as sea ice conditions and temperature) (Armitage 2005). The Baffin Bay narwhal population summers north of Baffin Bay and along the eastern and southern coasts of Baffin Island. The North Water Polynya is important winter habitat for narwhal in the Area of Focus (Heide-Jørgensen et al. 2016). Once the species reaches their summering habitats (e.g., Eclipse Sound, Navy Board Inlet, Admiralty Inlet, Prince Regent Inlet, and Peel Sound) they concentrate at the edges of the fast-ice (Armitage 2005; COSEWIC 2004a). During the late summer, narwhals tend to concentrate in deep coastal waters that offer shelter from the wind (fjords and continental slopes between 300 and 600 m in depth), and this tendency is thought to relate to bottom feeding activity and calving (Dietz et al. 2001; Finley and Gibb 1982a; Richard et al. 1994). The species is also reported to occasionally visit deeper sites during this time (greater than 1,000 m in depth) (Dietz et al. 2001). Inuit of Grise Fiord have noted an increase in narwhal sightings in recent years (Nunavut Department of Environment n.d.). The common summer and winter distributions and ranges of narwhal in the Area of Focus are shown in Figure 4.10.



Base Features

- Community[1]
- Limit of Exclusive Economic Zone[4]
- Nunavut Settlement Area[3]
- Tallurutiup Imanga / Lancaster Sound NMCA[2]
- Protected Area or National Park[4]

Bathymetry[5] Depth (m)

< 200, 200 - 1000, 1000 - 2000, 2000 - 3000, > 3000

Project Features

- Area of Focus[2]

1:10,000,000

0 50 100 200 300 Kilometres

Beluga[6]

- Known Range
- Common in Summer
- Summer Range
- Winter Range

Narwhal[6]

- Known Range
- Common in Summer
- Summer Range
- Common in Winter
- Winter Range

Nunavut Impact Review Board Strategic Environmental Assessment

Figure 4.10 Narwhal and Beluga Distributions

NUNAMI STANTEC LIMITED

N.I.R.B. NUNAVUMI AVATILIKIYIN KATIMAYIN

Prepared By: Nunami Stantec Limited
Projection: Canada Lambert Conformal Conic, North American 1983
Date: Apr 13, 2018
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In late September- early October, when sea ice begins to freeze in their summering habitats, narwhal begin their southern migration south along the east coast of Baffin Island (Dietz et al. 2001). Lancaster Sound is the primary migration route for the Baffin Bay population as narwhal migrate south-east along the east coast of Baffin Island. The population winters in Baffin Bay and northern Davis Strait (COSEWIC 2004a). During the winter, narwhals occupy offshore broken pack ice habitats that provide shelter from rough seas and some refuge from predation by killer whales (DFO 2002b; Dietz et al. 2001). Narwhal over-wintering in southern Baffin Bay and northern Davis Strait have been reported to forage at depths of over 1,000 m (Richard et al. 2014).

Once the ice edge starts to recede in the spring, narwhals begin their migration north along the offshore ice edge east of Baffin Island. Large numbers of narwhal then move west into the sounds and inlets surrounding northeast Baffin Island and Lancaster Sound. Both spring and fall migrations involve concentrations of hundreds of individuals moving together, whereas typically, at other times of the year, narwhal travel in smaller groups (less than 10 individuals) (COSEWIC 2004a; Richard et al. 1994).

Mating occurs in offshore pack ice during the spring (Evans and Raga 2001). Female narwhals reach sexual maturity at six to eight years of age, and the interval between calving is typically three years (COSEWIC 2004a; Evans and Raga 2001). Females carry one calf at a time and typically give birth in July and August (Evans and Raga 2001).

Narwhal use highly directional acoustic signals during ascents and descents in the water column for echolocation of prey, and they scan within a vertical plane (Koblitz et al. 2016). The click of the narwhal is the most directional acoustic signal reported for any species to date (Koblitz et al. 2016). Narwhals do not appear to vocalize often, but an increase in vocalizations has been recorded during migrations when the species travels in large groups (Shapiro 2006). This increase in vocalizations is believed to be communication to enable separated individuals to identify the location of, and become reunited with, the travelling group.

There is evidence that the diet of narwhals varies by season and location (COSEWIC 2004a; Richard et al. 2014). It is believed that narwhal feed predominantly on deepwater fishes including Greenland halibut (turbot) (Richard et al. 1994; Richard et al. 2014), arctic and polar cod (Richard et al. 1994), as well as on squid, octopus and crustaceans (e.g., Pandallid shrimp) (DFO 2002b).

4.7.5.3 Key Habitat

Narwhals show a preference for deep and offshore waters and over-winter in the pack ice areas of Davis Strait and Baffin Bay along the continental slope (Dietz et al. 2001; Richard et al. 2014). Narwhals feed intensely over the winter, with lower feeding activity observed during the summer (Laidre and Heide-Jorgensen 2005; Richard et al. 2014). Therefore, over-wintering habitats may be considered of greater ecological importance to the species. Individuals that spend summers in the area of Admiralty Inlet, Melville Island, and Tremblay Sound reportedly over-winter in northern Davis Strait and Southern Baffin Bay; whereas narwhal that summer around Somerset Island (Creswell Bay) have been reported to use an over-wintering area farther to the north in central Baffin Bay (Richard et al. 2014). Habitats in these over-wintering areas are thought to be favorable to narwhal because they provide steep gradients in bottom temperatures. Steep gradients in bottom temperature are believed to support higher productivity areas of benthic prey (e.g., Greenland halibut) and predictable open water in the pack ice on the east side of Baffin Bay (Laidre et al. 2004).

Critical biophysical habitats include dense annual pack-ice, shear zone/leads, shelf break, deep ocean basins, and estuaries/lagoons/fjords. Important areas to narwhals include open-water and the interface between open-water and pack-ice. Areas with loose annual pack-ice are also used by narwhals (Laidre et al. 2008b).

4.7.6 Beluga Whale

4.7.6.1 Conservation Status

Beluga whale were assessed by COSEWIC in 2004; the Eastern High Arctic/Baffin Bay population (approximately 20,000 individuals circa 2004) of the species is listed under SARA as "Special Concern", and the Cumberland Sound population (approximately 1,500 individuals circa 2004), is listed under SARA as "Threatened" (COSEWIC 2004b). In 2017, the IUCN assessed beluga whale as being "Least Concern" globally, a change from the previous (2012) assessment that listed the species as "Near Threatened" based on uncertainties associated with population size estimates and declining trends in some parts of their range.

Prior to Greenland setting a catch limit of 310 in 2004 (Heide-Jørgensen et al. 2017), the Eastern High Arctic/Baffin Bay beluga population was heavily hunted in overwintering areas off west Greenland; however, most of the population winters in Baffin Bay and the High Arctic where it is not hunted (COSEWIC 2004b; Huntington 2009). Hunting of this population in Canadian waters is low during the summer.

A population decline of the Cumberland Sound beluga population (a decline of approximately 1,500 animals between 1920 and 2004) was documented and linked to hunting by the Hudson Bay Company for their skin and oil into the 1940s, coupled with hunting by the Inuit until 1979 (COSEWIC 2004b; DFO 2002a). Hunting of the Cumberland Sound population has been regulated since the 1980s, and the quota of 41 in 2003 was deemed sustainable (COSEWIC 2004b).

Elders from Iqaluit observed an overall decline in whale populations compared with the 1950s (Nunavut Wildlife Management Board (NWMB) 1998). Similarly, Inuit from Grise Fiord have recently noted a decline in the beluga whale population, while Inuit of Qikiqtarjuaq noted that beluga sightings were rare (Nunavut Department of Environment 2010, n.d.). Hunters from Kimmirut and Iqaluit report changing migration patterns, with beluga whales rarely encountered during the summer months. Inuit of Iqaluit note that the beluga whales that enter Frobisher Bay and the Iqaluit area spend very little time there during the summer but may be sighted along the floe-edge in the spring (Nunavut Wildlife Management Board (NWMB) 1998). A change in the size of the whales has also been noted, with larger whales no longer observed. Some Inuit from Kimmirut report an increase in the number of individual whales in the adjacent waters (Nunavut Wildlife Management Board (NWMB) 1998). Variations in the population and overall size of beluga whales may be attributed to changes in specific whale populations as Elders from multiple communities have observed differences in fin, tooth, and flipper morphology (Nunavut Wildlife Management Board (NWMB) 1998).

Beluga are a valued food source for the Inuit. Subsistence hunts typically involve cooperative efforts with several hunters and vessels, and proceeds are often shared among the hunters and other community members (DFO 2002a). Belugas provide the Inuit with an important source of meat, fat, oil, leather, tools and materials for fabrication of arts and crafts (DFO 2002a; Hovelsrud et al. 2008). Beluga *maktak* (the skin and top layer of blubber) is a highly-prized food source, high in energy content and rich in vitamin C (DFO 2002a).

Potential threats to beluga populations present in the Area of Focus include hunting, particularly that off west Greenland; increased predation linked to the expansion of the range of killer whales influenced by climate-change induced changes in ice cover; predation by polar bear; environmental contamination; ship strikes; and behavioural disruption by underwater noise generated by vessels and seismic exploration (COSEWIC 2004b; Higdon et al. 2012; Huntington 2009; Moore and Huntington 2008; Reeves et al. 2014; Smith and Sjare 1990). Inuit knowledge suggests that belugas are less suspicious of humans compared to other species (e.g., walrus) and, therefore, are easier to approach and hunt (Richard et al. 2001). The strong site-fidelity of beluga also makes them easier targets for commercial and subsistence hunters, compared with other species (Huntington 2009).

4.7.6.2 Distribution and Ecology

Belugas range in arctic and subarctic waters along the northern coasts of Canada, Alaska, Russia, Norway, and Greenland (DFO 2002a; Reeves et al. 2014). The various populations are distinguished by their summer distribution and several show distinct genetic differences. There are seven defined populations of beluga whale in Canadian waters, the ranges of at least two populations overlap the Area of Focus: the Eastern High Arctic/Baffin Bay population and the Cumberland Sound population (COSEWIC 2004b).

The Eastern High Arctic/Baffin Bay beluga population migrates from open-water overwintering areas of Baffin Bay, the High Arctic, and West Greenland, to spring and summer calving and feeding areas of the Canadian High Arctic, including Lancaster Sound, Barrow Strait, Prince Regent Inlet and Peel Sound (COSEWIC 2004b; Heide-Jørgensen et al. 2017; Smith and Martin 1994). The winter distribution of beluga is not well understood by Inuit hunters and the scientific community, but in general seems dependent on areas of shifting ice where open water provides access to air (DFO 2002a; Kilabuk 1998). It is believed that many belugas spend the winter in the North Water Polynya (Heide-Jørgensen et al. 2016). An estimated 9,072 individuals (CV = 32%) migrate to waters off central West Greenland to spend the winter, arriving in November/December and remaining until April (Heide-Jørgensen et al. 2017). In early spring, migrating beluga are seen near the floe-edge by Inuit hunters from communities of Iqaluit, Pangnirtung and Kimmirut (Kilabuk 1998). Many of the Inuit hunters from these three communities believe that some of the beluga whales spend the winter near the mouth of Frobisher Bay. The species moves into shallow coastal waters in late June to early July once the annual land fast ice breaks up, and concentrates at coastal calving, moulting, and feeding areas, which are typically river estuaries (COSEWIC 2004b; Smith and Martin 1994; St. Aubin et al. 1990). The shallow waters are thought to provide some shelter from predators, such as killer whales (COSEWIC 2004b). In the autumn, belugas begin to migrate to other locations (e.g., deep-water areas) where they may feed more intensely (COSEWIC 2004b). The common summer and winter distributions and ranges of beluga in the Area of Focus are shown in Figure 4.10.

Belugas show fidelity to summering areas, even returning to the same grounds after being exposed to disturbances such as hunting (DFO 2002a). Pods of 15 to 20 adult males have been seen in larger estuaries, but are typically avoided by females that use quieter parts of estuaries to suckle their young (DFO 2002a).

Belugas typical lifespan is between 15 and 30 years (Harwood and Smith 2002). Sexual maturity of belugas is attained at eight years of age in males, and approximately five years of age in females (DFO 2002a). Mating occurs in late winter and early spring (e.g., April-May), and there is evidence that males breed with several females (COSEWIC 2004b; DFO 2002a). The gestation period lasts 14 months, and births occur between the end of June to early August (DFO 2002a). It is thought that peak calving occurs during the late spring migration in offshore areas (Beland et al. 1990). The long gestation period is followed by an 18-month nursing period, and results in female only being capable or reproducing approximately every 3 years (DFO 2002a).

Belugas are toothed whales with a diverse diet of fish and invertebrates, including Arctic cod, herring, capelin, shrimp, squid, and marine worms (DFO 2002a). Diet varies seasonally based on prey availability (DFO 2002a). Belugas rarely feed on schooling fish in estuaries during the summer but appear to make frequent feeding dives outside the estuaries. During the late summer and autumn, migrating belugas from Arctic waters feed heavily on Arctic cod in deep waters (COSEWIC 2004b); this is an important time for accumulating a thick layer of blubber that provide both insulation and a large reserve of energy necessary for the winter (DFO 2002a). Kimmirut Elders and hunters reported that belugas visit Kimmirut in the spring when feeding off Arctic cod at the floe-edge or when following the direction of the currents while searching for cod in the summer (Nunavut Wildlife Management Board (NWMB) 1998). Belugas are capable of frequent dives to depths of 400 to 800 m, with the greatest dive depth recorded for a male beluga being greater than 1,000 m (DFO 2002a).

Belugas are a highly vocal and social species, with high-pitched whistles and grunts thought to be used for communication, and to express alarm (DFO 2002a). The species has a well-developed hearing capability and uses echolocation to detect prey in dark waters at depth (DFO 2002a).

4.7.6.3 Key Habitat

Key winter habitats for beluga in Baffin Bay and Davis Strait are offshore pack ice with between approximately 4/10–8/10 ice cover (COSEWIC 2004b).

Specific estuaries and coastal habitats are used by beluga in the summer that offer shallow (typically less than 40 m in deep), brackish and relatively warm waters with sandy or muddy substrates (DFO 2002a; Martin et al. 2001).

4.7.7 Killer Whale

4.7.7.1 Conservation Status

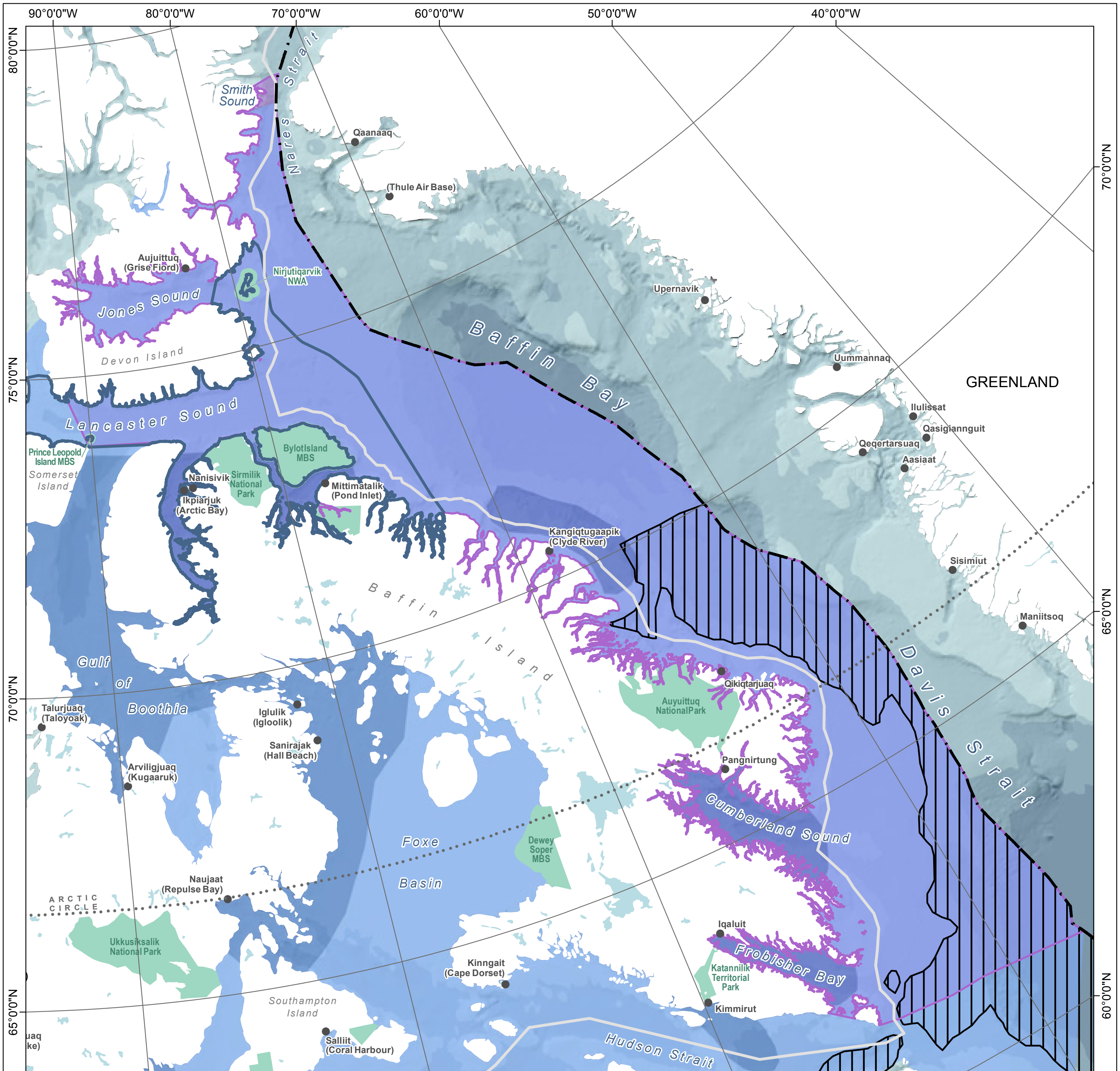
The Northwest Atlantic/Eastern Arctic (NWA-EA) killer whale population was reexamined and designated as “Special Concern” by COSEWIC in November 2008 (COSEWIC 2008a). The assessment estimated the NWA-EA population size to comprise fewer than 1,000 individuals, and likely fewer than 250. An increase in sightings of the NWA-EA killer whales has been reported, per decade, between 1850 and 2008, throughout its range, suggesting the population is rising (Ferguson et al. 2010; Higdon and Ferguson 2009). During interviews in 2009, Inuit hunters and Elders from coastal communities of Nunavut indicated that killer whale sightings were of similar or higher frequency than previous decades. The Inuit Elders and hunters estimated that numbers of killer whales around the Nunavut coast were fewer than 50 in total (estimates ranged from 12 to 500) (Westdal and Ferguson 2009).

The primary cause of killer whale mortality is hunting, predominantly by Greenland Inuit. Although killer whales were hunted occasionally by Canadian Inuit historically, this no longer occurs (Higdon 2007). Killer whales have no natural predators (COSEWIC 2008a). Occasional mass stranding or ice entrapment events can occur and may have a notable effect on killer whale populations (COSEWIC 2008a). Other threats to killer whale populations include reduced prey availability, physical and acoustic disturbance, and susceptibility to chemical contaminants (e.g., persistent bioaccumulating toxins) linked to the long life and apex-predator status of the species (COSEWIC 2008a). Killer whales in the Pacific are among the most heavily contaminated marine mammals (Higdon 2007); however, studies of contaminant levels in Arctic killer whales are still in their infancy.

4.7.7.2 Distribution and Ecology

Killer whales are distributed throughout the world’s oceans, including in Arctic waters. Killer whale presence and distribution in Nunavut is limited by ice, with the species tending to avoid heavy ice cover (greater than 50% coverage) (Matthews et al. 2011). Since the mid-1990s killer whales have expanded their range from Baffin Bay and Davis Strait into northern Foxe Basin and Hudson Bay (Ferguson et al. 2010). NWA-EA killer whales generally move with the seasonal retreat and advance of sea ice, and follow migrations of prey species (e.g., marine mammals) (Higdon et al. 2012). In the eastern Arctic, killer whales are sighted regularly in Cumberland Sound, Pond Inlet/Bylot Island, Lancaster Sound, Admiralty Inlet and western Hudson Bay (particularly in the Repulse Bay area). The highest number of sightings are reported in the Lancaster Sound region (Higdon 2007). Off the eastern coast of Baffin Island, members of Qikiqtarjuaq observed as many as 100 killer whales in Merchants Bay near Palligvik/Padloping Island over the course of several days in September 1994 (NWMB 2000). The common and uncommon distribution of killer whale in the Area of Focus is shown in Figure 4.11.

It is currently not known whether NWA-EA killer whales are segregated into “transient” marine mammal-eating and “resident” fish-eating ecotypes (Ferguson et al. 2010). The predominant predation by killer whales reported in Nunavut is of marine mammals, suggesting that the population is transient; however, fish predation events have also been reported in Davis Strait (Ferguson et al. 2010).



Base Features

- Community
- Limit of Exclusive Economic Zone[4]
- Nunavut Settlement Area[3]
- Tallurutiup Imanga / Lancaster Sound NMCA[2]
- Protected Area or National Park[4]

Bathymetry[5] Depth (m)

< 200 | 200 - 1000 | 1000 - 2000 | 2000 - 3000 | > 3000

Project Features

- Area of Focus[2]

Killer Whale[6]

- Common
- Uncommon

Northern Bottlenose Whale[7]

- Range

1:10,000,000

0 50 100 200 300

Kilometres

Nunavut Impact Review Board Strategic Environmental Assessment

Figure 4.11 Killer Whale and Northern Bottlenose Whale Distributions

References:
[1]Atlas of Canada Base Maps, 2017
[2]NIRB, 2017
[3]Nunavut Planning Commission, 2010
[4]National Framework Canada, 2017
[5]Natural Earth, 2016
[6]Stephenson, S.A. and Hartwig, L., 2010
[7]COSEWIC 2011

Prepared By: Nunami Stantec Limited
Projection: Canada Lambert Conformal Conic, North American 1983
Date: Apr 13, 2018
Project Number: 12322100
Produced By: L. Trudell
Verified By: J. Beckett
Revision: 01

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Female killer whales give birth at an average age of 15 years, with a highly variable calving interval of between 2 and 11 years (COSEWIC 2008a; Evans and Raga 2001). Mortality of Northern Resident killer whales on the Pacific coast is high during the first six months of life (estimated up to between 37–50%) (Olesiuk et al. 2005). During the period of population growth (1973–1996), average life expectancy was estimated as 46 years for females and 31 years for males (maximum longevity of approximately 80 years and 60–70 years, respectively) (Olesiuk et al. 2005). Studies of the Northern Resident killer whale provide evidence of reproductive senescence in older females (mean age of onset of post-reproduction was 40 years) (Olesiuk et al. 2005), but it is unknown whether transient killer whales experience the same. The gestation period lasts for approximately 17 months, and it is thought that weaning continues for between 1 and 3 years following birth (COSEWIC 2001; Evans and Raga 2001).

Inuit Traditional Ecological Knowledge and scientific observations provide evidence of killer whale predation on various Arctic marine mammal species (e.g., narwhal, beluga, bowhead whales, walrus and seals) (COSEWIC 2008a; Ferguson et al. 2010; Higdon et al. 2012; Westdal and Ferguson 2009). A compilation and review of sighting records associated with predation events revealed that narwhal and beluga are the most frequently observed prey species of killer whale in the Canadian Arctic, followed by bowhead whale, and phocids (harp, ringed, bearded and harbour seals) (Higdon et al. 2012). Most beluga predation events that have been reported in Nunavut have been observed in Cumberland Sound and Hudson Bay, whereas predation of bowhead whale has been reported throughout Baffin Bay and Lancaster Sound in addition to other areas (COSEWIC 2008a; Higdon 2007). Observations of predation events involving bowhead whale are common, and killer whales often leave visible tooth rake marks on the flukes of that species (Ferguson et al. 2010; Finley 2001).

4.7.7.3 Key Habitat

Killer whales generally appear to use and tolerate wide habitat variability (depth, size of water body, water temperature), although this varies by population (COSEWIC 2008a). Habitat requirements of transients are not well understood, but habitats must be sufficiently quiet for prey detection by passive listening to enable effective hunting (Barrett-Lennard et al. 1996). It is generally assumed that killer whales do not range into regions of pack ice (due to their large dorsal fin) but this assumption has not been verified. Killer whales occasionally move into freshwater, though usually only for short periods (hours or days) (Higdon 2007).

4.7.8 Northern Bottlenose Whale

4.7.8.1 Conservation Status

Two genetically distinct populations of northern bottlenose whale are present in Canada, the Davis Strait-Baffin Bay-Labrador Sea population (no abundance estimate), which has been assessed by COSEWIC as “Special Concern”, and the Scotian Shelf population (estimated at 164 individuals in 2011), which is listed under SARA as “Endangered” (COSEWIC 2011). The Davis Strait-Baffin Bay-Labrador Sea population has been genetically linked to the populations off Iceland (COSEWIC 2011).

A period of intense commercial whaling of northern bottlenose whale occurred between approximately 1880 and 1920, substantially reducing population levels of the species throughout its range (Whitehead and Hooker 2012). A second phase of whaling occurred between 1937 and 1973 (Whitehead and Hooker 2012). Between 1969–1971, commercial whalers took 818 animals from the Baffin Bay and Davis Strait-Labrador Sea population (COSEWIC 2011). Northern bottlenose whales are no longer hunted in Canada. The two current principal threats to the species are entanglement in fishing gear in the Labrador Sea, and behavioural disruption from underwater noise throughout its range (Whitehead and Hooker 2012).

4.7.8.2 Distribution and Ecology

The Davis Strait-Baffin Bay-Labrador Sea population of northern bottlenose whale are found in deep (greater than 500 m) waters in the Area of Focus (COSEWIC 2011). The distribution of northern bottlenose whales in the Area of Focus is shown in Figure 4.11. Belonging to the family Ziphiidae (beaked whales), the species is known for its particularly prolonged (exceeding 70 minutes) and deep dives (deeper than 800 m) relative to most other marine mammal species.

Northern bottlenose whale predominantly feed on squid from the genus *Gonatus* that typically occur in greater abundance and with a larger body size at depth throughout the Arctic and sub-Arctic waters of the North Atlantic (Compton 2004).

Males mature at 7–9 years of age, and females at 8–13 years of age. Females give birth to a single calf approximately every 2 years, after a gestation period of approximately 12 months. Northern bottlenose whales have a life span of at least 37 years, and a generation time of approximately 15.5 years (COSEWIC 2011). Killer whales have been observed attacking northern bottlenose whales; however, it is believed that the deep-diving capabilities of the species help them avoid predation by killer whales (COSEWIC 2011).

4.7.8.3 Key Habitat

Northern bottlenose whales typically are found in continental slope waters (between 800 and 1,500 m deep) (COSEWIC 2011), and appear to prefer cold waters along the edge of pack ice during the spring and summer (Compton 2004). The cold Labrador Current creates areas of strong upwelling at the edge of the continental shelf slopes (e.g., where Davis Strait meets the Labrador Sea). The upwelling in these areas supports high biological productivity and an abundance of prey for northern bottlenose whale (Whitehead and Hooker 2012).

4.7.9 Bowhead Whale

4.7.9.1 Conservation Status

The bowhead whale is a species traditionally hunted by the Inuit as an important source of protein, and raw material for carvings and jewelry (Hovelsrud et al. 2008; NWMB 2000). Following the cessation of commercial whaling (c. 1915), a substantial increase in bowhead populations was observed, and Inuit in Nunavut resumed a limited subsistence hunt for the species in 1996 (approximately one to three individuals harvested per year (DFO 2015c; Priest and Usher 2004). Although some Inuit continue to be reluctant in their support of bowhead whale hunting, often citing a lack of need given modern life styles, many others support this renewed activity out of respect of the Elders who wish access to bowhead maktak (NWMB 2000). The Eastern Canada-West Greenland (EC-WG) population of bowhead whale is listed by COSEWIC as "Special Concern" (COSEWIC 2009), and internationally, the species is listed as "Least Concern" on the IUCN Red List (Reilly et al. 2012).

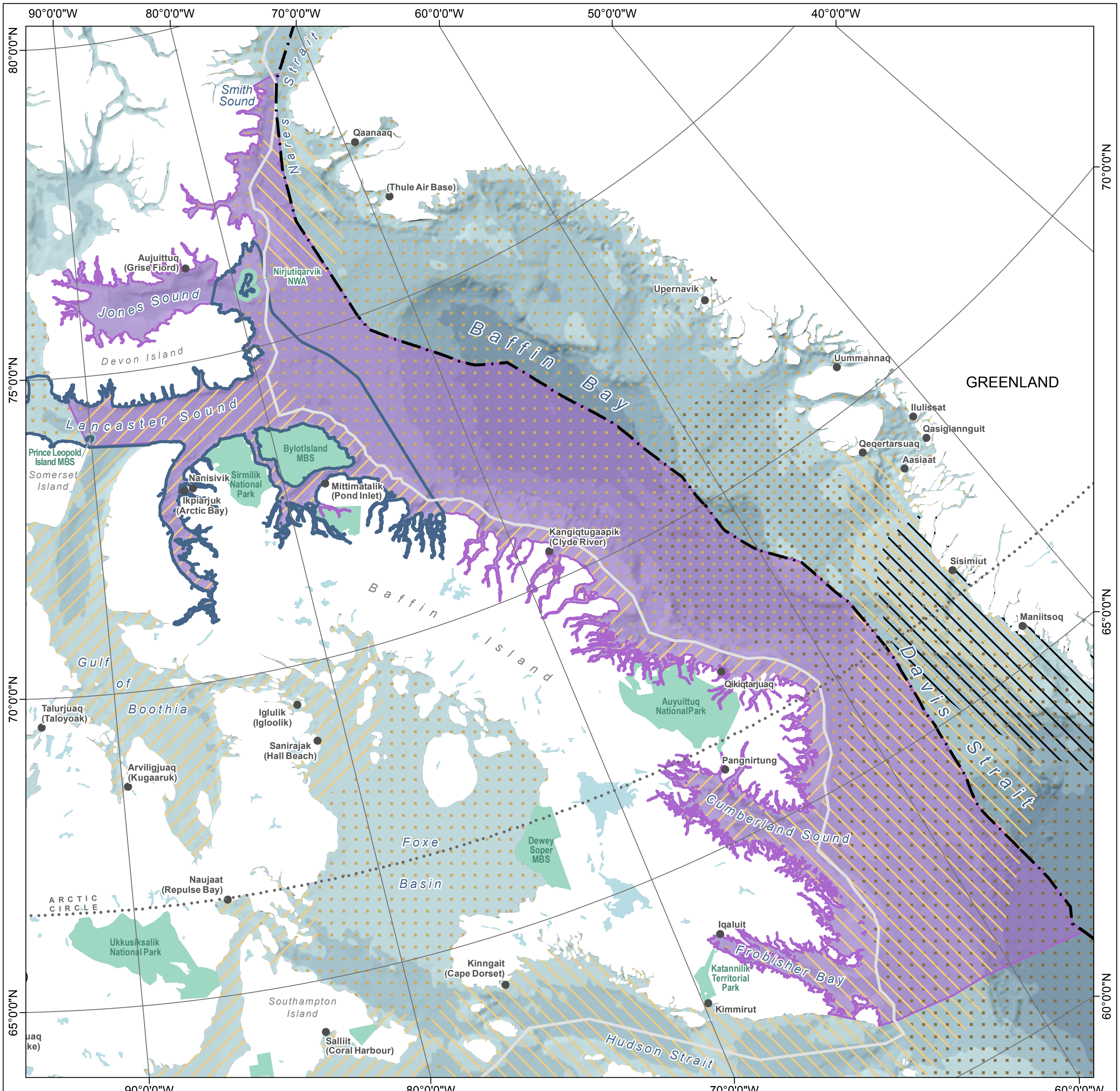
Current threats to bowhead whales include predation, environmental contamination, disease, illegal hunting, ship strikes, accidental ingestion of foreign objects (e.g., plastics), and potential disturbance and displacement from preferred habitats by offshore oil and gas exploration, commercial shipping, and tourism (COSEWIC 2009; Reeves et al. 2014). Predation by killer whales, not observed in the region until the mid-1990s, is a growing concern and may currently be the primary threat to bowhead whale populations in the eastern Canadian Arctic (Ferguson et al. 2010; Finley 2001; Higdon 2007; Higdon et al. 2012; Moshenko et al. 2003). Inuit from Qikiqtarjuaq have reported that many bowhead whales have been sighted in the area, and that killer whale predation had also been observed (Government of Nunavut 2010). Inuit from Pangnirtung have observed a decline in bowhead whales, as well as other marine mammals in Cumberland Sound, and have attributed this to the killer whales (Keeniainak, J. 2000, as cited in NWMB 2000). Although less prone to accumulation of contaminants than toothed whales, bowhead are capable of accumulating low levels of toxins (e.g., cadmium) in their liver and kidneys over their long life span (some living over 100 years) (Finley 2001). A positive correlation between summer sea ice loss and bowhead body condition has been identified using data collected between 1989 and 2011 for the Bering-Chukchi-Beaufort population (George et al. 2015). However, there are concerns that seasonal food abundance for bowhead and timing of their migration may become detached in the future, resulting in an unfavourable uncoupling for the species (Reeves et al. 2014).

During interviews for the Inuit Bowhead Knowledge Study (NWMB 2000), Inuit hunters from Arctic Bay, Clyde River, Iqaluit, Kimmirut, Pangnirtung, Pond Inlet, and Qikiqtarjuaq reported increases in bowhead whale populations (Akavak, S. 2000 as cited in NWMB 2000; Etuangat 2000 as cited in NWMB 2000; Ipellie 2000 as cited in NWMB 2000; Koksiak 2000 as cited in NWMB 2000; Papatsie 2000, as cited in NWMB 2000). The community of Grise Fiord notes regular sightings of bowhead whales, but as the townsite was established in the 1950s, it is difficult for residents to speak to population changes (NWMB 2000).

4.7.9.2 Distribution and Ecology

Bowhead whales have a near-circumpolar distribution in Arctic and sub-Arctic waters. Studies to track the distribution and migration of the species by satellite tagging (DFO 2006) supported a conclusion of one combined population in the Eastern Canada-West Greenland region, rather than two as previously thought (COSEWIC 2009). Bowheads have a widespread distribution in Nunavut. The summer range of the EC-WG bowhead population covers northwestern Hudson Bay, and extends from northern Foxe Basin, through Prince Regent Inlet, Gulf of Boothia, and Lancaster Sound, and across western Baffin Bay into Cumberland Sound (Dueck et al. 2006; Wheeler and Gilbert 2007). Aerial surveys conducted with concurrent satellite tracking of individuals in August 2013 identified summer aggregations of bowhead in the Gulf of Boothia and Cumberland Sound (DFO 2015c). Several potential foraging areas of bowhead were identified through satellite tracking in Baffin Bay and adjacent waters in 2009-2011, including Clyde Inlet, Isabella Bay, Broughton Island, Cumberland Sound, and Frobisher Bay (Nielsen et al. 2015). Recent observations of bowhead in Cumberland Sound, during the summer of 2014, found evidence of skin moulting and individuals were seen to rub against large rocks in shallow coastal areas to promote exfoliation (Fortune et al. 2017). The EC-WG population winters in areas of unconsolidated icepack in northern Hudson Bay, Hudson Strait, central Davis Strait, and southern Baffin Bay (Dueck et al. 2006; Koski et al. 2006; Wheeler and Gilbert 2007). Bowheads have been observed in the North Water Polynya (an area of year-round open water), at the northwestern end of Baffin Bay in March; however, the abundance of the species in this area appears to be low (Koski et al. 2006). The common summer and winter distributions and range of bowhead whales in the Area of Focus are shown in Figure 4.12.

Bowheads occur in variable marine conditions ranging from open water to leads, polynyas, and in areas with thick, unconsolidated pack ice. The species is well adapted for life in Arctic environments. The species has a long lifespan (greater than 100 years old) (COSEWIC 2005b; Evans and Raga 2001); a large energy storage capability; sophisticated acoustic senses (e.g., for navigational use in high ice environments) and long-range communication; and a padded crown on their head for pushing through ice (up to 20-cm thick) to breathe (Finley 2001).



Base Features

- Community
- Limit of Exclusive Economic Zone[4]
- Nunavut Settlement Area[3]
- Tallurutiup Imanga / Lancaster Sound NMCA[2]
- Protected Area or National Park[4]

Bathymetry[5] Depth (m)

< 200; 200 - 1000; 1000 - 2000; 2000 - 3000; > 3000

Project Features

- Area of Focus[2]

Bowhead[6]

- Range
- Common in Summer
- Common in Winter

Humpback[7]

- Seasonal Habitat

Fin Whale[8]

- Range

1:10,000,000

0 50 100 200 300

Kilometres

Nunavut Impact Review Board
Strategic Environmental Assessment

Figure 4.12
Baleen Whale Distributions

NUNAMI STANTEC LIMITED

N.I.R.B.

Prepared By: Nunami Stantec Limited
Projection: Canada Lambert Conformal Conic, North American 1983
Date: Apr 13, 2018
Project Number: 12322100
Produced By: L. Trudell
Verified By: J. Beckett
Revision: 01

References:
[1]Atlas of Canada Base Maps, 2017
[2]NIRB, 2017
[3]Nunavut Planning Commission, 2010
[4]National Framework Canada, 2017
[5]Natural Earth, 2016
[6]Stephenson, S.A. and Hartwig, L., 2010
[7]Stevick et al., 2003
[8]Fisheries and Oceans Canada, 2012

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Bowhead whales are known to congregate and forage in areas that aggregate zooplankton and create productive feeding habitat (e.g., troughs, upwellings, eddies, water mass boundaries) (Finley 2001). Prey species for bowheads include crustacean zooplankton, predominantly euphausiids and copepods, and epibenthic organisms, such as mysids and gammariid amphipods (Finley 2001; Lowry 1993). The species forages intensely during the open-water season (July–September), and for supplemental protein intake during the winter and spring (Burns et al. 1993; Matthews and Ferguson 2015).

Available biological information on bowheads mostly comes from studies of harvests involving the Bering-Chukchi-Beaufort population. Bowheads are slow swimming, highly vocal baleen whales (Clark and Johnson 1984). Studies suggest that bowhead calls may function to maintain social cohesion of groups, and monitor changes in ice conditions that may require a migratory response (Evans and Raga 2001).

Bowheads reach sexual maturity at approximately 20–25 years of age (Finley 2001). Most social-sexual activity takes place in shallow waters, such as Isabella Bank, which may provide protection from killer whales and shelter from strong currents (Finley 1998; Finley et al. 1994). Sexual activity occurs during much of the year; however, conceptions typically occur in late winter or early spring. Females carry one offspring per pregnancy, and gestation lasts between 12 and 16 months (Evans and Raga 2001).

4.7.9.3 Key Habitat

The relative importance of Arctic habitats used by bowhead whales is described by Laidre et al. (2008b). Critical bowhead habitats are identified as regions of shallow water/continental shelf. Important bowhead habitats include dense annual pack ice, shear-zone/leads, polynyas, open water, and ice edges (pack ice and open water). Other habitats used by bowhead whales include loose annual pack ice and shelf break regions (Laidre et al. 2008b). The importance of shallow water habitats to bowhead is supported by other work that was conducted to define their critical summer and fall habitats (Wheeler et al. 2012).

4.7.10 Humpback Whale

4.7.10.1 Conservation Status

The Western North Atlantic population of humpback whale were assessed by COSEWIC in 2003 as “Not at Risk”, which was a change from the previous listing as “Special Concern” in 1985 (COSEWIC 2003).

Commercial whaling affected all humpback populations, and it is estimated that up to 90–95% of the world-wide population of humpbacks were killed in this way (Johnson and Wolman 1984). Since the late 1960s and 1970s, after the whaling period ended, populations have generally increased, albeit not to former levels (Baird 2003). Data for the breeding population in the Caribbean estimated an annual population growth of 3% (Stevick et al. 2003). A population abundance estimate of 2,080 humpbacks (95% CI: 1,337-3,172) was produced following the aerial surveys for the Trans North Atlantic Sightings Survey in 2007, covering waters of eastern Canada from the Scotian Shelf and Gulf of St Lawrence to Labrador (Lawson and Gosselin 2009). Aerials surveys of humpbacks off West Greenland were conducted in 2007 and used to establish an abundance estimate of 4,090 individuals (CV = 0.50) (Heide-Jorgensen and Laidre 2015).

Threats to humpback whales in the western North Atlantic include predation, parasitism, disease, biotoxins, changes in prey species abundance (e.g., capelin), accidental beaching, vessel strikes, and entrapment. Predation by killer whales is thought to be infrequent; however, approximately one third of humpbacks in the western North Atlantic have been reported as having scars from the species. Scars on first sightings of individuals suggests that predation is targeted at calves (Baird 2003).

4.7.10.2 Distribution and Ecology

Humpback whales are found in tropical, temperate, and sub-polar waters across the world. In the North Atlantic, humpbacks typically undertake long-distance migrations between winter breeding and calving areas in the tropical waters of the Caribbean or, to a lesser extent off the Cape Verde Islands, to summer feeding areas off the northwest coasts of North America, southwest coasts of Greenland and Iceland, and into the Barents Sea (Baird 2003). In the northwest Atlantic, some humpbacks have recently been found to remain in areas surrounding Nova Scotia (e.g., the Gully) and Newfoundland over the winter (Kowarski et al. 2017). Humpbacks feed predominantly at higher latitudes, with only rare feeding reported at winter breeding grounds.

Four recognized humpback stocks occur in the western North Atlantic; the “western Greenland” stock’s summer range is most relevant to the Area of Focus (shown in Figure 4.12) and has been observed in the Area of Focus. Humpback whales in the western North Atlantic exhibit high site fidelity at shared tropical breeding areas, and moderately-high site fidelity at summer feeding areas (Clapham and Mead 1999; Weinrich 1998). Movement of individuals between summering areas in the western North Atlantic summer stocks has been reported on rare occasions; however, stocks are believed to interbreed at a common breeding ground (Weinrich 1998).

Humpbacks in the northern hemisphere feed primarily on euphausiids and various species of schooling fish including capelin (Baird 2003; Weinrich 1998).

The mean age of sexual maturity for female humpback is five years. Although humpbacks have the ability to reproduce annually two or three-year long calving intervals are more common (Baird 2003). Mothers and calves remain together for at least nine months, and weaning occurs later in the stay at summer feeding areas, or following return to lower latitudes (Weinrich 1998). The life span of humpbacks is unknown, but is expected to be longer than 48 years of age, which was the age of the oldest animal recorded, from western Australia (Baird 2003). Natural predation of humpbacks (particularly on calves in breeding grounds) by killer whales, false killer whales and large sharks has been reported, but appears to be infrequent (Baird 2003)

Humpback whales are highly social, and both sexes use a wide range of non-song vocalizations for social and feeding-related communication. Complex songs are only sung by male humpbacks and are mostly heard on low-latitude winter breeding grounds; however, recent studies have found that male humpback also sing on summer feeding grounds (Vu et al. 2012).

4.7.10.3 Key Habitat

Humpbacks frequent nearshore areas between their migrations (Baird 2003). In their summer higher-latitude feeding grounds, humpback whales tend to concentrate around areas of upwelling and high productivity, which are typically associated with bottom topography and relief (Weinrich 1998).

4.7.11 Fin Whale

4.7.11.1 Conservation Status

The Atlantic population of fin whale was assessed by COSEWIC in 2005, and is listed as "Special Concern" under SARA (COSEWIC 2005a). Internationally, the species is listed as "Endangered" on the IUCN Red List (Reilly et al. 2013). Commercial whaling reduced the Atlantic population of fin whales during the 20th Century up until a cessation of hunting in 1971, but abundance is thought to have increased off the coast of western Greenland since (COSEWIC 2005a; Edwards et al. 2015). The best available recent abundance estimate for a proportion of the western North Atlantic fin whale population is 3,522 (CV = 0.27), based on surveys in July–August 2007 conducted as part of the Canadian Trans-North Atlantic Sighting Survey, between northern Labrador and the Scotian Shelf (Waring et al. 2014,). The fin whale is the second longest animal on Earth, after the blue whale, and is one of the fastest whale species.

Potential threats to Atlantic fin whales include acoustic disturbance from shipping and seismic exploration, ship strikes, entanglement in fishing gear, and habitat degradation possibly due to altered prey quality or abundance (Castellote et al. 2012; COSEWIC 2005a; DFO 2012; Waring et al. 2014,). Predation of old, ill, or juvenile animals by killer whales or sharks is thought to be feasible; however, no conclusive reports of successful predation appear in the available literature (COSEWIC 2005a).Climate change may increase the number of summer-visiting baleen whales, such as fin whales, in the southern portion of the North Atlantic Arctic and increase the duration of their stay (Kovacs and Lydersen 2008).

4.7.11.2 Distribution and Ecology

Fin whales occur in all the oceans of the world, and the southern and northern hemisphere fin whales are considered subspecies (COSEWIC 2005a). Of the Northern hemisphere fin whales, the Pacific population passes through waters off the coast of British Columbia, and summer concentrations of the Atlantic population in the west North Atlantic occur in the Gulf of St. Lawrence, on the Scotian Shelf, in the Bay of Fundy, nearshore and offshore waters of Newfoundland, and off Labrador (COSEWIC 2005a). The northern distribution of fin whales extends into Davis Strait and the southern portion of Baffin Bay (DFO 2012), as shown in Figure 4.12. Most of the available literature for fin whales relates to the summer feeding grounds, and relatively little is available for wintering grounds, or the location of calving and breeding areas. Although conception and calving is believed to occur during the winter at lower latitudes, there is evidence that some fin whales mate prior to migration to these areas. Passive acoustic monitoring of fin whale calls in Davis Strait, over two years, established that some fin whales remained in the area later than thought (call frequencies peaked in November–December), and were thought to be mating prior to migrating south (Simon et al. 2010). The average age at which individuals reach sexual maturity is 6–7 years for males and 7–8 years for females (COSEWIC 2005a). Calves are born after a gestation period of 1–12 months, then wean for approximately 6–7 months (COSEWIC 2005a). A mean interbirth interval of 2.7 years was calculated for fin whale (Agler et al. 1993).

Migrations of fin whale appear to generally occur between high-latitude summer foraging grounds and lower-latitude breeding and calving winter grounds. The Newfoundland stock of the North Atlantic population has been observed moving to waters off Nova Scotia during the winter, while the Nova Scotia stock moves farther south at that time (DFO 2012).

Fin whales feed on small invertebrates (predominantly euphausiids), schooling fishes (predominantly capelin and Atlantic herring) and squids, and their diet is thought to be as much a function of prey availability as preference (COSEWIC 2005a; DFO 2012; Vighi et al. 2015).

4.7.11.3 Key Habitat

Fin whales exhibit a preference for low surface temperatures and oceanic fronts during the summer that support high concentrations of prey (e.g., euphausiids and small schooling fish) (COSEWIC 2005a). Fin whales in the western North Atlantic may be found close inshore to far beyond the continental shelf break (COSEWIC 2005a).

4.7.12 Polar Bear

4.7.12.1 Conservation Status

Polar bears were listed as a species of Special Concern under SARA in 1991 (COSEWIC 2008b), but the management plan has yet to be completed (ECCC 2018d). A draft co-management plan for this species has been developed by the Nunavut Department of Environment and is currently under review by the NWMB (NWMB 2016). Polar bears are classified as “Vulnerable” by the IUCN (Wiig et al. 2015).

The estimated global population of polar bears is 15,500 individuals (COSEWIC 2008b). There are 19 subpopulations of polar bear, including subpopulations identified for Baffin Bay, Davis Strait, and Lancaster Sound (Wiig et al. 2015). Considering population variability analyses and IQ, both the Lancaster Sound and the Davis Strait subpopulations are considered stable or increasing (Wiig et al. 2015; York et al. 2016). The trend of the Baffin Bay subpopulation is uncertain due to differences in data collection between years (Wiig et al. 2015), and differences between IQ and population viability analyses (PVA) trends (York et al. 2016). The Davis Strait subpopulation was estimated to be 2,158 ± 180 individuals in 2007 (Peacock et al. 2013), the Lancaster Sound subpopulation was estimated to be 2,541 ± 391 individuals in 1997 (Taylor and Dowsley 2008), and the Baffin Bay subpopulation is estimated at 2,826 (95% CI = 2,059-3,593) (SWG 2016). Inuit of Grise Fiord and Qikiqtarjuaq have noted increases in polar bear sightings in recent years (Nunavut Department of Environment 2010, n.d.).

Polar bear are an important source of protein and clothing for the Inuit of Nunavut (Hovelsrud et al. 2008). Interviews of 48 Elders and senior hunters from three Inuit communities (Pond Inlet, Clyde River and Qikiqtarjuaq) were conducted by Dowsley (2005) in 2005 regarding climate change and the Baffin Bay polar bear population. Most interviewees reported, based on their observations, that numbers of polar bears from the population had increased during the previous 10–15 years; however, it was suggested by some to possibly relate to behaviour changes (e.g., increased contact with, and reduced fear of, humans) (Dowsley 2005). Similar observations were reported following interviews of 31 Elders and hunters, in 2007/2008, regarding the Davis Strait polar bear population (Kotierk 2010a). Most respondents suggested that polar bear abundance was above their preference but within their tolerance based on dangers faced by their communities (Kotierk 2010b). Theories for the apparent increase in community observations of polar bear in Baffin Bay, while scientific studies have reported a declining population, include (1) immigration of individuals from a nearby abundant population (Lancaster Sound); (2) scientific studies have underestimated the population; and (3) climate change has caused an increase in densities of bears along the coast by inducing changes in their habitat (Dowsley 2007). In 2004, Nunavut used IQ to support an increase in the polar bear total allowable harvest from 64 to 105 for Nunavut communities. Greenland communities also harvest from the Baffin Bay population of polar bear, and in 2006 implemented a quota system to reduce their harvest to appropriately 100 individuals annually (Dowsley 2007; Dowsley and Wenzel 2008). Co-management discussions of the Baffin Bay polar bear population are ongoing between Greenland and Nunavut. Inuit of Grise Fiord also noted changes in the size of individual polar bears, observing an absence of larger bears (Nunavut Department of Environment n.d.).

Threats to this species include declines in sea ice and increases in the duration and extent of ice free periods (Amstrup et al. 2008; Hamilton et al. 2014; Laidre et al. 2008b; Moore and Huntington 2008; Pagano et al. 2018). Consultations with Hunters and Trappers Organizations from Baffin Bay found that there was a shared concern between communities that increased marine and ice breaker traffic in Baffin Bay was having an impact on polar bear habitat, and having a negative impact on local sea ice conditions (Government of Nunavut 2017g).

4.7.12.2 Distribution and Ecology

Polar bears are circumpolar and rely on the sea ice for hunting and travel. Their distribution within the Area of Focus, in spring and summer, is often associated with moving first year ice (Ferguson et al. 2000), and the density and distribution of ice-dependent seals (especially ringed seals) that they prey on (COSEWIC 2008b). From early winter until spring break-up of annual sea ice, polar bears disperse throughout the Area of Focus. Polar bears may range over 200 km offshore (COSEWIC 2008b), but are most frequently present near the 300-m depth contour (on shelf waters and near land) (SWG 2016). Female polar bears typically spend most of the year closer to land than males, except at the end of breakup (June-July) where they remain on offshore sea ice as long as possible to maximize feeding (SWG 2016). Potential long-distance swimming events identified through collar transmissions during the summer have seen polar bears swim over 100 km (from offshore sea ice to Baffin Island), and the observed frequency of these events has increased between the 1990s and 2000s (SWG 2016). Polar bears have been reported by Inuit Elders and hunters near Pond Inlet, Clyde River and Qikiqtarjuaq along the eastern coast of Baffin Island (Kotierk 2010a). The summer and winter distributions and denning areas for polar bear in the Area of Focus are shown in Figure 4.13 (Kotierk 2010a).

Coastal regions of Baffin Island, Bylot Island, Coburg Island, and Devon Island have denning habitat for polar bears, including maternity dens and shelter dens, which are typically occupied from early October to mid-March (Escajeda et al. 2018). Between the 1990s and 2000s the denning habitat on Baffin Island has shifted to significantly higher elevations and areas of steeper slopes, bears are entering dens more than a month later, and staying in dens for a significantly shorter duration (Escajeda 2016; SWG 2016).

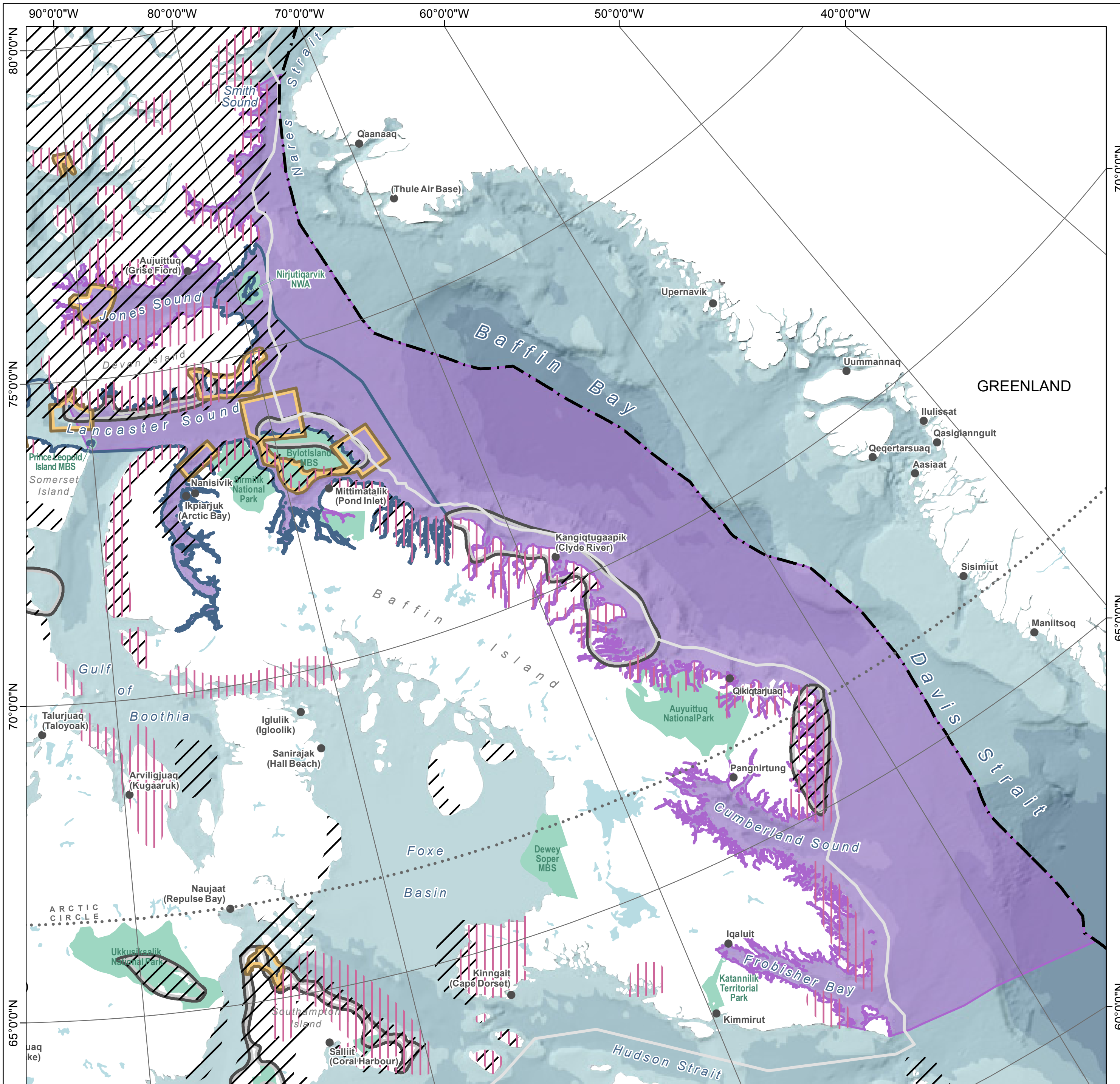
Female polar bears reach sexual maturity at 4–6 years of age, while males mature later at 8–10 years of age (COSEWIC 2008b). Females give birth to 1–2 cubs approximately every 3 years. Few polar bears live longer than 25 years, but the species has no natural predators (COSEWIC 2008b).

Harp seals are the primary prey for polar bears throughout much of Davis Strait; however, hooded seals form their primary prey in northern Davis Strait (Iverson et al. 2006). Other prey of polar bears include ringed seals, bearded seals, walrus, beluga, and narwhal (COSEWIC 2008b).

4.7.12.3 Key Habitat

Critical habitats for polar bear include shore-fast ice, dense annual pack ice, and land denning areas, and (Laidre et al. 2008b). Polar bears exhibit long-fidelity to these habitats, and sea ice habitats are conducive to polar bear predation on marine mammals. Other important habitats for polar bear include loose annual pack ice, multiyear pack ice, and shear zones/leads (Laidre et al. 2008b).

Denning habitat on Baffin Island, Coburg Island, and Devon Island are characterized by snowdrifts, or sometimes frozen ground, located on steep slopes near the coast (COSEWIC 2008b; Escajeda 2016). Inuit from Clyde River and Pond Inlet have noted that polar bears have recently been moving further inland than they had in the 1990s, although participants could not confirm whether this is a reflection of the sampling methods (Nunavut Environment 2017). Inuit from Pond Inlet explained that if there is less snow or if polar bear populations increase, polar bears will travel higher into fiords where there is more snow; female polar bears will also find high areas to den out of the way of other bears (Nunavut Environment 2017).



Base Features

- Community
- Limit of Exclusive Economic Zone[4]
- Nunavut Settlement Area[3]
- Tallurutiup Imanga / Lancaster Sound NMCA[2]
- Protected Area or National Park[4]

Bathymetry[5] Depth (m)

< 200 | 200 - 1000 | 1000 - 2000 | 2000 - 3000 | > 3000

Project Features

- Area of Focus[2]

Polar Bear

- Summer Retreat[6]
- Denning[6, 7]
- IBP - Polar Bear Habitat[8]
- WASI - Polar Bear Habitat[9]

1:10,000,000

0 50 100 200 300

Kilometres

References:
[1]Atlas of Canada Base Maps, 2017
[2]NIRB, 2017
[3]Nunavut Planning Commission, 2010
[4]National Framework Canada, 2017
[5]Natural Earth, 2016
[6]Urquhart and Schweinsburg, 1984
[7]Stephenson, S.A. and Hartwig, L., 2010
[8]Nettleship and Smith, 1975
[9]Ferguson, 1995

Nunavut Impact Review Board Strategic Environmental Assessment

Figure 4.13
Polar Bear Distribution and Important Habitats

NUNAMI STANTEC LIMITED

N.I.R.B.

Prepared By: Nunami Stantec Limited
Projection: Canada Lambert Conformal Conic, North American 1983
Date: Apr 13, 2018
Project Number: 12322100
Produced By: L. Trudell
Verified By: J. Beckett
Revision: 01

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4.8 Special and Sensitive Areas

The following section provides an overview of special and sensitive areas in or near the Area of Focus. These include areas identified and/or designated under territorial and/or federal legislation, processes, and frameworks. These include National Parks, National Wildlife Areas, Territorial Parks, Migratory Bird Sanctuaries, Marine Refuges, Ecologically and Biologically Significant Areas (EBSA), Important Bird Areas (IBAs), the Lancaster Sound National Marine Conservation Area, and the Narwhal Overwintering and Coldwater Coral Zone (see Figure 4.14).

Rare and unique habitats such as the North Water polynya (see Section 3.4.4.1), and other important areas (e.g., migration routes, spawning and breeding areas) specific to marine fish (Section 4.5), waterbirds (Section 4.6), and marine mammals (Section 4.7) are previously described in above sections.

4.8.1 National Parks

There are three national parks located within the Area of Focus: Auyuittuq, Quttinirpaaq, and Sirmilik national parks (see Figure 4.14). Features of these parks are described in the following section.

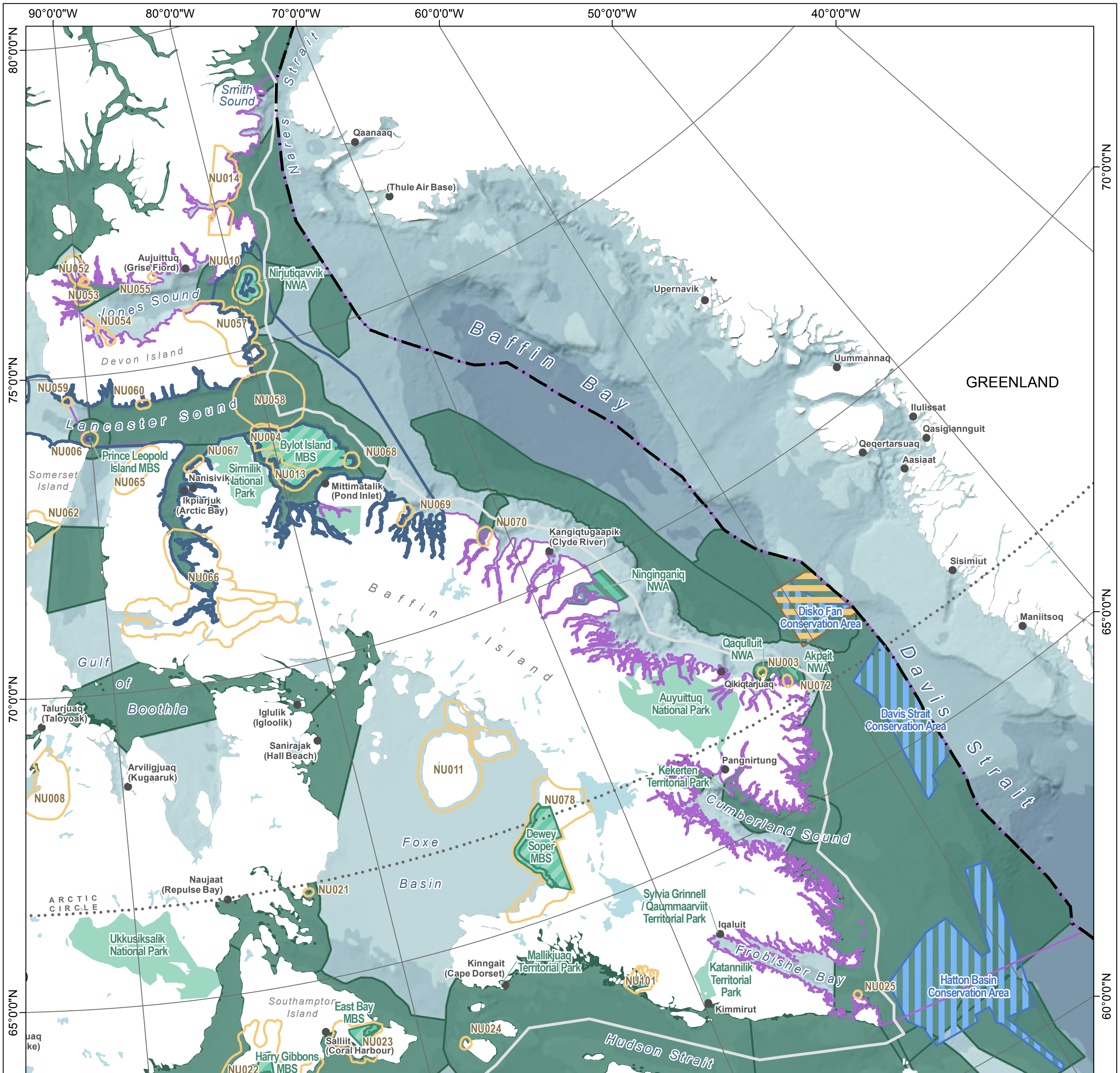
Parks Canada's objective for National Parks is "to protect for all time representative natural areas of Canadian significance in a system of National Parks, to encourage public understanding, appreciation, and enjoyment of this natural heritage so as to leave it unimpaired for future generations"

Parks Canada establish National Parks to protect natural environments representative of Canada's natural heritage (Parks Canada n.d.). National Parks are administered federally under the *National Parks Act*.

4.8.1.1 Auyuittuq National Park

The Auyuittaq National Park covers an area of 19,089 km^2 and is located between the communities of Pangnirtung and Qikiqtarjuaq on Baffin Island's Cumberland Peninsula (Nunavut Tourism n.d.-a) The word Auyuittuq in Inuktitut means "the land that never melts" (Municipality of Pangnirtung n.d.). The landscape of the park is 85% rock and ice, and is dominated by steep and rugged mountains, with vast glaciers and powerful rivers (Nunavut Tourism n.d.-a).

There is a 6,000 km^2 ice cap, the Penny Ice Cap, which is the most southerly remnant of the former Laurentide Ice Sheet (Municipality of Pangnirtung n.d.). The rest of the landscape in the park is glacier-formed that still displays glacial processes, large outlet glaciers, and small cirque glaciers radiating from the Penny Ice Cap (Municipality of Pangnirtung n.d.). Other features of the park include landforms such as cirques, aretes, and horns formed by Alpine glaciers (Municipality of Pangnirtung n.d.).



Base Features

- Community
- Limit of Exclusive Economic Zone[4]
- Nunavut Settlement Area[3]
- Tallurutiup Imanga / Lancaster Sound NMCA[2]
- Protected Area or National Park[4]

Bathymetry[5] Depth (m)

< 200 | 200 - 1000 | 1000 - 2000 | 2000 - 3000 | > 3000

Project Features

- Area of Focus[2]
- Important Bird Area[6]
- Narwhal Overwintering and Coldwater Coral Zone[9]
- Migratory Bird Sanctuary[7]
- National Wildlife Area[7]
- Marine Refuges[7]
- Ecologically and Biologically Significant Area[8]

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0 50 100 200 300

Kilometres

Nunavut Impact Review Board
Strategic Environmental Assessment

Figure 4.14
Special and Sensitive Areas

NUNAMI STANTEC LIMITED

N.I.R.B.

Prepared By: Nunami Stantec Limited
Projection: Canada Lambert Conformal Conic, North American 1983
Date: Apr 13, 2018
Project Number: 12322100
Produced By: L. Trudell
Verified By: J. Beckett
Revision: 01

References:
[1]Atlas of Canada Base Maps, 2017
[2]NIRB, 2017
[3]Nunavut Planning Commission, 2010
[4]National Framework Canada, 2017
[5]Natural Earth, 2016
[6]Important Bird Areas Canada (IBA Canada), 2017
[7]CARTS - CCEA, 2017
[8]Fisheries and Oceans Canada, 2017
[9]Fisheries and Oceans Canada, 2018

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4.8.1.2 Quttinirpaaq National Park

The Quttinirpaaq National Parks is 37,775 km^2 and covers the northern portion of Ellesmere Island (UNESCO 2004). The word Quttinirpaaq in Inuktitut means "top of the world" (Nunavut Tourism n.d.-b). The park borders on the Arctic Ocean and consists of sedimentary mountains, ice caps, ice shelves, and fiords (UNESCO 2004). Mount Barber, a nunatak, is the highest mountain in eastern North America with an elevation of 2,616 m (UNESCO 2004). Much of the park is a polar desert; however, some areas of highly productive sedge grasslands occur, which support wildlife such as muskox, Arctic hare, wolves, and endangered Peary caribou (UNESCO 2004). One of the largest freshwater lakes in the circumpolar region, Lake Hazen, is also located within the park (UNESCO 2004). A unique physical feature of the park are the ancient deposits of 80 m thick freshwater ice shelves that extend several kilometres over the Arctic Ocean (UNESCO 2004).

The major valleys of the park were used as a travel route by early Indigenous peoples moving between the Canadian Arctic and Greenland (UNESCO 2004). All pre-contact cultural groups known to have occupied the High Canadian Arctic, including the Independence I, Independence II, Late Dorset, and Thule, are represented by archaeological sites within the park. The park has one of the highest concentration of these pre-contact sites surveyed in the High Arctic (UNESCO 2004).

4.8.1.3 Sirmilik National Park

The Sirmilik National Park is 22,252 km^2 and is located at the northwest end of Baffin Island near the communities of Pond Inlet and Arctic Bay (Nunavut Tourism n.d.-c) The word Sirmilik in Inuktitut means the "place of glaciers" (Nunavut Tourism n.d.-c).

The park represents the Northeastern Arctic Lowlands natural region and parts of the Lancaster Sound marine region. It consists of four land areas: Bylot Island, Borden Peninsula, Oliver Sound, and Bailliarge Bay." (Nunavut Tourism n.d.-c). The inlets that separate these four park areas include Navy Board Inlet, between Bylot Island and the Borden Peninsula, and Eclipse Sound, separating Bylot Island from Baffin Island (Nunavut Tourism n.d.-c). Navy Board Inlet is an important wildlife area for narwhals, caribou, polar bears, and ringed seals, while Eclipse Sound is a migration route for harp, bearded, and ringed seals, walruses, narwhals, belugas, killer whales, and bowhead whales (Nunavut Tourism n.d.-c).

Features of the park include the glaciers that flow into Eclipse Sound, the plateaus and valleys of the Borden Peninsula, and seabird colonies of Bylot Island and Baillarge Bay (Nunavut Tourism n.d.-c).

4.8.2 National Wildlife Areas

National Wildlife Areas (NWA) are established by Environment and Climate Change Canada under the *Canada Wildlife Act* for the purposes of conservation, research, and interpretation, with a focus on protecting migratory birds, species at risk, and other wildlife and their habitats (Environment Canada 2014b)

There are four NWAs that occur in or near the Area of Focus: Ninginganiq, Akpait, Qaqulluit, and Nirjutiqarvik NWAs (see Figure 4.14).

4.8.2.1 Ninginganiq National Wildlife Area

The Ninginganiq NWA covers over 3,360 km^2 and is located on the northeast coast of Baffin Island (Environment Canada 2014b). In Inuktitut, Ninginganiq translates roughly as "the place where the fog sits" (Environment Canada 2014b). The Ninginganiq NWA is the largest NWA in Canada and was designated in 2010 (Environment Canada 2014b). The NWA includes the shoreline and islands of Isabella Bay and adjacent ocean out to 12 nautical miles from shore (Environment Canada 2014b).

The Ninginganiq NWA provides important habitat for marine wildlife. The NWA supports the largest known concentrations of bowhead whales in Canada, and is frequented by ringed seals, narwhals, and polar bears (Environment Canada 2014b). The NWA also provides habitat for seabirds, including king eiders, long-tailed ducks, dovekies, and northern fulmars (Environment Canada 2014b).

The NWA is managed by Environment and Climate Change Canada, in partnership with the Ninginganiq Area Co-Management Committee of Clyde River, Nunavut (Environment Canada 2014b).

4.8.2.2 Akpait National Wildlife Area

The Akpait NWA is located on the northeastern tip of the Cumberland Peninsula, on Baffin Island (Environment Canada 2014c). Akpait is the Inuktitut word for "murres" (Environment Canada 2014c). There are both marine and terrestrial components to this NWA, with the marine portion covering 792 km^2, and the terrestrial portion covering 48 km^2 (Environment Canada 2014c). The terrestrial component is located on a promontory that overlooks Akpait Fiord and consists of rock pinnacles and steep cliffs bordered by a high talus slope and beach (Environment Canada 2014c). Akpait was established as an NWA in 2010 (Environment Canada 2014c).

The Akpait NWA supports one of the largest thick-billed murre colonies in Canada estimated at 133,000 pairs, which represents 10% of the Canadian population (Environment Canada 2014c). The NWA also provides breeding sites for at least 20,000 northern fulmars, over 1,000 pairs of black-legged kittiwakes, and glaucous gulls and black guillemots (Environment Canada 2014c). Due to its importance for seabirds, the NWA also contributes to the Reid Bay IBA (Environment Canada 2014c). The NWA also provides habitat for marine mammals, such as polar bears, walrus, and several seal species (Environment Canada 2014c).

The Akpait NWA is managed by Environment and Climate Change Canada, in partnership with the Sululiit Area Co-Management Committee of Qikiqtarjuaq, Nunavut (Environment Canada 2014c).

4.8.2.3 Qaqulluit National Wildlife Area

The Qaqulluit NWA covers over 398 km^2 and is located off the eastern coast of Baffin Island (Environment Canada 2014a). Qaqulluit is the Inuktitut word for "fulmars" (Environment Canada 2014a). The only land portion of the NWA is the northeastern tip of Qaqulluit Island, also called Cape Searle, where there are rock spires that rise over 430 m above sea level, surrounded by rugged cliffs (Environment Canada 2014a).

The NWA supports large numbers of seabirds; the Cape Searle IBA is located within its boundaries (see Table 4.11 in Section 4.8.7 for more details on the Cape Searle IBA) (Environment Canada 2014a). The NWA is home to approximately 40,000 pairs of northern fulmars, which is the largest breeding colony in Canada (Environment Canada 2014a). The NWA is also an important nesting and feeding area for other seabirds, such as black guillemots, glaucous gulls, and Iceland gulls (Environment Canada 2014a). The NWA is also an important area for marine mammals such as walrus and ringed seals (Environment Canada 2014a).

The Qaqulluit NWA is managed by Environment Canada, in partnership with the Sululiit Area Co-Management Committee of Qikiqtarjuaq, Nunavut (Environment Canada 2014a).

4.8.2.4 Nirjutiqarvik National Wildlife Area

The Nirjutiqarvik NWA covers over 1,783 km^2 and is located off the southern tip of Ellesmere Island (Environment Canada 2017d). The NWA was established in 1995 to protect seabirds and marine mammal populations (Environment Canada 2014d). The NWA includes Coburg Island, Princess Charlotte Monument, and the surrounding marine waters within a 10 km radius (Environment Canada 2014d).

Most of Coburg Island is covered in glaciers and ice fields; those areas not covered by these features have rugged, mountainous terrain rising over 800 m above sea level (Environment Canada 2014d). The NWA is also the location of a recurrent polynya that has open water year-round (Environment Canada 2014d; Pikialasorsuaq Commission 2017).

The NWA supports large numbers of seabirds and is part of the Cambridge Point IBA (see Table 4.11 in Section 4.8.7 for more details on the Cambridge Point IBA) (Environment Canada 2014d). The NWA is home to approximately 385,000 nesting seabirds, including 11% of Canada's breeding thick-billed murres, and 16% of Canada's breeding black-legged kittiwakes (Environment Canada 2014d). It is also one of the few known Atlantic puffin breeding sites in the Arctic (Environment Canada 2014d). The NWA is an important feeding area for a variety of marine mammals including polar bears, walrus, belugas, narwhal, and ringed and bearded seals (Environment Canada 2014d).

The Nurjutiqarvik NWA is managed by Environment Canada, in partnership with the Area Co-Management Committee of Grise Fiord, Nunavut (Environment Canada 2014d).

4.8.3 Territorial Parks

There are seven Territorial Parks within the Qikitaaluk Region which are located in or near the Area of Focus (see Figure 4.14). Four of these—Katannilik, Kekerten, Quammaarviit, and Sylvia Grinnell Territorial Parks—are described in the following section.

The remaining four Territorial Parks located within or near the Area of Focus are campgrounds located in Inuit communities. Pisuktinu Tunngavik Territorial park is a campground located in the hamlet of Pangnirtung, on the Cumberland Peninsula of Baffin Island (Nunavut Parks n.d.-c). Tamaarvik Territorial Park is a campground located in the hamlet of Pond Inlet on northern Baffin Island (Nunavut Parks n.d.-d). Taqaiqsirvik Territorial Park is a campground located in the hamlet of Kimmirut on southeast Baffin

Island (Nunavut Parks n.d.-b). Finally, Tupirvik Territorial Park is a campground located in the hamlet of Resolute Bay on the southern coast of Cornwallis Island at the northern end of Resolute Bay (Nunavut Parks n.d.-a).

4.8.3.1 Katannilik Territorial Park

The Katannilik Territorial Park stretches across Baffin Island's Meta Incognita Peninsula from Frobisher Bay to the Hudson Strait (Nunavut Parks 2008c). Katannilik means "where there are waterfalls" in Inuktitut (Nunavut Parks 2008c). The landscape of the park was formed by several ice sheets, leaving behind glacial landforms and deposits, glacial erratic boulders, and striations in the bedrock (Nunavut Parks 2008c). The park also contains a rare deposit of blue lapis lazuli (Nunavut Parks 2008c).

The Soper River, called Kuujuaq or "great river" by the Inuit, is a Canadian Heritage River than runs through the park. There are numerous waterfalls in the park, including Soper Falls, located in the lower half of the Soper River (Nunavut Parks 2008c). The Soper River valley runs through the park and is sheltered from harsh winds: as a result, it is four to five degrees warmer that elsewhere in the region (Nunavut Parks 2008c). The unique microclimate formed in the valley supports a variety of Arctic wildflowers and willows. This vegetation supports other wildlife such as caribou, Arctic fox, Arctic hare, wolves, lemmings and multiple species of birds (Nunavut Parks 2008c).

The area of the park has been a prime hunting ground for millennia and remains an important area for modern-day Inuit (Nunavut Parks 2008c).

4.8.3.2 Kekerten Territorial Park

Kekerten Territorial Park is located on Kekerten Island, located 50 km south of the community of Pangnirtung on Baffin Island (Nunavut Parks 2008b). Kekerten Island is a place of national historic importance. The park was established to preserve the historic remains from the 19th and early 20th century when the Inuit worked together with whalers in a harsh Arctic environment (Nunavut Parks 2008b). There are many old houses and storage caches on the island, as well as hundreds of barrel loops, blubber-hauling pins, and some old iron trypots that remain along with the fragments of old whaleboats and buildings (Nunavut Parks 2008b). There are also reconstructions of the whalebone frameworks used to support the roofs of Inuit winter houses, and old tent rings and house foundations that remain in the park (Nunavut Parks 2008b).

The park is known as a good place for observing marine mammals and birds. Marine mammals that occur include ringed and hard seal, walrus, belugas, and occasionally narwhal (Nunavut Parks 2008b). Bird species include jaegers, eiders, thick-billed murre, black guillemot, and dovekies (Nunavut Parks 2008b). Shorebirds, such as Baird's and white-rumped sandpiper, red-necked phalaropes, and golden plovers, occur along the shorelines and beaches of the park (Nunavut Parks 2008b). Peregrine falcons and gyrfalcons may also occur on the cliffs that are found along the coasts of the island (Nunavut Parks 2008b).

4.8.3.3 Qaummaarviit Territorial Park

Qaummaarviit Territorial Park is located on small island near Peterhead Inlet, approximately 12 km southwest of Iqaluit (Nunavut Parks 2008a) This island has grassy swales that alternate with rocky bedrock hills and colourful heath tundra. The island has some of the best-preserved examples of structures made by the Inuit prior to the arrival of outsiders (Nunavut Parks 2008a).

Artifacts on the island represent 750 years of occupation by the Thule and modern Inuit. It is believed that people probably spent a large part of the winter on this island, hunting caribou on the mainland, and seals on the ice of Frobisher Bay (Nunavut Parks 2008a). There are the remains of several semi-subterranean winter houses, and many tent rings, storage caches, and kayak stands on the island. Tiny stone tools have also been found that have been traced back to the Dorset, who likely occupied the island prior to the Thule (Nunavut Parks 2008a).

Visitors to the island may observe ringed seals, walrus, belugas, and occasionally narwhals and bowhead whales (Nunavut Parks 2008a). Peregrine falcons, gyrfalcons and ravens nest on the cliffs of the island and adjacent mainland, and long-tailed ducks, eiders, and guillemots are present during the summer months (Nunavut Parks 2008a).

4.8.3.4 Sylvia Grinnell Territorial Park

Sylvia Grinnell Territorial Park is located 1 km away from the city of Iqaluit on southeast Baffin Island. Within the park, magenta and pink dwarf fireweed lines the sides of paths, and yellow poppies are found on gravel ridges (Nunavut Parks 2008d). Slopes on the island are crowded with wildflowers during the summer months, including white mouse-eared chickweed, brooklet saxifrage, and white bladder campion (Nunavut Parks 2008d).

The Sylvia Grinnell River meanders through the tundra valley of the park, and low rocky hills alternate with sedge meadows along the river, with heath tundra on the slopes (Nunavut Parks 2008d). Arctic char are found in this river, and in other streams within park boundaries (Nunavut Parks 2008d).

More than 40 species of birds have been recorded in the park, including Lapland longspurs, horned larks, redpolls, snow bunting, and ptarmigan, along with rough-legged hawks, peregrine falcons, and ravens on nearby cliffs (Nunavut Parks 2008d). Caribou, Arctic fox, Arctic hare, and lemming are also found in the park (Nunavut Parks 2008d).

One of the most important archaeological sites in Nunavut, the Crystal II site, is located just outside of park boundaries to south on the east side of Sylvia Grinnell River (Nunavut Parks 2008d). This site contains the remains of three semi-subterranean houses used by the Thule, and other artifacts from the older Dorset culture (Nunavut Parks 2008d).

4.8.4 Migratory Bird Sanctuaries

Migratory Bird Sanctuaries (MBS) are established by Environment and Climate Change Canada under the *Migratory Birds Convention Act*, 1994. MBSs are established for the protection and conservation of migratory birds, and any activities that could harm them, or their nests and eggs, are prohibited (ECCC 2017b). Access to MBSs varies by site and is at the discretion of the land owner and land manager (private, provincial, territorial, and federally owned lands) (ECCC 2017b). Nunavut Inuit, under the *Nunavut Agreement* and IIBA for NWA and MBSs in the NSA, have access to MBSs for subsistence harvesting (ECCC 2017b).

There are two MBSs that occur in or near the Area of Focus: Bylot Island and Prince Leopold Island MBS (see Figure 4.14). An overview of these MBSs are provided in the following sections.

4.8.4.1 Bylot Island Migratory Bird Sanctuary

Bylot Island MBS is 12,827 km^2 and is located off northeastern Baffin Island and is bounded by Lancaster Sound to the north, Baffin Bay to the east, Pond Inlet and Eclipse Sound to the south and Navy Board Inlet to the west (ECCC 2017b). The Bylot Island MBS was established in 1965 to protect the nesting grounds of Thick-billed murre, black-legged kittiwake, and snow geese. Its boundaries include the entire island and its adjacent marine waters within 3.2 km from shore (ECCC 2017b). Most of the terrestrial portion of the MBS became part of Sirmilik National Park in 2001 (ECCC 2017b). The Bylot Island MBS also makes part of the Cape Hay, Southwest Bylot, and Cape Graham Moore IBAs (see Table 4.11 in Section 4.8.7 for more details on IBAs in the Area of Focus) (ECCC 2017b).

The landscape of the island is composed of mountains, snowfields, ice fields, glaciers, and pingos (ECCC 2017b).

Birdlife is diverse on the island and 71 species have been identified in the MBS (ECCC 2017b). There are prime nesting grounds for seabirds, which concentrate on the cliffs on the northwestern tip of the island at Cape Hay, and the southeastern corner of the island at Cape Graham Moore (ECCC 2017b). Beyond the boundaries of the MBS, the polynya and lead system that develops at the junction of Lancaster Sound and Baffin Bay provide foraging grounds for tens of thousands of seabirds, including murres and kittiwakes (ECCC 2017b). More than 10% of the black-legged kittiwakes, and 25% of the thick-billed murre population in Canada are present in the MBS in the spring. Along with seabirds, songbirds, waders, and waterfowl are found in the lowland tundra in the southwest region of the island (ECCC 2017b). There are also at least three Old World species that visit or nest on Bylot Island, including the knot, common ringed plover, and the northern wheatear, who fly to northern Canada via Greenland and Iceland from their wintering grounds in Europe, Asia, and Africa (ECCC 2017b).

There are 21 species of marine and terrestrial mammals that have recorded in and around the MBS (ECCC 2017b). Marine mammals include five species of seal, four species of whale, and polar bears (ECCC 2017b). Terrestrial mammals include Arctic fox, collared lemming, and Arctic hare (ECCC 2017b).

4.8.4.2 Prince Leopold Island Migratory Bird Sanctuary

The Prince Leopold Island MBS is 304 km^2 and is located in Lancaster Sound, approximately 13 km off the northeast tip of Cape Clarence on Somerset Island (ECCC 2017f).

The MBS was established in 1995 and covers the entire island and waters within 5 km of shore (ECCC 2017f).

Prince Leopold Island is flat-topped and surrounded by vertical sandstone and limestone cliffs that rise 245 to 265 m above sea level (ECCC 2017f). There are gravel spits that extend approximately 1 km out from the cliff base at the northeast and southeast corners of the island, and extensive talus slopes are found on the south and west sides of the island (ECCC 2017f).

Sheer cliffs are the MBS most significant natural feature: these provide ideal nesting habitat for thousands of seabirds (ECCC 2017f). The MBS is one of the most important multi-species seabird colonies in the Arctic and supports large numbers of nesting thick-billed murre, northern fulmar, black-legged kittiwake, and black guillemot (ECCC 2017f). In terms of Canadian populations; approximately 16% of black-legged kittiwakes, 11% of northern fulmars, 6% of thick-billed murres, and 5% of the black guillemots in Canada's nest on Prince Leopold Island.

Early break-up of ice in adjacent waters and abundant shore leads induce the spring phytoplankton and zooplankton blooms much earlier than other high Arctic regions. These blooms provide food for fish and crustaceans, which are then consumed by seabirds (ECCC 2017f). A variety of marine mammals are also present in the area including beluga, bowhead whale, narwhal, walrus, ringed seal, bearded seal, and polar bear. Collared lemmings are the only resident population of terrestrial mammal on the island (ECCC 2017f).

4.8.5 Marine Refuges

DFO has established three new marine refuges announced in or near the Area of Focus: the Davis Strait, Disko Fan, and Hatton Basin Conservation Areas (DFO 2018b) (see Figure 4.14).

4.8.5.1 Davis Strait Conservation Area

The Davis Strait Conservation Area is 17,298 km^2 and is located within the Hatton Basin-Labrador Sea-Davis Strait EBSA (see Table 4.9 in Section 4.8.6) (DFO 2017c). This closure was created to protect significant concentrations of sponges and cold-water corals, including large gorgonians, small gorgonians, and sea pens (DFO 2017c). The closure is also of conservation benefit to benthic fish and invertebrate species, including those of commercial importance (e.g., Greenland halibut and northern shrimp), as many species use the structural habitat created by corals and sponges for various purposes including spawning, breeding, and nurseries (DFO 2017c). All bottom-contact fishing activities are prohibited within the Davis Strait Conservation Area (DFO 2017c).

4.8.5.2 Disko Fan Conservation Area

The Disko Fan Conservation Area is 7,485 km^2 and was identified initially as an EBSA in 2011 based on oceanographic characteristics, its function as an overwintering habitat for narwhal, and the presence of several species of coldwater coral (DFO 2017a). The Disko Fan Conservation Area was established to protect significant concentrations of cold-water corals and minimize the impacts on food sources used by narwhals in the winter (DFO 2017a). Significant concentrations of large gorgonians, including large tracts of globally unique, high-density bamboo corals (*Keratoisis* sp.) are present within the Conservation Area (DFO 2017a). The closure is also of conservation benefit to sperm whales and northern bottlenose whales that use the area, as well as benthic fish and invertebrate species, including those of commercial importance (e.g., Greenland halibut and northern shrimp), as many species use the structural habitat created by corals for various purposes, including spawning, breeding, and nurseries (DFO 2017a). All bottom-contact fishing activities are prohibited within the Disk Fan Conservation Area (DFO 2017a).

4.8.5.3 Hatton Basin Conservation Area

The Hatton Basin Conservation Area is approximately 42,459 km^2 and overlaps 80% of the Hatton Basin/Labrador Sea/Davis Strait EBSA, and 21% of the Outer Shelf Saglek Bank EBSA (DFO 2017b). This closure protects significant concentrations of small gorgonians, large gorgonians, and sponges, as well as non-aggregating species such as black corals (*Antipatharia*), Scleractinian cup corals, and hydrocorals (DFO 2017b). The closure is also of conservation benefit to benthic fish and invertebrate species, including those of commercial importance (e.g., Greenland halibut, northern shrimp, and striped shrimp) as many species use the structural habitat created by corals and sponges for various purposes, including spawning, breeding, and nurseries (DFO 2017b). All bottom-contact fishing activities are prohibited within the Hatton Basin Conservation Area (DFO 2017b).

4.8.6 Environmentally and Biologically Significant Areas

DFO identifies EBSAs to provide focus on marine areas with high ecological or biological activity (DFO 2005). The identification of an area as an EBSA does not designate this as a protected area, but rather informs processes that may eventually lead to protection or other management measures (DFO 2005).

EBSAs are determined through a ranking process that uses fitness consequence, aggregations, uniqueness, naturalness, and resilience as criteria (DFO 2005). DFO has identified 21 EBSAs that occur in or near the Area of Focus; these are described in Table 4.10 and shown above in Figure 4.14.

Most EBSAs in the eastern Arctic were identified based on aggregations of birds or marine mammals, as these are the most visible, and therefore most studied Arctic marine species (DFO 2005).

Table 4.10 Environmentally and Biologically Significant Areas within the Area of Focus

EBSA	Features/Description
North Water Polynya	• Identified as an EBSA based on it being the largest and most productive polynya in the Arctic • Important area for beluga, narwhal, bowhead whale, and ringed and bearded seals (March to July) • Polar bears rely on ringed seal in the fast ice adjacent to the polynya in winter and spring • Some belugas, narwhal, and bowhead whales may use the North Water as an overwintering area • Seabirds use the area from April to September, including dovekie, thick-billed murre, black guillemot, black-legged kittiwake, ivory gull, glaucous gull and northern fulmar • Fitness consequences for seabird feeding and staging, marine mammal feeding, high biological productivity, and high benthic diversity and production
Eastern Jones Sound	• Identified as an EBSA based on seabird use of the area • EBSA includes the largest breeding colony of black-legged kittiwake in the Canadian Arctic (16% of Canadian population) (late April to September) and the third largest breeding colony of thick-billed murre (12% of Canadian population) (late May to late August) • Outside the breeding season, the ice edges around Coburg Island supports thousands of seabirds from April through October • Fitness consequences for seabird nesting, foraging and staging • EBSA encompasses and buffers the Nirjutiqavvik National Wildlife Areas (see Section 5.2) • Area is frequented by narwhal, beluga, ringed and bearded seal • Marine birds nest in the EBSA including northern fulmar, black guillemot, common eider, ivory gull, glaucous gull, and long-tailed duck • A small colony of Atlantic puffin nest on Princess Charlotte Monument, within the EBSA, and this is the most northerly breeding site for Atlantic puffin in Canada • Recurrent area of open water occurs near Coburg Island. Atlantic walrus haul-out sites are in this area and polar bear feed in the area
Northern Baffin Bay	• Identified as an EBSA based on significant concentrations of sea pens (*Umbellula* sp.) at the outflow of Lancaster Sound in Baffin Bay • Fitness consequences for epibenthic habitat
Cardigan Strait/Hell gate	• Identified as an EBSA based on the use of the area by the Western Jones Sound Atlantic walrus stock • A tidally-driven polynya forms in Cardigan Strait and Hell Gate which allows the walrus stock to remain in the area year-round • Fitness consequences for walrus feeding and overwintering • The polynya allows early access to feeding and nesting seabirds in the area • There is large variability in the use of this area by nesting birds, may be due to ice • Polar bear feed in the area, and the area is also frequented by narwhal, ringed and bearded seals • Aggregation area with fitness consequences for the Western Jones Sound Atlantic walrus stock (High Arctic Atlantic walrus population)

Table 4.10 Environmentally and Biologically Significant Areas within the Area of Focus

EBSA	Features/Description
Lancaster Sound	• Identified as an EBSA based on its importance as a migratory corridor for several species of marine mammals (beluga, narwhal, bowhead whale, Atlantic walrus, harp seal, polar bear) (March to November) and as an important nesting, foraging and staging area for numerous seabirds (e.g., thick-billed murre, black-legged kittiwake, northern fulmar, dovekie) (May through September) • High productivity and biological diversity • Ice edge that forms across from the Sound, and the shoreleads, and polynyas are important aggregation areas for marine mammals and seabirds. • Aggregation area for seabirds and migrating marine mammals with fitness consequences. Area of high productivity and biological diversity. • Fitness consequences for marine mammal migration, and seabird nesting, feeding and staging • Area has the highest polar bear density in the Canadian Arctic
Prince Leopold Island	• Identified as an EBSA based on seabird use • Largest multi-species aggregation of breeding seabirds in the Canadian Arctic • Northern fulmar, black-legged kittiwake, thick-billed murre and black guillemot nest on the island and may use the area between May and September depending on ice break-up and prey availability • Many bird species also make use of the open water leads that form near the island • Fitness consequences for seabird breeding, nesting, rearing, foraging, and staging
Admiralty Inlet	• Identified as an EBSA based on summer aggregations of the Admiralty Inlet summering stock of the Baffin Bay narwhal population (July to mid-September) and northern fulmar breeding colony (13% of the Canadian population) (April through October) • Fitness consequences for narwhal rearing, and northern fulmar nesting and foraging • Bowhead whales (Eastern Canada – West Greenland population) aggregate and feed in the EBSA during the summer • Admiralty Inlet is a breeding area for glaucous gull • May have large aggregations of marine birds from May to September depending on the annual patterns of ice break-up and prey distribution • Polar bears use the area in the summer
Eclipse Sound	• Identified as an EBSA based on summering aggregations (July to November) of the Eclipse Sound summering stock of the Baffin Bay narwhal population and includes spring/fall migration corridors between summering and over-wintering areas • Aggregations of narwhal principally located in the Milne Inlet and Tremblay Sound areas, and these areas may provide refuge from killer whales that feed in Eclipse Sound • Fitness consequences for narwhal rearing and migration corridor • Used as a migration and staging site for various seabirds such as ivory gulls and black-legged kittiwakes

Table 4.10 Environmentally and Biologically Significant Areas within the Area of Focus

EBSA	Features/Description
Baffin Island Coastline	• Identified as an EBSA due to its importance as a migration pathway and breeding grounds for marine mammals • Physical features: Floe-edge; deep-sea troughs • Fitness consequences for walrus feeding, seabird nesting and foraging, marine fish, polar bear denning, rearing and feeding, and epibenthic habitat • Bowhead whale (Eastern Arctic–West Greenland population) nursery grounds • Walrus feeding and haul-out sites • Migration corridor for Arctic char • Corals and seabirds present, including ivory gull; some seabird colonies present
Baffin Bay Shelf Break	• Identified as an EBSA based on importance as a migratory pathway for a number of marine mammal species • Physical features: continental shelf • Aggregations of marine fish (inferred from shelf habitat), marine mammals, and corals and sponges • Fitness consequences for epibenthic habitat • Baffin Bay narwhal, and Eastern Canada–West Greenland bowhead whales present
Scott Inlet	• Identified as an EBSA based on its unique hydrocarbon seep and associated biological community • Harbours a chemolithic community, including the predatory sponge *Claorhiza*, which is the only record of this chemolithic species in Baffin Bay or the Canadian Arctic • Redfish and spotted wolffish observed in area • Bacteria of the genus *Beggiatoa* have been observed covering the seabed near the seep • Concentrations of the anemone *Actinoscyphia Aurelia*, nephtheid soft corals, sea pens (*Umbellula* sp.), and unstalked crinoids. • Supports an important colony of northern fulmar (5% of the Canadian population) that is almost entirely composed of light-phase birds, unusual for Canadian Eastern Arctic fulmar colonies • Area also likely used as a migration and staging site for various seabirds, including Ivory gull and black guillemot • The extension of the EBSA out to the Baffin Bay shelf break captures cross section of the Baffin Bay narwhal migration corridor • East Baffin Island summering stock of Baffin Bay narwhal population use the inlet as a nursery area
Isabella Bay	• Identified as an EBSA based on bowhead whale feeding aggregations • Area regularly used by the Eastern Canada – West Greenland population of bowhead whale, particularly in late summer/early fall (August to October) • High densities of bowhead whales, mostly adults and subadults, have been observed in area • Fitness consequences for bowhead whale feeding • Boundaries of this EBSA are based on the Ninginganiq National Wildlife Area (see Section 5.8.2) • Area is frequented by ringed seals, narwhal, and polar bear • Provides habitat for seabirds, including king eider, long-tailed duck, dovekies, and northern fulmar

Table 4.10 Environmentally and Biologically Significant Areas within the Area of Focus

EBSA	Features/Description
Southern Baffin Bay	• Identified as an EBSA based on narwhal and bowhead whale over-wintering and occurrence of corals • Black corals (Antipatharia) occur • Fitness consequences for narwhal feeding and epibenthic habitat • Baffin Bay narwhal, and Eastern Canada–West Greenland bowhead whales present
Cape Searle	• Identified as an EBSA based on the largest nesting colony of northern fulmar in Canada (22% of Canadian population) and one of the largest nesting colonies of thick-billed murre in Canada (10% of Canadian population) • Northern fulmars are present from mid-April to early October • Thick-billed murre present from late May to late August • Fitness consequences for northern fulmar and thick-billed murre nesting and foraging • EBSA encompasses both the Qaqulluit and Akpait National Wildlife Areas (see Section 5.8.2) • Important area for other seabirds including black-legged kittiwake, black guillemot, glaucous and Iceland gull • May contain nesting Atlantic puffin • Important habitat for Atlantic walrus and ringed seal, polar bears may also use the area
Hatton Basin-Labrador Sea-Davis Strait	• Identified as an EBSA based on the diversity of cold-water corals, and as a recurring marine mammal over-wintering site • Physical features: continental shelf; mixing waters; deep basin; polynyas in Cumberland Sound and Baffin Bay • Area of high biological productivity • Fitness consequences for marine mammal over-wintering and feeding, seabird and seaduck nesting and foraging, epibenthic habitat, and polar beer feeding • Hooded and harp seal feeding, and hooded seal breeding in EBSA • Migration corridor for bowhead whale (Eastern Canada – West Greenland population) • Haul-out sites for walrus, also ice-edge winter habitat, and migration corridor to Greenland for walrus • Beluga (Eastern High Arctic/Baffin Bay population) and narwhal (Baffin Bay population) present in EBSA • Aggregations of marine fish and shrimp; wolffish species • Seabirds present include ivory gull and harlequin duck, and some seabird colonies occur in EBSA
Eastern Cumberland Sound	• Identified as an EBSA based on over-wintering (December to May) aggregations of Cumberland Sound beluga population, and year-round use by Eastern Canada – West Greenland bowhead populations • Fitness consequences for beluga feeding and over-wintering habitat, and bowhead whale feeding • EBSA also encompasses areas used by other marine mammals (harp and ringed seal, narwhal, Atlantic walrus) • Productive marine area that supports a Greenland halibut fishery • Important bird feeding and staging habitat

Table 4.10 Environmentally and Biologically Significant Areas within the Area of Focus

EBSA	Features/Description
	• Hoare Bay is included as part of the EBSA, which is an important area for walrus and polar bear
Clearwater Fiord	• Identified as an EBSA based on summer use by the Cumberland Sound beluga population • Cumberland Sound beluga population lives in the area year-round; aggregation from July to September • Fitness consequences for beluga feeding and rearing • Area also encompasses open-water feeding habitat for Arctic char from several char runs
Cunningham Inlet	• Located just outside the western extent of the Area of Focus • Identified as an EBSA based on summer aggregations of the Eastern High Arctic–Baffin Bay beluga population (July to August) • Fitness consequences for beluga summer refugia from predators
Eastern Hudson Strait	• Identified as an EBSA based on use as migratory corridor to summer feeding and nursery grounds, and over-wintering area for marine mammals • Physical features: conduit for Arctic waters and periodic intrusions of Atlantic waters • Fitness consequences for marine mammal migrations. Seabird nesting and foraging, marine mammal over-wintering, and epibenthic habitat • Aggregations of corals, sponges, and shrimp • Over-wintering beluga (Western and Eastern Hudson Bay populations) and bowhead whale (Eastern Canada–West Greenland population) • Walrus haul-out sites (Northern Hudson Bay–Davis Strait population) • Ivory gull present
Ungava Bay	• Identified as an EBSA based on depleted stock of beluga (Ungava Bay population), polar bears, and nesting seabirds • Fitness consequences for seabird and seaduck nesting and foraging, polar bear breeding, denning, and feeding, and epibenthic habitat • Supports the largest number of breeding thick-billed murres in Canada • Seasonal refuge for polar bears
Wellington Channel	• Identified as an EBSA based on walrus haul-out site and seabird breeding • Physical features: strong current, polynya • Fitness consequences for walrus feeding, and seabird and seaduck nesting and foraging • Nesting population of Ross's gull • Summer feeding area for polar bears
SOURCES: (Canada) 2011; COSEWIC 2008b; DFO 2015a; Gaston 2014; Kenchington et al. 2011; Mallory and Fontaine 2004)	

4.8.7 Important Bird Areas

Important bird areas are established to conserve and monitor a network of sites that provide essential habitat for specific groups of birds, including those that are threatened species; species restricted by range or by habitat requirements; and congregatory species (IBA Canada 2017). IBAs range in size, can include terrestrial and aquatic areas, and include lands that are private, public, and legally protected.

There are 12 IBAs located within the Area of Focus (see Figure 4.14). A short description of each IBA is provided in Table 4.11 below.

Table 4.11 Important Bird Areas within the Area of Focus

Site	Significance				Site Summary
	Congregatory Species	Threatened Species	Colonial Waterbirds or Seabirds	Restricted Range	
Inglefield Mountains, Southeastern Ellesmere Island (NU014)	A, C				• This IBA supports ice fields and rocky cliffs. The nunataks within this site support up to 35% of the national population, and up to 5% of the global population of ivory gull.
Cambridge Point, Coburg Island (NU010)	A, C		A		• A National Wildlife Area located in proximity to the North Water Polynya, providing dependable open water feeding habitat during early breeding. • Coastal cliffs support approximately 1.5% of the global population and 11% of the eastern Canadian population of breeding thick-billed murres, and up to 15% of the western Atlantic breeding population of black-legged kittiwakes.
Eastern Devon Island Nunataks, Eastern Devon Island (NU057)	A	C		C	• Eastern Devon Island is comprised primarily of nunataks. Four ivory gull colonies are located in this IBA, supporting 4% of the national and North American population.
Hobhouse Inlet, Devon Island (NU060)	A		A		• Cliff faces within this IBA provide grassy ledges for breeding and are in proximity to important foraging habitat in Lancaster Sound. This IBA supports 2.4% of the North American breeding population of northern fulmars.
Lancaster Sound Polynya, Nanisivik (NU058)	C		A		• Leads that form between November and December provide important winter and spring foraging habitat. Between 1 and 14 million dovekies have been recorded using this area during migration to breeding grounds.
Cape Hay, Bylot Island (NU004, NU013)	A, B		A		• As a Migratory Bird Sanctuary, Cape Hay supports vertical cliffs used for nesting by colonially breeding seabirds. This IBA supports 1.3% of the global population and 9.5% of the eastern Canadian population of thick-billed murres, and up to 10% of the western Atlantic population of black-legged kittiwake.
Cape Graham Moore, Bylot Island (NU068)	A, B		A		• A designated Migratory Bird Sanctuary, provides continentally important habitat for dovekies and nationally important habitat for ivory gull.
Buchan Gulf, Eastern Baffin Island (NU069)	A		A		• Steep coastal cliffs and rock pinnacles that support approximately 2.4% of the North American population and 8% of the Canadian population of breeding northern fulmars.

Table 4.11 Important Bird Areas within the Area of Focus

Site	Significance: Congregatory Species	Significance: Threatened Species	Significance: Colonial Waterbirds or Seabirds	Significance: Restricted Range	Site Summary
Scott Inlet, Eastern Baffin Island (NU070)	A, C		A		• Steep cliffs located along the entrance to the inlet with grassy-turfed ledges. This IBA supports 3.2% of the Canadian breeding population of northern fulmars and 1% of the Canadian population of glaucous gull.
Cape Searle, Eastern Baffin Island (NU003)	A				• Two large rock outcrops with jagged pinnacles surrounded by flatter regions covered by tundra vegetation. This IBA supports the largest northern fulmar colony in Canada, supporting 1% of the global breeding population an 33% of the Canadian population. Glaucous gull and black guillemot also use this region in smaller numbers.
Reid Bay, Eastern Baffin Island (NU072)	A, C		A		• Steep cliffs separated by deep gullies and talus slopes. This IBA supports approximately 1% of the global breeding population and 9% of the Canadian population of thick-billed murre. Up to 3.3% of the Canadian northern fulmar population also breeds here. Large numbers of black-legged kittiwake, glaucous gull, Iceland gull, and black guillemot also nest on cliffs in this IBA.
Hantzsch Island, Resolution Island Group (NU025)	A, B		A		• Small island with steep coastal cliffs and grassy slopes, adjacent to the Frobisher Bay Polynya. This IBA supports approximately 3% of the Canadian breeding population of thick-billed murre, and 2% of the Canadian breeding population of black-legged kittiwake.

NOTES:
A – Indicates that the site holds global significance (as defined by IBA Canada (2017)) for one or more bird species
B – Indicates that the site holds regional significance (as defined by IBA Canada (2017)) for one or more bird species
C – Indicates that the site holds sub-regional significance (as defined by IBA Canada (2017)) for one or more bird species

4.8.8 Lancaster Sound National Marine Conservation Area

The establishment of the proposed Tallurutiup Imanga/Lancaster Sound National Marine Conservation Area (NMCA) will make it Canada's largest protected area, encompassing approximately 110,000 km^2 (Parks Canada 2017). The Government of Canada, Government of Nunavut, and the Qikiqtani Inuit Association recently agreed upon the final boundary for the future NMCA. NMCAs are a type of Marine Protected Area (MPA) that are established under the *National Marine Conservation Area Act* and administered by Parks Canada (Parks Canada 2017). Activities such as mineral and hydrocarbon exploration and development, and ocean dumping are prohibited within the boundaries of the NMCA, while sustainable commercial uses such as fishing and shipping are permitted and are regulated by DFO and Transport Canada (Parks Canada 2017). Shell Canada Ltd. announced in June 2016 that they voluntarily relinquished 8,600 km^2 of hydrocarbon exploration permits in offshore Lancaster Sound. There are presently no hydrocarbon exploratory permits in either Lancaster Sound or in the Canadian portion of Baffin Bay (Parks Canada 2017).

Lancaster Sound is one the most significant ecological areas in the world; the area is teeming in marine life in the spring and summer with the return of warmer weather (Parks Canada 2017). Physical processes such as currents, tides and upwelling, described above in section 3.4, result in the formation of polynyas (see Section 3.4.6) and high biological productivity (Parks Canada 2017). Hundreds of thousands of seabirds and marine mammals migrate to Lancaster Sound region to feed and reproduce (Parks Canada 2017). Lancaster Sound has been designated as critical habitat for polar bear, bowhead whale, narwhal, and beluga whale (Parks Canada 2017). More on marine mammal species at risk can be found in Sections 4.1 and 4.7.

The Lancaster Sound region is extremely important for seabirds, with approximately one third of eastern Canada's colonial seabirds breeding and feeding in Lancaster Sound (Nunami Stantec 2012). Narwhals and belugas use the area as a feeding ground during the summer and as a migration route (Nunami Stantec 2012). The NMCA will also protect the winter habitat of polar bears, in addition to conserving areas high ringed seal concentrations (Nunami Stantec 2012).

Lancaster Sound will remain an ecologically important area, regardless of climate change, as the processes responsible for its productivity will remain, though species composition may change over time (Parks Canada 2017).

Lancaster Sound has been used for millennia by the Inuit and their ancestors due to the rich biodiversity of the area (Parks Canada 2017). The Lancaster Sound region has been identified as the heart of High Arctic Inuit existence; it has provided food, shelter, materials, and tools in such an abundance that Inuit have been able to thrive in one of the harshest environments on Earth (Parks Canada 2017). In agreement with the Government of Canada, the Government of Nunavut, and the Qikiqtani Inuit Association, IQ will inform decision making and protection of the NMCA. The NMCA will protect Inuit harvesting rights established under the Nunavut Land Claims Agreement, while also ensuring the protection of species at risk (see Section 4.1) (Parks Canada 2017).

4.8.9 Narwhal Overwintering and Coldwater Coral Zone

The Narwhal Overwintering and Coldwater Coral Zone was established to reduce impacts on the winter food source and overwintering habitat for narwhal and to conserve cold-water coral concentrations (DFO 2017d). The location of the Narwhal Overwintering and Coldwater Coral Zone overlaps with the Disko Fan Conservation Area, a new marine refuge established in December 2017 (see Figure 4.14). The bathymetry of the closure area is characterized by a very steep gradient between the 400 m and 1,000 m depth contours, leveling off somewhat between 1,000 and 1,500 m (DFO 2007). The Narwhal Overwintering and Coldwater Coral Zone is currently closed to the Greenland halibut fishery, but fisheries for northern shrimp operate within the closure area (DFO 2017d).

4.9 Areas of Concern or Importance

In the following section, areas of concern or importance, as identified through IQ, academia, non-governmental organizations, local communities, and commercial fish harvesters are presented.

4.9.1 Areas Identified by Inuit Qaujimaningit

4.9.1.1 Traditional Use Areas

The coastline extending to the floe edge within the Area of Focus is used by Inuit for harvesting, habitation, travelling and cultural and spiritual purposes. Animals such as polar bears and caribou are known to exploit both the coastline and sea ice, with harvesting occurring opportunistically in these areas. Harvesting locations noted in the literature review include:

- Admiralty Inlet, Baffin Bay, Borden Peninsula, northeast Brodeur Peninsula, Button Point, Bylot Island, the north half of southern Cumberland Peninsula, Devon Island, Henry Kater Fiord, Lavoie Point, Milne Inlet, Penny Ice Cap, Pikialasorsuaq, and Somerset Island
- In the vicinity of the townsites of Arctic Bay, Iqaluit, Kimmirut, Pond Inlet, Pangnirtung, Cape Dorset, Clyde River, Resolute, Grise Fiord and Qikiqtarjuaq (Kilukishuk 2001 as cited in Nunavut Tunngavik 2001; Dowsley 2005: Nunavut Department of Environment 2005; Dowsley 2007; Ford et al. 2008; Kotierk 2010a; Kotierk 2010b; Aronsen 2013 as cited in The Association of Fishers and Hunters Greenland 2013; Jenkins and Goorts 2013; NIRB 2017; Nunavut Department of Environment 2017)

Fish, muskox, seals (bearded, harp, hooded, ringed), walrus, waterbirds, and whales [beluga, bowhead (historically), narwhal] are reported to be harvested from the sea ice (including Pikialasorsuaq), and or floe edge. Specific harvesting locations reported in the literature include:

- Baffin Bay, Bon Accord, Clearwater Fiord, Clyde River, Cumberland Sound, Davis Strait, Frobisher Bay, Jones Sound, Iqalugadyuk, Isabella Bay, Irvine Inlet, Navy Board Inlet, Nettling Fiord, Sauniqjak (near Imigen Islands), and Lancaster Sound

- Offshore near Arctic Bay, Clyde River, Grise Fiord, Iqaluit, Kimmirut, Pangnirtung, Pond Inlet, Qikiqtarjuaq, Qivituuq/Kivitoo, Sauniqtuuradyuk, Tinnujivik/Cumberland Sound, Tunnuniq region, and Usualak (NWMB 1998; over 50 Inuit as cited in NWMB 2000; Ivalu as cited in Nunavut Tunngavik 2001; Kilukishuk 2001 as cited in Nunavut Tunngavik 2001;Pijamini as cited in Nunavut Tunngavik 2001; Qarpik 2001 as cited in Nunavut Tunngavik 2001; Qaunaq 2001 as cited in Nunavut Tunngavik 2001; Joamie, S. as cited in Nunavut Environment 2005; Keenaiak, A. as cited in Nunavut Environment 2005; Nunavut Environment 2005; Manniapik, 2002. as cited in Nunavut Environment 2005; Ford et al. 2006; Ford et al. 2008; Nunavut Environment 2010; Barnabas 2013 as cited in The Association of Fishers and Hunters Greenland 2013; Ootoowak 2013 as cited in The Association of Fishers and Hunters Greenland 2013; Jenkins and Goorts 2013; NIRB 2017; Nunavut Environment 2017; Nunavut Environment n.d.a).

Alterations to the coastline, sea ice and floe edge may affect these species, as well as the ability to harvest and consume these species.

During the community engagement sessions for the SEA, Inuit participants expressed concern about effects to sea ice and harvested species as a result of previous oil and gas activities (NIRB 2017). Participants from many of the engaged communities indicated that additional baseline studies should be conducted prior to any further oil and gas activities. An Elder from Arctic Bay stated: "We need to know as Elders what the impacts will be on our sea mammals. Please inform our communities as much as you can if there will be impacts to mammals. We need proper studies and there have been other studies done and tests out at sea" (NIRB 2017). Furthermore, Inuit from Qikiqtarjuaq state: "If the SEA will happen, I would like to see different species included and what kinds of animals and species have been seen and for how long have they been here. There used to be research conducted on hunters' catches, for example, on the livers and kidneys. If any animals were caught, such as narwhals, walrus, seals, and other species, maybe there could be research to assess their health and this could be included in the SEA. I would also like to see research on whether populations are increasing or decreasing." (NIRB 2017).

If studies are conducted, incorporation of IQ will be integral. Inuit from Iqaluit noted that Elders' knowledge extends to time immemorial, prior to when studies or counts started in the 1960s. Residents of Iqaluit also note that IQ should have been included in the final reports of these studies, as many Inuit participated in the actual counts and studies (NWMB 1998).

With reference to potential accidents and malfunctions, participants indicated concerns regarding the extent of effects a spill would have on harvested species (including potential effects on the entire food chain); disposal of deceased animals; community health as a result of consuming contaminated foods; and compensation for a loss of local food (NIRB 2017). One participant from Arctic Bay stated: "I know a number of important hunting areas we are concerned with, including seals, beluga, muskox, and polar bear (areas were pointed out on a map). How will our hunting areas be protected? We cannot depend on food from the store since it is too expensive so we must rely on country food."

Specific areas of concern identified during the community engagement sessions (NIRB 2017) include Baffin Bay, Cumberland Sound, Davis Strait, Lancaster Sound, Scott Inlet, and Sverdrup Basin. General statements for the protection of animals in Baffin Bay, Cumberland Sound, and Davis Strait were made during the engagement sessions. An Inuit participant from Pangnirtung said: "I have a concern about

Baffin Bay and Davis Strait being opened up to oil and gas. We hunt marine mammals. If I had my way I would be against exploration. I would be disappointed if the moratorium was lifted."

Inuit from Pond Inlet voiced the following concerns regarding Lancaster Sound:

- "We always have concerns about Lancaster Sound area. We don't want oil and gas development in that region as there are lots of animals there."
- "Will Lancaster Sound be made a Marine Protected Area before the SEA goes ahead? Will information from this process be used for the SEA?"

A request to avoid Lancaster Sound was also stated (NIRB 2017). Scott Inlet was identified as an area of concern given the presence of a natural oil seep. Residents of Clyde River inquired about government mitigations relative to this seep (NIRB 2017).

Finally, Inuit of Pond Inlet recommended that Sverdrup Basin be included within the SEA.

4.9.1.2 North Water Polynya–Pikialasorsuaq

The Pikialasorsuaq Commission (Pikialasorsuaq Commission 2017) recommends the identification of protected area adjacent to the North Water polynya, in consultation with local communities. The protected area would consist of the polynya itself and include a larger management zone that reflects the connection between communities and their natural resources in the area of the polynya (Pikialasorsuaq Commission 2017). As the region that is affected by the polynya extends far past its physical boundaries, an Inuit-led Pikialasorsuaq Management Zone would include the Inuit communities that are dependent on the polynya for sustenance, livelihoods, culture, health and wellbeing, and the travel routes used to access the polynya and historical special sites like food caches.

The proposed Pikialasorsuaq Management Zone includes some marine areas over which coastal states (Canada and Greenland) have limited jurisdiction under international law, and thus, the Pikialasorsuaq Commission (Pikialasorsuaq Commission 2017) recommends including international law instruments such the United Nations Convention on the Law of the Sea and the assistance of International Maritime Organization in the protection of the Pikialasorsuaq Management Zone.

The location and features of the North Water polynya, and other polynyas in the Area of Focus, are described in Section 3.4.4.

During the NCRI for Qikiqtarjuaq, interviewees indicated the presence of several traditional habitations, meeting places, and burial sites along the coastline of Qikiqtarjuaq, and that some of these sites are remains from the Thule culture (Nunavut Environment 2010). Interviewees also expressed some interest in creating local tourism opportunities through bird sanctuaries for thick-billed murres and northern fulmars (Nunavut Environment 2010).

It was reported in the NWMB (NWMB 2000) that near the community of Pangnirtung, Inuit established camps where they would harvest whales, and that old sod houses called "qarmait", containing whale bones, are widely distributed on the islands and on the adjacent mainland.

4.9.2 Areas of Academic Interest

Baffin Bay and Davis Strait was identified as an Arctic Marine Area designated for biodiversity monitoring by the Marine Expert Working Group of the Circumpolar Biodiversity Monitoring Program, and as directed by Conservation of Arctic Flora and Fauna, the biodiversity working group of the Arctic Council (Niemi et al. 2017).

4.9.3 Areas of Conservation Interest to Commercial Fisheries

There is a voluntary fisheries closure of 12,500 km^2 located in the northern Labrador Sea in an area referred to as the Hatton Basin. As first mentioned in Section 4.4.4, this closure was enacted by the Canadian Association of Prawn Producers, the Groundfish Enterprise Allocation Council, and the Northern Coalition to protect coral concentrations, namely large gorgonians (see Section 4.4.4 for more on cold-water corals) (DFO 2015d).

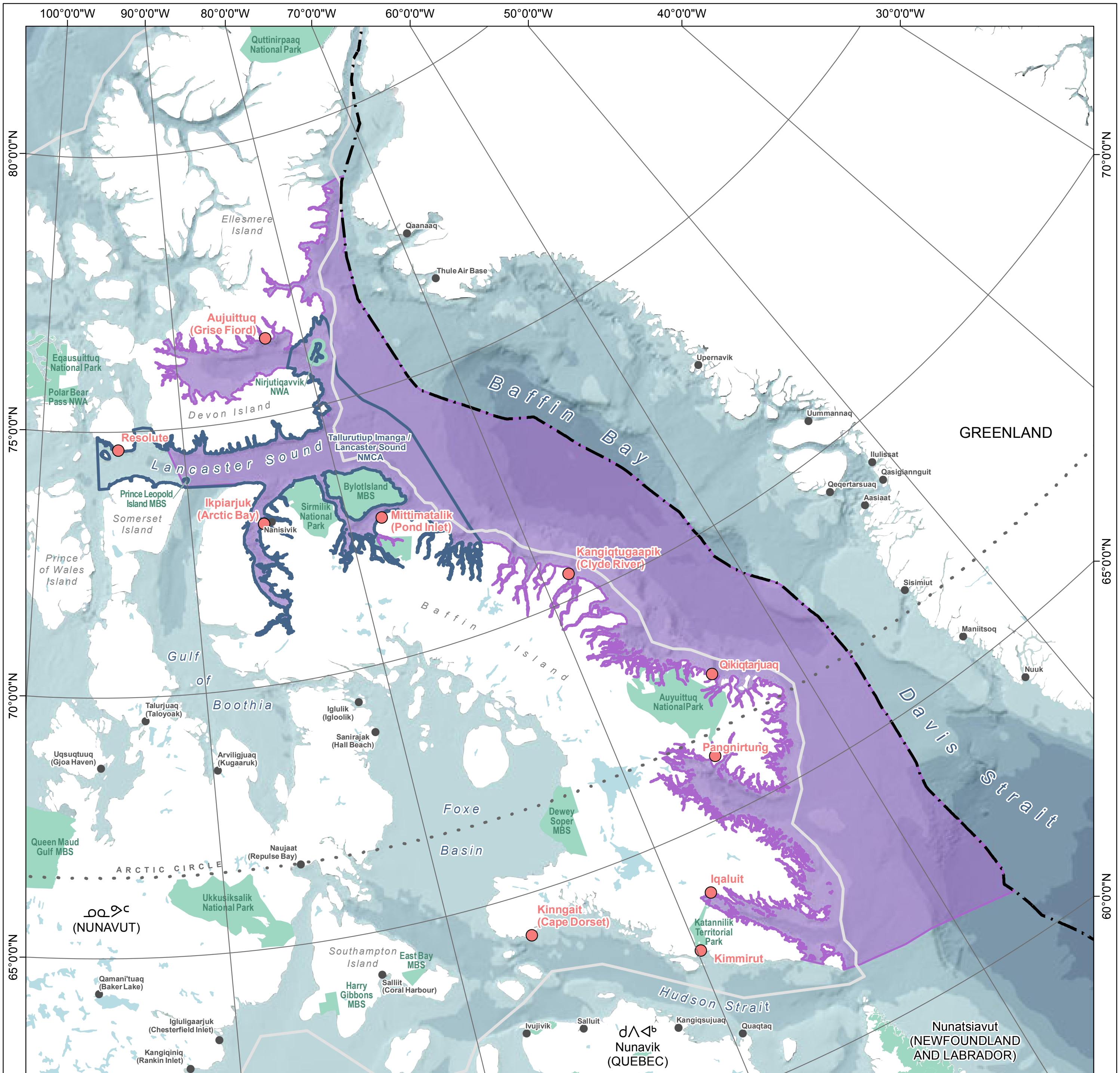
5 ENVIRONMENTAL SETTING—HUMAN ENVIRONMENT

5.1 Potentially interested communities

Spatially, the focus of the socio-economic assessment is on people and communities in the Qikiqtani administrative region of Nunavut. More specifically, the focus, where information is available, is on the potentially interested communities of Grise Fiord, Resolute Bay, Arctic Bay, Pond Inlet, Clyde River, Qikiqtarjuaq, Pangnirtung, Iqaluit, Cape Dorset and Kimmirut (see Figure 5.1). These communities are widely dispersed and remote from each other, and except for Iqaluit, have small populations and limited infrastructure and services.

The following sections provide an overview of socio- economic conditions in the potentially interested communities, with a focus on the VSECs identified in the Final Scope List (Nunavut Impact Review Board 2018);

- Economic development and opportunities
- Employment
- Contracting and business development
- Education and training
- Health and wellbeing
- Community infrastructure and services
- Traditional use and practices
- Traditional harvest
- Traditional foods
- Heritage resources
- Non-traditional use
- Commercial harvest
- Marine transportation



Base Features

- Community
- Limit of Exclusive Economic Zone
- Nunavut Settlement Area
- Tallurutiup Imanga / Lancaster Sound NMCA[2]
- Protected Area or National Park[4]

Bathymetry[5] Depth (m)

< 200 | 200 - 1000 | 1000 - 2000 | 2000 - 3000 | > 3000

Project Features

- Area of Focus[2]
- Potentially Affected Community

1:12,000,000

0 50 100 200 300 400

Kilometres

References:
[1]Atlas of Canada Base Maps, 2017
[2]NIRB, 2017
[3]Nunavut Planning Commission, 2010
[4]National Framework Canada,2017
[5]Natural Earth, 2016

Nunavut Impact Review Board Strategic Environmental Assessment

Figure 5.1 Potentially Affected Communities

Prepared By: Nunami Stantec Limited
Projection: Canada Lambert Conformal Conic, North American 1983
Date: Apr 13, 2018
Project Number: 12322100
Produced By: L. Trudell
Verified By: J. Beckett
Revision: 01

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5.1.1 Population Demographics

Between 2011 to 2016, the total population of Nunavut increased by approximately 12.7%, growing from 31,906 residents to 35,944 residents within that period. Within the Qikiqtani Region, the trend was similar, with population increasing approximately 12.1% from 16,939 to 18,988 people. Table 5.1 below illustrates population changes within the potentially interested communities of the Area of Focus. Within those communities, Clyde River witnessed the largest population increase (12.7%), while Kimmirut showed the largest decrease (-14.5%). Most the communities exhibited population growth within that timeframe.

Table 5.1 Population Statistics—2016

Location	Total Population			Indigenous Population			Percent of Population of Indigenous Identity (2016)
	Population		Percent Change	Population		Percent Change	
	2016	2011	2011-2016	2016	2011	2011-2016	
Canada	35,151,728	33,476,688	5.0	1,673,785	1,400,685	19.5	4.8
Nunavut	35,944	31,906	12.7	30,555	27,365	11.7	85.0
Qikiqtani / Baffin Region	18,988	16,939	12.1	15,145	13,745	10.2	79.8
Clyde River	1,053	934	12.7	1,020	N/A	N/A	96.8
Arctic Bay	868	823	5.5	830	795	4.4	95.6
Resolute Bay	198	214	-7.5	165	170	-2.9	83.3
Grise Fiord	129	130	-0.8	120	115	4.3	93.0
Pond Inlet	1,617	1,549	4.4	1,520	1,500	1.3	94.0
Qikiqtarjuaq	598	520	15	565	485	16.5	94.5
Cape Dorset	1,441	1,363	5.7	1,350	1,255	7.6	93.7
Kimmirut	389	455	-14.5	360	425	-15.3	92.5
Iqaluit	7,740	6,699	15.5	4,505	4,040	11.5	58.2
Pangnirtung	1,481	1,425	3.9	1,395	N/A	N/A	94.2

NOTES:
Numbers that were not recorded or suppressed are indicated by N/A
Numbers may not add due to rounding

SOURCE: (Statistics Canada 2012, 2017)

As illustrated in Table 5.1 above, Nunavut's population is characterized by a large Indigenous (Inuit, First Nation or Metis) presence. Nunavut residents who identified themselves as Indigenous in 2016 comprised approximately 85% of the total population. Within the Qikiqtani Region, this number decreased to 79.8%, with Iqaluit showing the lowest percentage of Indigenous residents (58.2%). This can potentially be attributed to the larger population of Iqaluit, its role as the territorial capital and main service centre in the region, and the resulting larger influx of non-Indigenous residents moving into the area for work. Clyde River had the highest percentage of residents identifying themselves as Indigenous at approximately 96.8%.

Within the segment of the population that has identified themselves as Indigenous, most residents identified as being of Inuit decent. Table 5.2 illustrates the percentage of Indigenous residents that identified as Inuit. The lowest percentage of Indigenous residents identifying as Inuit in the Area of Focus communities was in Iqaluit, which identified the Inuit population of the total Indigenous population at approximately 94.8%. The number of Indigenous residents identifying as Inuit reaches 100% in many of the smaller communities.

Table 5.2 Inuit Population Statistics—2016

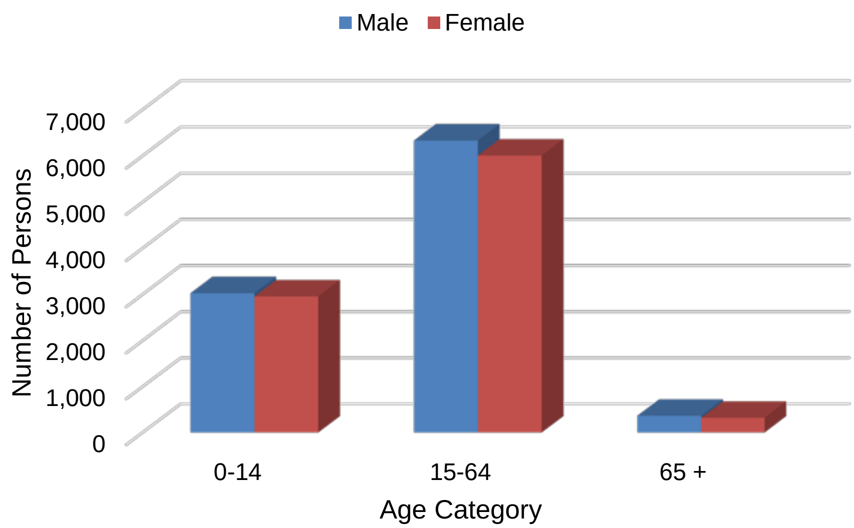
Location	Indigenous Population	Inuit Identity	Percentage
Canada	1,673,785	65,030	3.9
Nunavut	30,555	30,135	98.6
Qikiqtani / Baffin Region	15,145	14,875	98.2
Clyde River	1,020	1,020	100.0
Arctic Bay	830	825	99.4
Resolute Bay	165	165	100.0
Grise Fiord	120	120	100.0
Pond Inlet	1,520	1,510	99.3
Qikiqtarjuaq	565	565	100.0
Cape Dorset	1,350	1,345	99.6
Kimmirut	360	360	100.0
Iqaluit	4,505	4,270	94.8
Pangnirtung	1,395	1,390	99.6
NOTE: Numbers may not add due to rounding			
SOURCE: (Statistics Canada 2012, 2017)			

In terms of population breakdown by gender, Table 5.3 and Figure 5.2 illustrate the breakdown of the population of Nunavut, the Qikiqtani Region, and the potentially interested communities. Within the Qikiqtani Region, for each of the selected age groups, there is a slightly higher number of male residents than female. The largest differences are a higher number of males between the ages of 15 and 64, than females.

Figure 5.2 also illustrates that most of the population in the Qikiqtani Region is between the ages of 15 and 64, with a relatively low number of residents that are above the age of 65. In this instance, the population can be generally defined as being young and growing. The lowest median age in the potentially interested communities occurs in Clyde River (22 years), while Iqaluit has the highest median age (31 years). All median ages within the Baffin Region are well below the Canadian average of 41.2 years (Statistics Canada 2017). Some factors that may contribute to this population characteristic could be the higher birth rates among Indigenous populations, the lower life expectancy of Indigenous peoples in the north, and industry sectors tending to hire younger workers during times of economic activity (Southcott 2015b).

Table 5.3 Population Statistics, by Gender and Age—2016

Location	Gender	Age Category			Median Age
		0-14	**15-64**	**65 +**	
Canada	Male	2,992,920	11,576,130	2,695,150	41.2
	Female	2,846,645	11,800,400	3,240,485	
Nunavut	Male	5,975	11,710	1,360	25.1
	Female	5,710	11,160	710	
Qikiqtani Region	Male	3,025	6,330	365	26.3
	Female	2,955	6,005	320	
Clyde River	Male	180	335	15	22
	Female	190	315	15	
Arctic Bay	Male	165	260	20	22.3
	Female	165	240	15	
Resolute Bay	Male	35	70	5	25.8
	Female	25	60	5	
Grise Fiord	Male	15	55	5	26.4
	Female	10	45	5	
Pond Inlet	Male	300	510	35	22.6
	Female	285	460	25	
Qikiqtarjuaq	Male	110	200	10	24.8
	Female	85	180	10	
Cape Dorset	Male	275	425	25	23.3
	Female	245	445	35	
Kimmirut	Male	80	130	15	23.9
	Female	55	105	5	
Iqaluit	Male	935	2,820	135	31.1
	Female	995	2,760	105	
Pangnirtung	Male	255	470	45	23.9
	Female	250	425	45	
SOURCE: (Statistics Canada 2017)					



SOURCE: (Statistics Canada 2017)

Figure 5.2 Population by Gender and Age Group, Baffin Region, 2016

Migration rates in Nunavut are lower than in other areas of Canada. This may be related to the high percentage of Indigenous residents in Nunavut, and their strong sense of belonging to their home (Southcott 2015a). As illustrated in Table 5.4 below, during the 2016 / 2017 year, Nunavut saw a net gain of 104 interprovincial migrants enter the territory. This gain follows a three-year period in which the territory recorded more individuals leaving than entering. In terms of age, Table 5.5 shows the age ranges for interprovincial migrants over the same timeframe. The largest number of interprovincial migrants were between 25 and 29 years of age This may be related to young professionals that are moving to Nunavut for employment opportunities.

Table 5.4 Nunavut Net Interprovincial Migration, by Province, Annual, July 1 to June 30, 2010 to 2017

Location	Year						
	2010/2011	**2011/2012**	**2012/2013**	**2013/2014**	**2014/2015**	**2015/2016**	**2016/2017**
Total	**73**	**-153**	**5**	**-59**	**-172**	**-200**	**104**
NL	11	-48	-9	-47	-23	-24	16
PEI	-1	-7	5	-16	0	3	-1
NS	-21	6	30	11	-22	-15	32
NB	-7	14	-16	-1	-27	19	40
QUE	-2	1	46	7	16	-16	4
ON	55	29	46	39	-47	-131	76
MB	6	-40	-7	-22	17	-32	-83

Table 5.4 Nunavut Net Interprovincial Migration, by Province, Annual, July 1 to June 30, 2010 to 2017

Location	Year						
	2010/2011	2011/2012	2012/2013	2013/2014	2014/2015	2015/2016	2016/2017
SK	2	-24	-3	5	-2	-6	-22
AB	6	-60	-18	-52	-1	13	35
BC	21	11	-13	-1	-10	23	41
YU	-4	-6	-7	-15	-18	-13	-24
NWT	7	-29	-49	33	-55	-21	-10
SOURCE: (Government of Nunavut n.d.-a)							

Table 5.5 Nunavut Total Interprovincial Migration by Age Group, Annual, July 1 to June 30, 2010 to 2017

Age	Year						
	2010/2011	2011/2012	2012/2013	2013/2014	2014/2015	2015/2016	2016/2017
Total	**79**	**-152**	**11**	**-41**	**-188**	**-158**	**102**
0-4	-36	-37	1	-13	-35	-65	-47
5-9	10	-38	-21	-34	-41	-49	-55
10-14	21	-25	-13	-18	-33	-37	-32
15-19	-35	-11	8	4	-3	-6	1
20-24	43	-17	9	0	8	7	28
25-29	43	33	56	53	22	58	114
30-34	0	18	26	24	1	-4	34
35-39	25	-53	-37	-51	-72	-87	-50
40-44	16	21	33	29	15	52	63
45-49	13	-32	-30	-27	-31	-36	-15
50-54	46	41	33	53	40	55	75
50-59	-43	-9	-22	0	-8	5	18
60-64	-12	-35	-31	-29	-30	-21	-14
65 +	-12	-8	-1	-32	-21	-30	-9
SOURCE: (Government of Nunavut n.d.-a)							

5.2 Economic Development and Opportunities

The economic environment of Nunavut includes a mixed range of sources of economic activity. While there are increasing wage-based and employment opportunities, the increase in these opportunities is a relatively recent phenomenon. Nunavummiut still maintain a strong reliance on the traditional economy, using traditional knowledge and cultural practices to provide goods and services which contribute to the overall economy. Below is an overview of Nunavut's overall economy with specific reference to the Qikiqtani region, including GDP, its consumer price index, its main contributing industries, and sectors of importance to the territory and its communities.

5.2.1 Gross Domestic Product

Gross domestic product (GDP) is a common indicator used globally to provide an indication of economic growth and/or performance for a given jurisdiction. Nunavut has seen its GDP increase steadily from 2012 to 2016. According to the most recent economic status update by the Government of Nunavut, GDP increased by approximately 3.9% in 2016. This was following a 1.2% increase in 2015 (Government of Nunavut 2017c). Increasing iron ore production at the Mary River Mine has been an important factor in GDP growth. Engineering and construction activity also rose considerably, adding to the overall GDP increase. Non-residential construction decreased as larger construction projects such as the Canadian High Arctic Research Station passed their peak construction phase (Government of Nunavut 2017c). Table 5.6 illustrates the change in the GDP of Nunavut, relative to other provinces and territories in Canada, while Table 5.7 shows the changes in Nunavut's GDP by industry.

Table 5.6 Percent Change of Real Gross Domestic Product by Province, Annually

Location	Year				
	2012	2013	2014	2015	2016
Nunavut	**2.5**	**10.1**	**-1.4**	**1.2**	**3.9**
Canada	1.9	2.5	2.6	0.9	1.3
Newfoundland and Labrador	-4.5	5.0	-1.1	-1.8	1.9
Prince Edward Island	0.9	1.9	1.4	1.3	2.4
Nova Scotia	-1.0	-0.3	0.7	1.0	0.9
New Brunswick	-1.2	-0.4	-0.1	2.1	1.4
Quebec	1.3	1.3	1.2	1.2	1.7
Ontario	1.4	1.4	2.6	2.6	2.6
Manitoba	3.0	2.7	1.4	2.1	2.4
Saskatchewan	1.8	6.4	2.3	-1.3	-1.0
Alberta	4.0	5.8	4.9	-3.7	-3.8
British Columbia	2.6	2.4	3.2	3.1	3.7
Yukon	4.0	1.5	-0.2	-6.0	8.2
Northwest Territories	-0.6	2.8	5.0	1.3	-0.1
SOURCE: (Government of Nunavut 2017c)					

Table 5.7 Nunavut Real Gross Domestic Product by Industry, Millions of Chained (2007) Dollars

NAICS Category	Year					Percent change from 2015 to 2016	Percent change from 2012 to 2016
	2012	2013	2014	2015	2016		
	Millions of chained (2007) dollars						
All industries	1,785.3	1,965.6	1,938.8	1,962.5	2,039.6	3.9	14.2
Agriculture, forestry, fishing and hunting	5.5	5.1	5.0	4.9	4.9	0.0	-10.9
Mining, quarrying, and oil and gas extraction	286.7	319.1	335.1	350.2	377.8	7.9	31.8
Utilities	50.4	48.4	49.3	51.1	51.3	0.4	1.8
Construction	133.6	252.0	223.9	196.0	207.8	6.0	55.5
Manufacturing	6.8	7.2	4.9	4.3	4.4	2.3	-35.3
Wholesale trade	53.8	53.7	21.7	23.3	32.0	37.3	-40.5
Retail trade	71.9	73.3	75.8	80.4	85.4	6.2	18.8
Transportation and warehousing	44.3	44.3	43.9	47.4	49.1	3.6	10.8
Information and cultural industries	45.8	46.4	46.2	46.2	47.0	1.7	2.6
Finance and insurance	37.3	37.3	37.5	38.0	39.5	3.9	5.9
Other professional, scientific and technical services including scientific research and development	9.9	9.3	9.8	11.7	11.3	-3.4	14.1
Other professional, scientific and technical services	2.5	3.3	3.2	4.2	4.6	9.5	84.0
Administrative and support, waste management and remediation services	46.2	45.1	44.9	44.8	45.7	2.0	-1.1
Educational services	153.1	153.3	156.2	156.7	157.7	0.6	3.0
Health care and social assistance	106.7	111.5	113.9	115.1	119.3	3.6	11.8
Arts, entertainment and recreation	1.9	1.9	1.9	1.9	1.9	0.0	0.0
Accommodation and food services	24.5	26.4	25.0	25.7	26.5	3.1	8.2
Other services (except public administration)	24.5	22.7	23.0	23.2	23.0	-0.9	-6.1
Public administration	369.3	375.8	383.4	398.7	403.1	1.1	9.2
SOURCE: Government of Nunavut (n.d.-a); Statistics Canada (2017)							

5.2.2 Consumer Price Index

Nunavut's consumer price index (CPI) has also experienced change over time. The CPI measures the weighted average of prices of a group of consumer goods and services. The CPI is a tool used to assess changes in price associated with the cost of living. The Government of Nunavut releases status updates on the CPI for the city of Iqaluit. As of December 2017, residents of Iqaluit paid approximately 1.8% more for goods and services within the CPI grouping than in December 2016. This is slightly below the Canadian average increase of 1.9% for the same timeframe (Government of Nunavut 2018). The Government of Nunavut also conducted a survey to understand the changes in prices of foods between 2016 and 2017. Within the Qikiqtani Region there was a net decrease in the cost of items by approximately 2.1%. Within the communities identified within the Area of Focus, Grise Fiord saw the largest decrease in prices (approximately 14.6%), while Cape Dorset saw an increase of approximately 7.5% in the same timeframe (Government of Nunavut 2017d).

Food items are costlier in the Qikiqtani region and Nunavut than much of Canada. Table 5.8 illustrates the top 10 food items that were included in the most recent 2017 food price survey that had the highest Nunavut-Canada ratio (i.e., the average price for an item in Nunavut compared to the Canadian average). Fruits and vegetables constitute much of this list, as they are typically costlier to access in northern areas of Canada. Within the Qikiqtani Region, the average for food prices from these 10 foods were relatively similar to the average for Nunavut, except for apple juice and tomato juice.

Table 5.8 2017 Nunavut Food Price Survey, Comparison of Foods within Nunavut and Canada CPI Food Price Basket

Item	Size/Weight	($) Dollars				Ratio
		Qikiqtani Average	Nunavut Average	Ottawa	Canada Average	Nunavut-Canada
Apple Juice	1.36L	9.28	8.76	2.17	2.07	4.23
Tomato Juice	1.36L	10.38	9.71	2.23	2.44	3.98
Canned Tomatoes	796ml	5.49	5.61	1.81	1.54	3.64
Macaroni	500g	5.37	5.19	N/A	1.48	3.51
Celery	per kg	9.41	9.40	4.36	2.71	3.47
Sugar, White	2kg	9.01	9.14	3.48	2.83	3.23
Canned Baked Beans	398ml	4.09	4.11	1.51	1.30	3.16
Bananas	per kg	4.86	4.88	1.36	1.58	3.09
Carrots	per kg	5.85	5.93	3.45	2.03	2.92
Flour, All Purpose White	2.5kg	13.91	13.81	5.26	4.91	2.81
NOTE: N/A indicates that data is unavailable due to information missing or confidentiality reasons						
SOURCE: Government of Nunavut (n.d.-a) NOTE: NA = data is unavailable						

5.2.3 Economic Sectors

This section provides an overview of Nunavut's main economic sectors.

5.2.3.1 Minerals and Mining

Mineral exploration and production activities have historically been an important component of Nunavut's overall economic performance. As illustrated in Table 5.7, in terms of GDP by industry sector, the mining, quarrying, and oil and gas extraction industry contributed approximately 18.5% to Nunavut's total GDP in 2016 (Government of Nunavut n.d.-a).

According to the Government of Nunavut (2017c), mineral exploration expenditures in Nunavut in 2011 reached over $300 million, as gold, diamond, and metal deposits were found and explored throughout the territory. Production of gold at the Meadowbank Mine brought in a market value of approximately $420 million.

The Department of Natural Resources Canada have estimated that mineral production for Nunavut in 2016 totaled approximately $733 million, an increase of $89 million from 2015. In Nunavut, iron ore showed the highest increase, up approximately $170 million from $68 million in 2015, to $238 million in 2016 (Natural Resources Canada 2017; Northwest Territories and Nunavut Chamber of Mines 2017). This can be attributed to the ramping up of production of the Mary River Iron Mine on northern Baffin Island.

Based on the most recent assessment by The Conference Board of Canada (2017), Nunavut's economy has stayed strong through the correction in commodity prices, and that will continue in 2017, with a 6.4% expansion forecast for the territorial economy. Metal mining is the single largest contributor to economic growth, and all operating mines are planning increases in production, including TMAC Gold's Hope Bay mine, which opened in 2017. Production is proposed to increase at Hope Bay in 2018; however, production at Agnico Eagle's Meadowbank mine is declining as its reserves are drawn down. This decrease in production has the Conference Board of Canada predicting a 0.2% decrease in Nunavut's GDP in 2018. However, new mining developments such as Agnico Eagle's Meliadine mine are expected to help continue to contribute to a strong mining sector in the territory (Canadian Broadcasting Corporation (CBC) 2017c).

5.2.3.2 Public Sector

The public sector is another important component of Nunavut's economy, being the largest contributor to Nunavut's GDP in 2016 at 19.8% of the total (see Table 5.7). This is consistent with findings from the Canadian Northern Economic Development Agency, which showed that the public administration sector comprised approximately 19.5% of Nunavut's GDP in 2015. This was the largest contribution from any sector in 2015 (Canadian Northern Economic Development Agency 2016). According to the Government of Nunavut Department of Family Services, about 60% of people employed in Nunavut work in the public sector, at the municipal, territorial and federal government levels. This sector includes infrastructure, environment, justice, education, health and social services (Government of Nunavut n.d.-b). Statistics

Canada (2017) also identified public administration as a dominant employment sector in both Nunavut and the Qikiqtani Region, accounting for over 30% in Nunavut and over 25% in the Qikiqtani Region, with education being the second largest sector.

5.2.3.3 Construction

As the need for public and private infrastructure continues to grow in Nunavut, the construction industry has become a major contributor to the territory's economy; in 2016, it represented approximately 10.2% of Nunavut's total GDP (see Table 5.7). This increased contribution of the construction industry is closely tied to the investments that have been made by mining operations and the large-scale construction that accompanies it. Federal infrastructure, such as the Canadian High Arctic Research Station has also provided a large contribution to the sector. A report from the Conference Board of Canada has suggested that the construction industry will continue to perform strongly but will taper off as major capital projects reach completion (Nunatsiaq Online 2017).

5.2.3.4 Traditional Hunting and Harvesting

Hunting, fishing and harvesting of other renewable resources has always been an important contributor to Nunavut's economy. Harvesting animals provides meat for food and fur, skin and bones for clothing, tools, games and art. A recent study estimated the current traditional harvesting economy in Nunavut is worth approximately $40 million annually (Government of Nunavut 2017c). This includes hunting for polar bears, caribou, birds and marine mammals. Sealing is widespread and provides an important food source, as well as skins for clothing and art. An estimated over 40,000 seals are harvested annually in Nunavut, with the replacement food value of seal meat estimated at approximately $5 million. Seal skin products are worth an additional $1 million to the arts and crafts sector (Government of Nunavut 2017c). A 2011 study found that the highest economic values of both subsistence hunting and sport hunting were found in the Northwest Territories and Nunavut, at $543,000 and $923,000, respectively (Ecoresources Consultants 2011).

Harvesting of polar bears is both culturally and economically important to Inuit. Between 2007/08 and 2011/12 an average of 447 polar bears were harvested in Nunavut each year, many of which (311) were harvested in the Qikiqtani Region (Government of Nunavut 2013). There are two sub-populations of polar bears in the Area of Focus: the Baffin Bay and the Davis Strait populations. During 2015/16 there were 136 bears harvested from the Baffin Bay population and 95 bears harvested from the Davis Strait population (Polar Bears in Canada). Average annual harvest levels for the five- year period ending 2015/16 for Baffin Bay and Davis Strait populations was 146 and 110, respectively. Total harvest levels represent all bears killed annually, including subsistence harvest, commercial recreational harvest, and problem/self-defense kills. Commercial recreational polar bear hunts result in approximately $700,000 revenue annually for Nunavut, with an individual hunt contributing $25,000-30,000 to the local economy (Polar Bears in Canada).

5.2.3.5 Commercial Fishing

Commercial fishing has begun to play a more prominent role within Nunavut, as there are now offshore commercial fisheries for Greenland Halibut (turbot) and shrimp in Baffin Bay, and onshore fisheries for Arctic char throughout the territory (see Section 5.13). According to the most recent Nunavut Fisheries Strategy released by the Department of Environment—Fisheries and Sealing Division, over 72 metric tonnes of Arctic Char were caught as part of the inshore fishery in 2015, resulting in a market value of $1.8 million (Government of Nunavut Department of Environment 2016). In the offshore fishery, 2014 saw an overall landed value of northern shrimp in Nunavut of approximately $14 million, and $6.5 million in 2015. This decrease in value was due to a decrease in harvesting levels. Turbot saw a landed value of $73 million during the 2014-2015 fishing season, increasing to $78 million during 2015–2016 (Government of Nunavut Department of Environment 2016).

5.2.3.6 Tourism

Tourism is becoming a more prominent industry for Nunavut as access for tourists becomes easier. According to a 2015 study by Nunavut Tourism, Nunavut received approximately 16,750 non-resident visitors to the territory through air, land, and sea, who spent approximately $37.88 million in Nunavut, excluding the cost of airfare and cruise ship passage (Insignia Research 2015). As access through the Northwest Passage becomes easier with reducing summer ice cover, the tourism sector could see further increases and greater economic contributions to Nunavut. Tourism development has been cited as a priority for some communities in the Qikiqtani Region and increased marine access could potentially result in an increase of the number of tourists that visit the region.

5.2.3.7 Traditional Arts and Crafts

Arts and crafts production has been, and continues to be, an important part of the economy of many communities in Nunavut. The government of Nunavut has estimated that the arts and crafts sector contributes approximately $33 million to the territory's economy annually (Government of Nunavut 2017c). While most Canadians are familiar with soapstone carvings and prints from communities such as Cape Dorset and Baker Lake, internationally recognized tapestries and weavings are being produced in Pangnirtung. Another study conducted in 2010 estimated that the arts and crafts sector produces approximately 1,068 full-time equivalent positions within the territory. This sector contributes approximately $50 million direct economic contributions with indirect and induced economic effects and benefits approximately 3,000 Nunavut residents in some capacity (Nordicity Group and Uqsiq Communications 2010).

5.2.4 Economy of local communities

While the previously described sectors constitute most of the economic activity in Nunavut, some sectors may or may not be present or prominent in the potentially interested communities. A brief overview of the economic setting of potentially interested communities is provided below.

5.2.4.1 Arctic Bay

Currently, Arctic Bay does not have a large public-sector presence; the local economy includes traditional activities such as hunting, fishing, traditional crafting, and manufacturing of traditional clothing. Tourism is a development goal for the Hamlet (Government of Nunavut 2017e). The recently opened Mary River Iron Ore Project has provided new opportunities to residents. In 2016, 35 residents of Arctic Bay worked at Baffinland's Mary River Mine (Jason Prno Consulting Services Ltd. 2017). Aircraft flights are available from Iqaluit to Arctic Bay, and cruise ships visit the community during the summer months. Table 5.9 highlights some of the current local business within Arctic Bay.

A high rate of residents in the community still rely on and participate in the traditional economy, and the supply of country food remains an important support for the community in addition to residents being employed by the wage economy (Integrated Community Sustainability Plans Webtool 2016).

Table 5.9 Local Businesses within Arctic Bay

Community	Business Title	Description of Activities
Arctic Bay	Ikpiarjuk Marble Society	Marble stones sale and artist society
	Ikpiarjuk Services	Fabrics and notions sales and hardware store, building materials
	Katiqsivik	Retail and beauty supplies
	Northern Store	Groceries, general retail, light banking services
	Qimatuligvik Heritage Centre and Gift Shop	Arts and crafts gift shop, traditional diorama display, local information
	Taqqut Co-operative Ltd.	Store, Cable TV, Fuel, Post Office, hotel
	Tom's Place	Variety Store
	Tununet	Electronic sales and local ISP
	Ulu Enterprise	Retail and canteen
	Arqvartuuq Services Ltd.	Taxi / Bus services, vehicle rentals
	Arctic Fox	Local cartage and courier
	Koonoo Taxi Services	Taxi Service
	5027 Nunavut Ltd.	Customer Services of Arctic Bay
	Small Engine Repairs	Small engine repair and property rental, parts sales
	Ikajutit Hunters and Trappers Organization	Local information about the land, country foods, local outfitters
	Koonoo's Outfitting	Local outfitter
	Maniituq Outfitting	Local outfitter
	North Baffin Outfitting	Local Outfitter
	Qamutitaarvik	Qamutik, Iglutaq and Savikkuvik sales.
	Qimatuligvik Heritage Centre and Gift Shop	Traditional diorama display, local information, arts and crafts gift shop
	Tikiq	Custom clothing, traditional and modern
	Ullivik Outfitting	Local Outfitter
	Qamanirq's Interpreting and Translating Services	Interpreting and translating services
	Qauyivvik Services	Interpreting and translating Services
	Tununirusiq Translating and Interpreting	Interpreting and translating services
	Niksiglagu Services	Photo and printing services
	RH and CS	Repair, heating, and cleaning services
	Ron Elliott Photography	Photography
SOURCE: Government of Nunavut (2017e)		

5.2.4.2 Cape Dorset

Cape Dorset has been self-proclaimed as the Capital of Inuit Art, with approximately 22% of the population involved in some capacity with the production of visual art (Government of Nunavut n.d.-a), and having more artists per capita than any other community in Canada (Integrated Community Sustainability Plans Webtool 2016). In addition to the art industry, Cape Dorset also hosts several decentralized offices for the Government of Nunavut, including the Department of Economic Development and Transportation, the Nunavut Housing Corporation, and the Department of Community and Government Services (Government of Nunavut 2017e). In addition to the wage economy, residents of Cape Dorset also pursue traditional hunting and fishing activities. This is in part since the floe edge is much closer to the community than in other communities in the Qikiqtani Region (Integrated Community Sustainability Plans Webtool 2016). Due to the abundance of residents employed in the arts and culture sector, tourism has become an important contributor to the local economy. Table 5.10 highlights some of the local businesses within Cape Dorset.

5.2.4.3 Clyde River

Like most communities in Nunavut, Clyde River's economy consists of a mix of traditional activities such as hunting, fishing, traditional arts and crafts, and wage-based occupations. The development of the tourism potential for Clyde River is a priority for the community; currently there is a small number of outfitters and outdoor adventure activities available such as mountain climbing (Government of Nunavut 2017e). Thirty-two residents of Clyde River worked at Baffinland's Mary River Iron Ore Project during 2016 (Jason Prno Consulting Services Ltd. 2017). Table 5.11 highlights some of the local businesses within Clyde River.

Table 5.10 Local Businesses within Cape Dorset

Community	Business Title	Description of Activities
Cape Dorset	Kingnait Inn	Hotel and restaurant
	Huit Tours (Beach House and Guest House) (Inuit)	Rental properties
	Polar Lodge Hotel	Eight room lodge, restaurant
	Uksivik Bakery/Coffee Shop	Bakery and coffee shop
	Co-op Mart Corner Store	General corner store
	Northern Store	General retail, light banking services
	West Baffin Eskimo Cooperative	General retail, hardware/tools, fuel supply, arts and crafts
	Tuniit Taxi	Taxi service
	Island Equipment Ltd.	Local courier/delivery services, drilling contractor services, bulk dry trucking services, general contracting, industrial equipment, automobile rental
	Kingait Holdings	Construction equipment, auto supplies, fuel distribution, general contracting
	K.P. Contracting	Cabinet making
	Polar Supplies	Industrial supplies, building materials, general contracting, hardware/tools
	Power Painting Ltd	General Contracting
	Nanuk Repair Services	Mechanical repairs
	Huit Tours	Outfitting services, dog team excursions.
	Aiviq Hunters and Trappers Association	Local information about the land, country food
	PEN Outfitting	Tourism and culture
	Siku Outfitting	Tourism and culture
	J&D Cape Dorset Sculptures	Tourism and culture
	Atsiak and Hannberry Car Services	Radio; weather prediction
	Kingait CableVision Ltd.	Cable services
	Qiniq	High speed internet services
	Kinngait Property Management Ltd.	Scheduled air and charter services, cargo
SOURCE: Government of Nunavut (2017e)		

Table 5.11 Local Businesses within Clyde River

Community	Business Title	Description of Activities
Clyde River	Qammaq Hotel	Hotel
	Aarruja Development Corp.	Hotel/Restaurant/Coffee shop
	Aarruja Development Corp.	General retail, coffee shop, gas, cable service.
	Northern Store	General retail, groceries, light banking
	Qimiqpik Niuvirbik	Retail store, taxi, Community Liaison Officer service
	Raygeelee Paneak	Retail outlet
	Natanine Taxi Services	Water Taxi
	090117 Nunavut Ltd.	Construction and maintenance
	Iqaqrialu Enterprise	Contractor fuel tank clean-ups
	Nutaaq Construction Ltd.	Construction
	Prime Business Services Ltd.	General contracting, accountant
	Nangmautaq Hunters and Trappers Organization	Local information, land and country foods
	Palituq Outfitting	Outfitting /guiding
	Sajugiaq Outfitters and Guides	Outfitting /guiding
	Ilkoo Angutikjuak	Carver; marbles, stone and bones
	Leetia Qayaq	Carver: Marbles, stone and bones
	Piksuk Media Inc.	Film making, consultant
	Raygelie Piungituq	Carver: Marbles, stone and bones
	Ilisaqsivik Society	Public library, healing and counseling services
	Saipaaqivik Pairivik	Daycare Centre
	SSL Services	Income Tax Services
	TAPS Snacks	Catering, snack foods, retail outlet
	Cumberland Sound Fisheries Ltd.	Commercial fishing
	Uqqurmiut Inuit Artist Association	Traditional art

SOURCE: Government of Nunavut (2017e)

5.2.4.4 Grise Fiord

The economy of Grise Fiord is primarily focused on traditional activities such as arts and crafts, with many residents participating in traditional subsistence hunting and fishing to help offset the high cost of food (Integrated Community Sustainability Plans Webtool 2016). With beautiful scenery and wildlife in the area, tourism is a development priority for the community. Residents and businesses help provide supplies and guides for the commercial recreational polar bear hunt. The polar bear hunt is an economically important activity for the community and its residents (Government of Nunavut 2017e). Table 5.12 highlights some of the local businesses within Grise Fiord.

Table 5.12 Local Businesses within Grise Fiord

Community	Business Title	Description of Activities
Grise Fiord	Grise Fiord Lodge	Hotel
	Grise Fiord Inuit Co-operative	General retail and groceries, hardware/tools, arts and crafts, post office
	Oogliit Sannavik Business	Fuel contractor and office space rental
	Iviq Hunters and Trappers Organization Qutsiktumiut Outfitting (Business Arm)	Information about the land, country foods, outfitting
	Koonoo's Outfitting	Local outfitter
SOURCE: Government of Nunavut (2017e)		

5.2.4.5 Iqaluit

Iqaluit is the largest community in the Qikiqtani Region, the capital of Nunavut and is the centre of commercial and public-sector activity in the region. As a result, the economy of the city is more diversified than the other potentially interested communities. As capital of the territory, many territorial and federal government offices and employees are in the city. This includes the Legislative Assembly of Nunavut, Nunavut Courts of Justice, the Qikiqtani General Hospital, the largest campus of Nunavut Arctic College, and many other government agencies (Government of Nunavut 2017e). The offices of the Qikiqtani Inuit Association (QIA) which represents Inuit of the Qikiqtani region, and the Nunavut Tunngavik Incorporated, representing Inuit across Nunavut, are also located in Iqaluit. Iqaluit's airport is the hub of air service in the region and can accommodate large intercontinental aircraft. A new deep-water port to improve the existing marine resupply system has been proposed to commence construction before 2020. Iqaluit also hosts a large number of independent businesses, service companies, shops, hotels, restaurants, and entertainment facilities to support the local residents and the region. Tourism is another industry that continues to grow in Iqaluit. Traditional arts and crafts still play a role in the economy, and galleries act as agents for local artists to display their work to tourists and other residents of the city (Government of Nunavut 2017e).

5.2.4.6 Kimmirut

The economy of Kimmirut is based primarily on local arts and crafts, but occupations in the traditional economy are also mixed with wage-based sectors. The predominant sectors in the community are related to trades, transport, and equipment operations; business and finance; and sales and services occupations (Integrated Community Sustainability Plans Webtool 2016). There is also small-scale mining activity in the area, primarily for precious and semi-precious gems like sapphire, zircon, and moonstone. Local residents and artists also make jewelry using these local stones. In addition to these activities, residents also take part in subsistence hunting and fishing activities. The community also benefits economically from tourism, largely resulting from the presence of nearby Katannalik Territorial Park and Soper Heritage River (Government of Nunavut 2017e). Table 5.13 highlights some of the local businesses within Kimmirut.

Table 5.13 Local Businesses within Kimmirut

Community	Business Title	Description of Activities
Kimmirut	Kimik Co-op Hotel	Hotel & restaurant
	Kimik Co-operative	Retail, hardware, carvings, fuel supply
	Northern Store	Retail, hardware, light banking
	Akavak's Construction	Construction, gravel, vehicle rental
	Kimmirut Development Corporation	Contracting, rental, storage
	Mayukalik Hunters and Trappers Organization	Tourism, outfitting, home stay arrangements, country foods
	Qaitsuq	Rock cutting, ulus, stone-cut furniture
	Quliruakut, Arts and Crafts Society, Operated by Soper House Gallery	Non-profit carvings, sewn goods
	Pairivik Daycare	Daycare services
SOURCE: Government of Nunavut (2017e)		

5.2.4.7 Pangnirtung

Tourism has played a large part of the economy of Pangnirtung for many years. The community serves as the gateway to federal and territorial parks, and Parks Canada has made Pangnirtung the administrative centre for Auyuittuq National Park Reserve. Local outfitters take visitors to parks during all seasons, reaching the areas by snowmobile or boat. Mountain climbing is another recreational activity that draws tourists to the community. The community also hosts decentralized offices of the Government of Nunavut, including the Nunavut Bureau of Statistics, the Department of Economic Development and Transportation, and the Department of Education (Government of Nunavut 2017e). Commercial fishing activity for Arctic char and turbot is also another local economic activity, with marine infrastructure that can accommodate commercial size vessels. During the NCRI, it was reported that harvesting of these resources is important both economically and culturally, as a source of food and income (Nunavut Department of Environment n.d.). Pangnirtung is one of the eastern Arctic's primary art centres. In addition to the local service economy, many residents also engage in subsistence hunting and fishing (Government of Nunavut 2017e; Integrated Community Sustainability Plans Webtool 2016). Table 5.14 illustrates some of the local businesses within Pangnirtung.

Table 5.14 Local Businesses within Pangnirtung

Community	Business Title	Description of Activities
Pangnirtung	Auyuittuq Lodge	Hotel and restaurant
	Kilabuk Lodge	Accommodation, outfitting
	Auyuittuq Lodge Apartment	Apartment hotel
	Quick Stop (at Northern Store)	Fast foods
	Northern Convenience	Retail
	Pangnirtung Inuit Co-op	Retail and grocery store
	Northern Store	Retail and groceries, banking services
	J.R. Peyton Enterprises	Building materials, hardware, contracting, courier, cargo, automobile leasing
	Napu Works	Contracting, building materials, hardware and equipment rentals
	Qammaq Construction	Carpentry/Dry wall
	Qijuk Construction	Small job construction
	Qikiqtaq Equipment	Heavy equipment and construction goods, contracting
	Alivaktuk's Outfitting	Outfitting / guide tours
	Angmarlik Interpretive Centre	Visitor information / outfitting
	Pangnirtung Hunter's and Trappers Association	Local information: land and country food
	Komoartok Tours and Outfitting	Outfitting
	Qaqqasiq Outfitting	Outfitting
	Parks Canada Interpretive Centre	Federal Government
	Sakavik	Teaching traditional knowledge
	Rebecca's Craft Shop/Kakijivik	Traditional clothing sales, custom-made, yard sales.
	Uqqurmiut Arts and Crafts (1993) Ltd.	Craft gallery, print and tapestry studio
	Cumberland Sound Fisheries Ltd.	Commercial Fishing
	Tasiujaa Camp	Child Care
	Uqqurmiut Inuit Artist Association	Traditional arts
SOURCE: Government of Nunavut (2017e)		

5.2.4.8 Pond Inlet

The community hosts decentralized offices of the Government of Nunavut, including the offices for the Department of Community and Government Services, the Department of Education, and the Department of Economic Development and Transportation. The Mary River Iron Ore Project, located to the southwest, recently commenced production and has had an economic impact on the local community, as Pond Inlet serves as a transportation link and residents are employed with the mine development (Government of Nunavut 2017e). Thirty-four residents of Pond Inlet worked at Baffinland's Mary River Mine during 2016 (Prno 2017). Tourism is also an important economic activity with the presence of Sirmilik National Park nearby and increasing number of cruise ships visiting the community during ice free months. The local service economy provides wage employment for residents; however, traditional fishing and hunting is also an important activity for the community (Government of Nunavut 2017e). Table 5.15 provides an overview of some of the local businesses within the community.

Table 5.15 Local Businesses within Pond Inlet

Community	Business Title	Description of Activities
Pond Inlet	Black Point Lodge	Bed and Breakfast
	Sauniq Hotel Inns North	Hotel and dining room and conference facilities
	Toonoonik Snack Shop/Restaurant	Carving sale; take out or eat in restaurant
	JK Enterprises	Convenience store
	Northern Store	General retail; hardware, dry goods, skidoo dealership
	J.M. Sportswear	Sportswear/sporting goods
	Toonoonik Sahoonik Co-op	General retail, groceries, construction and heavy equip. services, outfitting tours, Inuit arts gallery
	Hibye Taxi	Taxi Service
	Aupillaqtuungua	Janitorial Services
	Merkosak Construction Ltd.	General construction and contracting; sealift; local cartage
	Kamikpak Construction	Construction and maintenance
	Qilaut Development Corporation	Heavy Equip., contraction, building materials
	Kinguk Services	Driving services / plumbing
	Aupillaqtuungua Outfitting	Outfitting and janitorial services
	Polar Sea Adventures	Outfitter
	Mittimatalik Hunters and Trappers Organization	Local information on land, country foods, outfitting services
	Nanooq Expeditions	Sport hunting (fishing, polar bear, walrus), Tourism photography
	Qiniq Internet Services	Internet services
	Paneak Interpreting/Translating	Interpreting/translating
	Solunarctic Designs	Computer/internet services; consulting
SOURCE: Government of Nunavut (2017e)		

5.2.4.9 Qikiqtarjuaq

Qikiqtarjuaq was originally established in the 1950s as Inuit moved to the location to participate in construction of the nearby distant early warning line site. With the decommissioning of the distant early warning line system and a move to increase the automation of its functions, the economy of Qikiqtarjuaq has declined. The economy now focuses around traditional arts and crafts, as well as goods and services to residents. Local artists are known for carvings in narwhal ivory, and many people engage in subsistence hunting and fishing for seal, walrus, narwhal and Arctic char (Government of Nunavut 2017e;

Integrated Community Sustainability Plans Webtool 2016). There is a small clam fishery growing in Qikiqtarjuaq. Parks Canada also has an office to support Auyuittuq National Park. Table 5.16 highlights some of the local businesses within the community.

Table 5.16 Local Businesses within Qikiqtarjuaq

Community	Business Title	Description of Activities
Qikiqtaruaq	LEELIE Enterprise Lodge	Lodging, fuel contractor
	Siku Lodge	Lodging and property leasing
	Tulugak Co-op Hotel/Inns North	Hotel, apartment, cable TV, retail sales, shuttle
	Arctic Fishery Alliance	Commercial offshore turbot fishery
	Masiliit Nativak HTO	Commercial Fisheries
	Northern Store	Retail store, light banking, post office
	Ikkira Design	Fur designer
	Nunavut Experience Outfitting	Outfitting Services
	Talillajuu	Clam harvesting (Diving)
	Usuit	Clam harvesting (Diving)
SOURCE: Government of Nunavut (2017e)		

5.2.4.10 Resolute Bay

Resolute Bay developed as a transportation and logistics hub to support oil and gas and mineral exploration and communities in the region. The airport in the community supports jet service and smaller aircraft to access other areas of Nunavut. The community also hosts a base for the Polar Continental Shelf Project for polar research, and an Arctic military training centre. Local businesses also provide support to tourists and adventurers who attempt to reach the North Pole. Local businesses and residents also offer supplies and guidance to for the commercial recreational polar bear hunt, which is an activity that is economically important to the community (Government of Nunavut 2017e). Table 5.17 highlights local businesses within the community.

Table 5.17 Local Businesses within Resolute Bay

Community	Business Title	Description of Activities
Resolute Bay	Atco Frontec Structure and Logistic	Hotel and restaurant / Logistical support, vehicle/equipment rental, general contracting
	Qausuittuq Inns North	Hotel and restaurant, tour operators.
	Tudjaat Co-operative Limited	Retail, groceries, hardware/tools, gift shop
	The Polar Bear Hunt Craft Shop	Retail
	953731 NWT Limited	General contracting, aircraft loading/unloading, sea-lift, heavy equipment/vehicle renting, construction material.
	Atirktaq Ltd.	General contracting
	Nanuk Outfitting Ltd.	Big game sport hunting, outfitting
	Ootoq's and Metiq's Outfitting	Wildlife viewing, sightseeing, camping, snowmobile trips, dog sledding
	Resolute Bay Hunters and Trappers Organization	Local information about the land, country foods, outfitting
	Aziz Kheraj	Eco-tourism, dog team, boat, ski-doo
	Salluviniq Tusajiuvinga	Office supply and service
	Polar Continental Shelf Project	Support for scientific projects and traditional knowledge studies
SOURCE: Government of Nunavut (2017e)		

5.2.5 Exports, Imports and Trade Balance

Nunavut has historically been a region that imports more goods and services than it exports. According to the Canadian Library of Parliament, in 2015, merchandise exports from Nunavut totaled approximately $91 million, an increase of 810% from export totals of $8 million in 2014. In the same timeframe, imports to Nunavut were approximately $605 million, a 0.3% decrease from 2014 (Parliament of Canada 2017). The trade deficit for Nunavut for 2015 was approximately $514 million.

Manufactured goods represented the highest percentage of merchandise exports, totaling approximately 97.2% in 2016, compared to 2.8% for resource goods. The most highly valued products being exported in 2016 included machinery and equipment, electronics and electronical components, and seafood products. The largest export destinations for goods from Nunavut in 2016 were Asia (30.9% of total exports), Europe (28.3% of total exports), and central/south America (22.6% of total exports) (Parliament of Canada 2017).

The services trade for Nunavut also shows a similar trend, with imports being larger than exports. In 2015, Nunavut's Services trade with the world was approximately $99 million, with exports totaling approximately $28 million, and imports accounting for approximately $71 million. The trade deficit was approximately $43 million in 2015 (Parliament of Canada 2017).

5.2.6 Business Investment

Nunavut has been subject to an increase in business investment activity over the past 10 years. Table 5.18 highlights the amount of funds that businesses have invested in Nunavut. Between 2006 and 2016, both capital expenditures and capital construction have seen a steady increase. Capital expenditures rose approximately 318%, while capital construction rose approximately 410% within that timeframe.

Table 5.18 Nunavut Private and Public Investment ($ millions), 2006 to 2016

Year	Capital Expenditures	Capital Construction	Capital Machinery and Equipment	Repair Expenditures	Repair Construction	Repair Machinery and Equipment
2006	177.3	121.8	55.5	46.6	25.9	20.7
2007	253.3	151.6	101.7	33.0	17.4	15.6
2008	651.8	504.4	147.4	46.2	28.6	17.6
2009	402.2	309.1	93.1	43.0	28.9	14.1
2010	483.9	407.0	76.9	77.4	25.5	51.9
2011	452.8	375.0	77.8	173.1	64.5	108.6
2012	340.0	272.7	67.3	111.8	30.1	81.7
2013	815.9	641.4	174.7	105.5	N/A	N/A
2014	661.9	554.1	107.8	129.9	44.7	85.2
2015	670.1	515.1	154.9	N/A	N/A	N/A
2016	740.7	621.6	119.1	N/A	N/A	N/A
NOTE: N/A indicates that data is unavailable due to information missing or confidentiality reasons						
SOURCE: Government of Nunavut (n.d.-a)						

Construction on residential and non-residential housing has also experienced change as the economy has evolved. Investments in residential construction hit a high in 2011 of approximately $106.1 million but contracted to $44.8 million in 2016. Renovations to existing homes and infrastructure has historically been where most investment has been concentrated (see Table 5.19).

Non-residential construction investment has also fluctuated considerably, with a high in 2014 of $108.6 million decreasing to $25.6 million in 2016 (see Table 5.20).

Table 5.19 Nunavut Investment in Residential Construction, 2006 to 2016

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Type of Construction	**Value ($,000)**										
Total Residential Construction	55,786	92,682	82,092	139,682	157,969	106,127	75,187	76,832	88,968	50,700	44,885
New Dwellings, Total	31,826	59,620	49,521	102,712	116,423	68,845	41,572	46,215	54,225	22,036	13,436
Singles	9,650	7,960	7,860	33,751	41,155	6,775	6,885	1,931	1,943	1,192	1,025
Doubles	72	1,034	510	3,384	1,636	6,489	2,800	2,433	1,233	58	0
Row	2,361	2,583	2,940	8,219	9,202	0	6,668	14,286	9,923	3,483	334
Apartments	19,743	48,043	38,211	57,358	64,430	55,581	25,219	27,565	41,126	17,303	12,077
Conversions	418	886	469	436	250	824	536	441	374	166	1,196
Total Acquisition Costs	3,207	9,683	8,605	11,938	15,678	10,147	5,612	6,643	9,227	2,466	2,252
Renovations	20,335	22,493	23,497	24,596	25,618	26,311	27,467	23,533	25,142	26,032	28,001
SOURCE: Government of Nunavut (n.d.-a)											

Table 5.20 Nunavut Investment in Non-Residential Building Construction

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Type of Building	**Value ($,000)**										
Total non-residential	9,437	16,183	22,499	36,397	63,422	45,439	34,383	95,813	108,587	46,636	25,649
Industrial	567	56	1,115	1,521	2,348	1,658	463	4,738	4,223	146	1,590
Commercial	7,035	11,821	15,652	27,528	35,592	32,582	31,574	78,703	71,472	34,935	24,012
Institutional or Government	1,835	4,306	5,732	7,348	25,482	11,199	2,346	12,372	32,892	11,555	47
SOURCE: Government of Nunavut (n.d.-a)											

5.3 Employment

5.3.1 Employment Characteristics

Nunavut is an area characterized by a higher rate of unemployment than other parts of Canada. In 2016, Nunavut's total unemployment rate was approximately 21.5%, while the unemployment rate of the Qikiqtani Region was approximately 17.3%. These rates were above the national unemployment rate of 7.7%. Within the Qikiqtani Region, Clyde River had the highest unemployment rate (40.2%), while Iqaluit had the lowest unemployment rate (9.6%). Table 5.21 below illustrates the employment breakdown for residents of Nunavut over the age of 15.

Table 5.21 Labour Force Statistics—2016

Location	Population (aged 15 years and older)	Labour Force	Participation Rate (%)	Employed	Unemployed	Unemployment Rate (%)
Nunavut	23,935	16,340	68.3	12,820	3,515	21.5
Qikiqtaaluk / Baffin Region	12,840	8,895	69.3	7,350	1,540	17.3
Clyde River	685	410	59.9	245	165	40.2
Arctic Bay	535	280	52.3	225	60	21.4
Resolute Bay	130	85	65.4	70	10	11.8
Grise Fiord	100	75	75	70	10	13.3
Pond Inlet	1,030	625	60.7	465	155	24.8
Qikiqtarjuaq	405	250	61.7	185	65	26.0
Cape Dorset	920	550	59.8	405	150	27.3
Kimmirut	255	155	60.8	120	40	25.8
Iqaluit	5,675	4,640	81.8	4,195	445	9.6
Pangnirtung	980	610	62.2	475	140	23.0
SOURCE: Statistics Canada (2017)						

Table 5.22 and Figure 5.3 break down the employment in Nunavut and the Qikiqtani Region, by occupation and industry. Within Nunavut, the occupations that reflect the highest levels of employment include "Sales and Service" (21.5%) and "Education, Law and Social, Community, and Government Services" (20.3%). Within the Qikiqtani Region, the trend is very similar, with "Sales and Service" (20.6%) and "Education, Law and Social, Community, and Government Services" (20.4%) representing the two highest sectors of employment. For both areas, occupations in "Manufacturing and utilities" and "Natural Resources, Agriculture, and Related Products" had the lowest levels of employment at 1.3% and 1.8%, respectively.

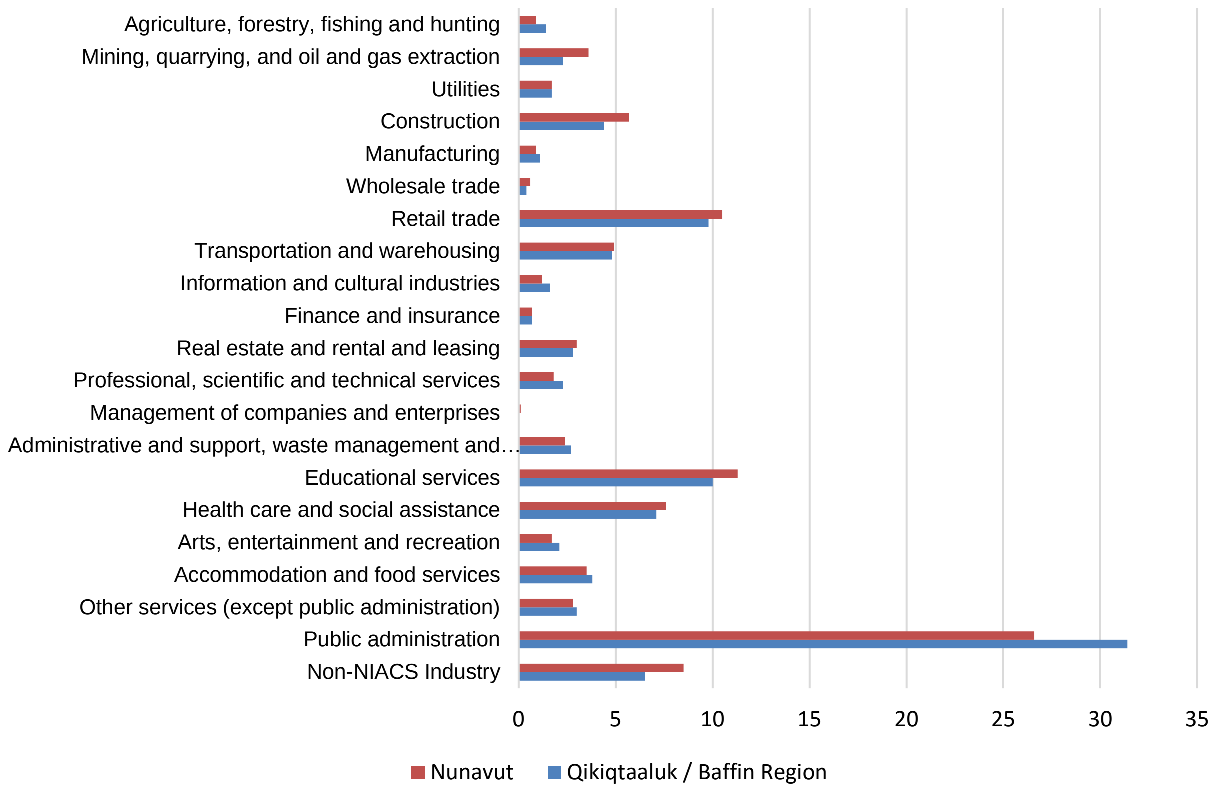
In terms of sectors, “Public Administration” is dominant in both Nunavut and the Qikiqtani Region, accounting for over 30% in Nunavut and over 25% in the Qikiqtani Region (Figure 5.3). This is followed by “Educational Services” and “Retail Trade”. The Government of Nunavut Department of Family Services identified that about 60% of people employed in Nunavut work in the public sector, at the municipal, territorial and federal government levels; this included infrastructure, environment, justice, education, health and social services (Government of Nunavut 2017a).

Table 5.22 Employment by Occupation (Number of Persons and Percent of Total Area Occupational Employment)—2016

Occupation	Qikiqtaaluk / Baffin Region		Nunavut- Province	
	Persons	**Percent**	**Persons**	**Percent**
Management	885	10.0	1,400	8.6
Business, finance and administration	1,355	15.2	2,205	13.5
Natural and applied sciences and related	305	3.4	455	2.8
Health	260	2.9	450	2.8
Education, law and social, community and government services	1,810	20.4	3,310	20.3
Art, culture, recreation and sport	390	4.4	570	3.5
Sales and service	1,830	20.6	3,505	21.5
Trades, transport and equipment operators and related	1,195	13.4	2,565	15.7
Natural resources, agriculture and related production	160	1.8	300	1.8
Manufacturing and utilities	120	1.3	205	1.3
Not applicable to the 2011 National Occupation Classification [1]	580	6.5	1,390	8.5
Total	**8,890**	**100.0**	**16,340**	**100.0**

NOTES:
Data is presented for persons aged 15 years and older (aligns with statistics on labour force status
[1] Statistics Canada’s nationally accepted framework of occupations in the Canadian labour market

SOURCE: Statistics Canada (2017)



SOURCE: Statistics Canada (2017)

Figure 5.3 Employment Percentage by Industry, Nunavut and Baffin Region, 2016

5.3.1.1 Income

Table 5.23 below illustrates the average level of income for individuals in the Qikiqtani Region, and potentially interested communities. Within the potentially interested communities, Iqaluit had the highest averages of both total and employment incomes for individuals. This can be attributed to Iqaluit being the capital city of Nunavut, and the most developed in terms of economic activity. Cape Dorset showed the lowest median average of both total and employment income, while Clyde River showed the lowest mean average for total income, and Qikiqtarjuaq showed the lowest mean average for employment income.

Table 5.23 Average Individual Total and Employment Incomes, 2015

Region / Community	Total Income ($)		Employment Income ($)	
	Median	Mean	Median	Mean
Canada	34,204	47,487	33,684	46,057
Nunavut	29,743	50,689	29,724	51,195
Baffin Region	34,894	55,283	38,043	55,997
Arctic Bay	21,696	38,361	14,592	37,046
Cape Dorset	18,933	35,515	15,189	36,820
Clyde River	20,320	32,911	12,144	31,139
Grise Fiord	N/A	N/A	N/A	N/A
Iqaluit	70,695	76,556	73,632	76,081
Kimmirut	26,816	39,129	23,040	37,703
Pangnirtung	23,424	42,323	16,691	42,062
Pond Inlet	19,456	38,590	13,904	37,083
Qikiqtarjuaq	21,344	34,815	13,088	30,872
Resolute Bay	N/A	N/A	N/A	N/A

NOTES:

[1] Median Income is presented using 100% of the data collected for the population over 15 years of age in private households

[2] Mean income is presented as the average total income using 25% of the data collected for the population over 15 years of age in private households

N/A indicates data that was unavailable or has been suppressed for confidentiality reasons.

SOURCE: Statistics Canada (2017)

In terms of employment composition, Table 5.24 outlines the income composition between employment income and government transfers for the Qikiqtani Region and the potentially interested communities. The Qikiqtani Region had a higher percentage of employment income (85%) accounting for income composition than the Nunavut average (80%), and a lower percentage of government transfers. Within the potentially interested communities, Iqaluit had the highest composition from employment income (89.9%) and the lowest composition of government transfers (4.9%). Qikiqtarjuaq had the lowest composition of employment income (73.9%), while Cape Dorset and Clyde River showed the highest composition of government transfers (21.6% each).

Table 5.24 Income Composition of Individuals, Baffin Region and Communities, 2015

Location	Income Composition (%)	
	Employment Income	Government Transfers
Nunavut	80.0	15.7
Baffin Region	85.0	10.2
Arctic Bay	76.7	20.0
Cape Dorset	74.2	21.6
Clyde River	76.0	21.6
Grise Fiord	N/A	N/A
Iqaluit	89.9	4.9
Kimmirut	79.6	16.7
Pangnirtung	78.7	17.2
Pond Inlet	78.0	16.9
Qikiqtarjuaq	73.9	20.1
Resolute Bay	N/A	N/A

NOTE:
Employment income and government transfers are presented as two separate categories and are not intended to add to 100%.

SOURCE: Statistics Canada (2017)

5.3.2 Employment Insurance and Social Assistance

According to the Government of Nunavut, approximately 460 people in Nunavut were receiving employment insurance in September 2017. This number was the same as in September 2016, resulting in no change. In Canada, the number of individuals receiving employment insurance decreased by 16.3% over that same period (Nunavut 2017).

Table 5.25 shows the most recent available information from the Government of Nunavut on the number of individuals in Nunavut and the Qikiqtani Region who received some type of social assistance between 2005 and 2013. Social assistance recipients in the Qikiqtani Region comprised between 40 and 50% of the total number of social assistance recipients in Nunavut, consistent with the region containing approximately 50% of Nunavut's population. Iqaluit has historically had the largest number of social assistance recipients, with Grise Fiord having the fewest.

Table 5.26 illustrates the total expenditures for social assistance in Nunavut and potentially interested communities from 2004 to 2014. Within 2013–2014, the Qikiqtani Region received more in social assistance than any other region in the territory. Within the region, Iqaluit had the highest expenditures on social assistance, while Resolute Bay recorded the lowest.

Table 5.25 Nunavut Social Assistance Recipients by Community, Region and Territory, 2005 to 2013

	2005	2006	2007	2008	2009	2010	2011	2012	2013
	Number of Recipients								
Nunavut	**12,392**	**13,570**	**14,820**	**15,523**	**14,037**	**13,716**	**13,197**	**13,797**	**14,578**
Kivalliq (Keewatin) Region	3,200	3,493	4,062	4,305	3,693	3,522	3,244	3,455	4,276
Kitikmeot Region	2,867	2,822	3,047	3,241	3,044	3,133	3,082	3,136	3,432
Qikiqtani Region	6,325	7,255	7,711	7,977	7,300	7,061	6,871	7,206	6,473
Arctic Bay	417	434	548	523	482	405	476	520	509
Cape Dorset	742	786	866	859	857	826	792	818	822
Clyde River	595	551	539	621	607	614	626	665	665
Grise Fiord	31	48	52	53	40	37	27	24	34
Iqaluit	1,005	1,496	1,680	1,644	1,476	1,320	1,265	1,231	1,209
Kimmirut	235	262	296	304	263	261	228	263	251
Pangnirtung	694	622	668	687	570	644	604	650	718
Pond Inlet	665	731	829	866	762	755	674	756	928
Qikiqtarjuaq	310	346	324	330	300	319	323	333	325
Resolute Bay	67	82	86	82	59	70	62	52	52

NOTE: Igloolik and Sanikluaq were not included in this table, therefore total numbers for Nunavut may not be reflective of the numbers for communities presented in the table.

SOURCE: Adapted from Government of Nunavut (n.d.-a)

Table 5.26 Nunavut Social Assistance Expenditures by Community, Region, and Territory, 2004 to 2014

	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014
	Total Expenditures ($)									
Nunavut	**23,875,590**	**26,238,656**	**28,005,709**	**28,709,116**	**28,130,783**	**28,309,089**	**27,949,037**	**34,337,843**	**35,870,794**	**37,941,868**
Kivalliq (Keewatin) Region	6,701,850	7,046,274	7,231,787	6,806,342	6,493,370	6,459,052	5,978,501	7,371,788	7,502,954	7,668,539
Kitikmeot Region	5,201,452	6,063,749	5,996,689	6,083,816	5,967,566	6,699,893	7,407,393	8,908,155	9,279,206	10,284,374
Qikiqtani (Baffin) Region	11,972,289	13,128,633	14,777,233	15,818,958	15,669,847	15,150,144	14,563,143	18,057,900	19,088,634	19,988,955
Arctic Bay	946,637	875,973	898,267	919,351	970,816	1,005,668	1,022,548	1,397,914	1,404,244	1,422,737
Cape Dorset	1,483,489	1,566,777	1,765,083	2,034,427	1,965,517	1,997,287	1,876,529	2,277,087	2,320,004	2,400,131
Clyde River	1,124,505	1,151,524	1,138,643	1,059,309	1,214,047	1,123,671	1,122,486	1,577,959	1,761,825	1,802,656
Grise Fiord	61,643	86,455	93,930	83,827	60,208	75,330	56,667	67,432	48,272	89,589
Iqaluit	2,083,360	2,704,366	4,187,730	5,243,921	5,005,278	4,376,859	3,436,465	3,855,783	3,724,307	4,054,373
Kimmirut	308,681	490,001	676,841	673,106	699,716	611,285	595,768	690,455	835,728	621,020
Pangnirtung	1,065,122	1,071,163	1,000,609	969,487	813,009	890,900	1,023,508	1,286,456	1,448,463	1,564,324
Pond Inlet	1,093,073	1,297,151	1,168,868	1,161,131	1,308,732	1,275,899	1,269,602	1,508,443	1,825,315	1,951,053
Qikiqtarjuaq	546,085	439,226	534,761	523,489	591,707	528,621	593,353	782,699	821,025	815,532
Resolute Bay	98,817	98,122	98,900	102,932	66,312	80,035	91,201	107,158	56,262	63,421
Source: Adapted from Government of Nunavut (n.d.-a)										
Note: Igloolik and Sanikluaq were not included in this table, therefore total numbers for Nunavut may not be reflective of the numbers for communities presented in the table.										

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5.4 Contracting and Business Development

Contract opportunities and contracting awards have experienced an increase in Nunavut. In the most recent Contract Activity Report from the Government of Nunavut's Department of Community and Government Services (Government of Nunavut 2017f) for the 2015/2016 fiscal year, the total value of contracts awarded by the Government of Nunavut increased by 38% over 2014/2015. The value of contracts awarded to Inuit firms (i.e., a company at least 51% owned by Inuit and included on the Inuit Firm List) increased by 112%, while the value awarded to Nunavut firms (i.e., a company located in Nunavut and at least 51% owned by residents and included on the Government of Nunavut's Registry of Approved Businesses) decreased by approximately 2%.

In terms of the volume of contracts, the number of contracts awarded in 2015/2016 decreased by approximately 1% from the 2014/2015 year. However, the total number of contracts awarded to Inuit businesses increased by 10%, and the number awarded to Nunavut businesses increased by 66%, respectively (Government of Nunavut 2017f).

The report found that sole source contracts between $25,000 and $100,000 are awarded in a large majority to other companies (i.e., non-Inuit and non-Nunavut businesses). Most these contracts are service contracts and are typically specialized services that are generally not available in Nunavut. Inuit and Nunavut businesses typically win contract work for major and minor construction projects, maintenance services, air charters, and purchase orders. Other firms are historically more successful at winning bids related to architectural / engineering work, service contracts, and consulting services (Government of Nunavut 2017f).

Other developments within the Qikiqtani Region have also provided contracting opportunities. In 2016, Baffinland awarded nine contracts for its Mary River Iron Ore Project, worth approximately $64.4 million to Inuit-owned businesses and joint ventures and, since project development began, a total of $431.9 million in contracts have been awarded to Inuit-owned businesses and joint ventures (Jason Prno Consulting Services Ltd. 2017).

5.5 Education and training

Education and training is commonly cited as one of the critical factors influencing improved economic and social development in modern society (Southcott 2015b). A high school diploma is starting to become a basic requirement for getting a job in Nunavut's developing wage economy (Government of Nunavut 2017a). Table 5.27 below provides a brief overview of the educational levels of residents over the age of 15, in both the Qikiqtani Region and for Nunavut as whole. Within both geographic areas, a large percentage of residents do not have a high school diploma or post-secondary education. However, the Qikiqtani Region does have a much higher percentage of residents that have attained an apprenticeship, trades certificate, or diploma compared with Nunavut as a whole. The Qikiqtani Region also possesses a higher percentage of residents with a high school diploma, non-university certificates / diplomas, and a university certificate, diploma, or degree at the bachelor level or higher.

Table 5.27 Educational Attainment, Nunavut and the Qikiqtani Region—2016

Certificate Level	Qikiqtani Region		Nunavut	
	Persons	**Percent**	**Persons**	**Percent**
Population	12,840	100	23,935	100
No certificate, diploma or degree	5,905	46.0	12,140	50.7
Secondary (high) school diploma or equivalency certificate	2,095	16.3	3,615	15.1
Apprenticeship or trades certificate or diploma	825	6.4	1,840	0.8
College, CEGEP or other non-university certificate or diploma	2,135	16.6	3,580	15.0
University certificate or diploma below bachelor level	130	1.0	215	0.9
University certificate, diploma or degree at bachelor level or above	1,755	13.7	2,545	10.6
Total population	12,840	100.0	23,935	100.0
NOTE: Data is presented for persons aged 15 years and older (aligns with statistics on labour force status)				
SOURCE: Statistics Canada (2017)				

A guide provided by the Government of Nunavut's Department of Family Services helps provide information on the most relevant or in-demand occupations in Nunavut, and what the educational requirements of these positions are to obtain them. Table 5.28 below illustrates the positions listed in the most recent publication of this guide.

Table 5.28 In-Demand Occupations in Nunavut and Educational Requirements, 2016/2017

Occupation	Industry / Sector	Educational Requirement
Senior government Managers and Officials	Management	College Diploma or University Degree
Facility Operation and Maintenance Managers	Management	College Diploma or University Degree
School Principals and Administrators of Elementary and Secondary Education	Management	Bachelor of Education
Managers in Social, Community, and Correctional Services	Management	College Diploma or University Degree
Construction Managers	Management	College Diploma or University Degree
Financial Managers	Management	College Diploma or University Degree
Human Resources Professionals	Business, Finance, and Administration	College Diploma or University Degree
Bookkeepers	Business, Finance, and Administration	College Diploma or University Degree
Accounting Clerks	Business, Finance, and Administration	Secondary School Diploma
Other Financial Officers	Business, Finance, and Administration	College Diploma or University Degree
Administrative Officers	Business, Finance, and Administration	Secondary School Diploma
Administrative Assistants	Business, Finance, and Administration	Secondary School Diploma
Property Administrators	Business, Finance, and Administration	Secondary School Diploma
Shippers and Receivers	Business, Finance, and Administration	Secondary School Diploma
Conservation and fisheries Officers	Natural and Applied Sciences	College Diploma or University Degree
Registered Nurses	Healthcare	Registered Nursing Program
Social and Community Services Workers	Education, Law, Social, Community, and Government Services	Diploma or Degree in Social Work
College and other Vocational Instructors	Education, Law, Social, Community, and Government Services	College Diploma or University Degree
Elementary and Secondary School Teachers	Education, Law, Social, Community, and Government Services	Bachelor of Education
Early Childhood Educators and Assistants	Education, Law, Social, Community, and Government Services	College Diploma or University Degree
Elementary and Secondary School Teacher Assistants	Education, Law, Social, Community, and Government Services	Secondary School Diploma

Table 5.28 In-Demand Occupations in Nunavut and Educational Requirements, 2016/2017

Occupation	Industry / Sector	Educational Requirement
Home Support Workers, Housekeepers, and Related Occupations	Education, Law, Social, Community, and Government Services	Secondary School Diploma
Janitors, Caretakers, and Building Superintendents	Sales and Service	Secondary School Diploma
Plumbers	Trades, Transport, and Equipment Operators	Secondary School Diploma
Carpenters	Operators	Secondary School Diploma
Electricians	Operators	Secondary School Diploma
Transport Truck Drivers	Operators	Secondary School Diploma
Heavy Equipment Operators	Operators	Secondary School Diploma
Public Workers and Maintenance Labourers	Operators	Secondary School Diploma
Material Handlers	Operators	Secondary School Diploma
Taxi Drivers and Chauffeurs	Operators	Secondary School Diploma
SOURCE: Government of Nunavut (2017a)		

5.5.1 Early Childhood Education

Early childcare and education programs are important to families, including those in Nunavut, who want to provide optimal conditions for the early development of their children. Table 5.29 below illustrates early childcare centres within the Qikiqtani Region. Most of these centres are located in Iqaluit. The 2013/2014 Annual Report from the Government of Nunavut's Department of Education also noted that the primary language used in early childcare centres was Inuktitut at approximately 58%. English was the second most common language used, at 32% (Government of Nunavut Department of Education 2014).

Table 5.29 Early Childcare Centres within the Qikiqtani Region

Location	Early Childcare Centre
Arctic Bay	Aboriginal Head Start
Cape Dorset	Saipaaqvik Day Care
Clyde River	Daycare and Pre-School
	Ilisaqsivik Afterschool Program
Grise Fiord	Saimavik Day Care
Iqaluit	Ecole des Trois Soleils–Service de Garde
	Ecole des Trois Soleils–Service de Garde 2
	Ecole des Trois Soleils–Francisation
	First Steps Daycare
	Centre De La Petit Enfance Les Petits Nanooks
	Inuksuk Infant Development Centre
	Iqaluit Inuktitut Daycare–Tumikuluit Saipaaqivik
	Iqaluralaaq Pairivik (Little Fish Daycare)
	Joamie Afterschool Program
	Kids on the Beach Daycare
	Kids on the Beach Daycare–519
	Pairivik Childcare Society–daycare
	Pairivik Childcare Society–Afterschool
	Tasiuqtigiit Preschool Program
	Tasiuqtigiit Afterschool Program
Kimmirut	Kimmirut Pairivik Daycare
Pangnitrung	Mianiqsivik Pairivik
	Attagoyuk Illisavik Daycare
Pond Inlet	Naurainnuk Day Care
	Nassivik Highschool Daycare
Qikiqtarjuaq	N/A
Resolute Bay	Qarmartalik School Early Childhood Readiness Program
SOURCE: Government of Nunavut - Department of Education (2011)	

5.5.2 Public School

Currently in Nunavut, there are 43 public schools in 25 communities offering education from kindergarten through to the grade twelve (Nunavut Teachers Induction Program n.d.). Within the Qikiqtani Region, there are 22 public schools These schools are presented in Table 5.30 below.

Table 5.30 List of Public Schools in Nunavut, Baffin Region

Community	School	Grades
Arctic Bay	Inuujaq School	K-12
Cape Dorset	Peter Pitseolak High School	7-12
	Sam Pudlat Elementary School	K-6
Clyde River	Quluaq School	K-12
Grise Fiord	Umimmak School	K-12
Hall Beach	Arnaqjuaq School	K-12
Igloolik	Ataguttaaluk Elementary School	K-7
Iqaluit	Nanook Elementary School	K-5
	Nakasuk Elementary School	K-5
	Joamie Elementary School	K- 5
	Inuksuk High School	9-12
	Aqsarniit Middle School	6-8
	École des Trois-Soleils	K-9 (10-12 at Inuksuk High School)
Kimmirut	Qaqqalik School	K-12
Pangnirtung	Alookie Elementary School	K-5
	Attagoyuk High School	6-12
Pond Inlet	Ulaajuk School	K-6
	Nasivvik High School	7-12
Qikiqtarjuaq	Inuksuit School	K-12
Resolute Bay	Qarmartalik School	K-12
Sanikiluaq	Nuiyak Elementary School	K-6
	Paatsaali High School	7-12
SOURCE: Nunavut Teachers Induction Program (n.d.)		

Qikiqtani School Operations (QSO) is one of three Regional School Operations in Nunavut. The QSO supervises and administers activities for the 22 public schools in the Qikiqtani Region, offering kindergarten through grade 12 programs. The main office for the QSO is in Pond Inlet.

In 2015, there were 4,323 full-time equivalent students enrolled in public schools in the Qikiqtani Region, representing an increase of 0.8% over 2014. There were 313.5 full-time equivalent teachers at Qikiqtani Region schools in 2015, giving a teacher/student ratio of 1:13.8 (Government of Nunavut n.d.-a; Nunavut Teachers Induction Program n.d.).

In terms of public school attendance rates, there has been a general increase over the years. During the 2013–2014 academic year (the most recent year for which information is available), public school attendance in the Qikiqtani Region was 78.3%. This was an increase of 5.2% from the 2011–2012 academic year. Statistics were not recorded for the 2012–2013 academic year (Government of Nunavut n.d.-a).

5.5.3 Post-Secondary Education

While education levels are low across the Area of Focus, many residents of the Qikiqtani Region have been engaged in training and upgrading through the local college system and through various specialized programs. Post-secondary education in Nunavut is provided through Nunavut Arctic College, which has five campuses, including Piqqusilirivvik in Clyde River and the Nunavut Research Institute Science Campus in Iqaluit. The College has Community Learning Centres in all 25 communities of Nunavut and each one is staffed by an Adult Educator. The College offers a variety of trades, certificate and diploma, degree, and non-certificate/diploma programs (Nunavut Arctic College 2016a).

Between 1,200 and 1,350 Nunavummiut enroll in full-time programs at the college. This equates to roughly one-quarter of the population between 20 and 29 years of age, or one fifth of the 20- to 34-year-old age group. In 2016, full-time enrollment at Nunavut Arctic College's five campuses was 1,386, up from 1,326 in 2015 (Nunavut Arctic College 2016b).

While higher levels of education are possible for Nunavummiut, financial and other barriers remain a challenge for many of those wishing to enroll and undertake additional training and education opportunities. The Government of Nunavut has several initiatives to assist students with post-secondary education and training.

The Nunavut Adult Learning Strategy supports and provides adult learners with training, education, and tools needed to actively participate in the further development of Nunavut (Government of Nunavut: Department of Education n.d.). This includes initiatives to help raise literacy levels in Nunavut, as well as provide the required training needed for Nunavut residents to take advantage of future economic opportunities that may arise and build capacity in Nunavut to fill employment opportunities with Nunavut residents. The Pathway to Adult Secondary School program, helps provide Nunavut residents who never completed their high school diploma the training and education needed to achieve it. The Pathway to Adult Secondary School program is a partnership between the Government of Nunavut, the Arctic College, and the Alberta Distance Learning Centre. The Arctic College provides space, equipment, and training facilitators to provide students in the program with the tools needed to achieve their high school diploma, and potentially move on to post-secondary education (Government of Nunavut: Department of Education n.d.).

Financial assistance for Nunavummiut to attend post- secondary institutions and training is available under the Government of Nunavut's Financial Assistance for Nunavut Student program. Scholarships also are available from the Government of Nunavut, and through partnerships with private industry and educational facilities for students in high school and post-secondary programs.

The Government of Nunavut's Department of Family Services provides training initiatives and funding for Inuit residents looking to advance their skills and education in preparation for the workforce. The Getting Ready for Employment and Training program is a 14-week program targeted towards Nunavut residents to assist them on making a successful entry back into the workforce. This includes, but is not limited to, a portfolio development, introduction to computers and basic computer skills, interview skills, and workplace ethics (Government of Nunavut n.d.-b).

The Adult Learning and Training Supports program is designed to help provide funding to applicants who are currently undertaking additional education or training programs. This would include things such as apprenticeship training, pre-trades training, and workplace training (Government of Nunavut n.d.-b).

The Targeted Training Initiatives program is another program from the Department of Family Services that helps enable Nunavut-based training and education for occupations that either are or will be in demand in the future (Government of Nunavut n.d.-b). Up to a year of funding may be provided to eligible employers.

5.6 Health and Wellbeing

5.6.1 Perceived Well-being

Table 5.31 provides the results from a survey by a partnership between Statistics Canada and the Canadian Institute for Health Information to provide a general overview into the perceived health and well-being of residents ages 12 and over within Nunavut. While the survey does not provide information specific to the Qikiqtani Region, the results provide a general overview of Nunavut's health indicators compared with those for the rest of Canada.

Overall, residents of Nunavut reported a higher overall sense of belonging to their local community and area than the Canadian average. This can likely be attributed to the strong connection that Inuit of Nunavut have with their land and their traditional way of life. Perceived life stress from individuals 15 years and older in Nunavut was lower than the Canadian average, and life satisfaction levels, although lower in Nunavut, were still close to the Canadian average.

However, perceived health condition (very good or excellent) was reported to be much lower in Nunavut than in the rest of the Canada. Smoking rate averages were higher (over double) in Nunavut than the Canadian average. This may account in part for the higher levels of chronic obstructive pulmonary disease and the higher rates of certain types of cancer in Nunavut (Government of Nunavut: Department of Health 2016). Access to a regular doctor was also reported at lower levels in Nunavut compared to Canada, with the average percentage of residents who had met with a physician in the last 12 months lower than the Canadian average. The average rate reported for the consumption of fruits and vegetables was lower in Nunavut than in other parts of Canada, which may be attributed to the high cost of fruits and vegetables relative to the income levels for individuals in the area.

Table 5.31 Nunavut Health Indicator Profile, Nunavut and Canada, 2010 to 2014

Indicators	Year									
	2010		2011		2012		2013		2014	
	Nunavut	Canada	Nunavut	Canada	Nunavut	Canada	Nunavut	Canada	Nunavut	Canada
Perceived health, very good or excellent	45.9	61.9	42.7	61.6	42.2	61.9	35.7	61.3	35.7	60.9
Perceived health, fair or poor	12.7^{E}	10.3	16.8	10.3	17.8	9.7	17.5	9.7	F	10.2
Perceived mental health, very good or excellent	70.2	74.4	50.9	73.1	57.6	72.2	55.0	71.6	56.0	71.5
Perceived mental health, fair or poor	F	5.1	4.2^{E}	5.4	12.3^{E}	5.6	5.1^{E}	6.1	F	6.3
Life satisfaction, satisfied or very satisfied	92.2	92.6	91.3	92.9	84.1	93	87.1	92.4	87.2	92.8
Perceived life stress, quite a lot (15 years and over)	16.7^{E}	23.5	23.4	23.9	19.2	23	16.5^{E}	23.3	17.7	23.5
Arthritis	16.5^{E}	13.6	12.1^{E}	14.2	14.8^{E}	12.7	14.0^{E}	13	16.6^{E}	13.3
Diabetes	F	5.4	F	5.1	F	5.2	F	5.3	F	5.2
Asthma	F	8.6	6.3^{E}	8.8	3.5^{E}	8.3	8.5^{E}	8.1	6.7^{E}	8.2
High blood pressure	10.0^{E}	14.2	19.6	14.4	17.7	14	16.6^{E}	14.1	12.6^{E}	13.9
Pain or discomfort by severity, moderate or severe	9.1^{E}	10.6	7.6^{E}	12.6	15.7	12.7	10.3^{E}	12.2	12.8	12.4
Pain or discomfort that prevents activities	11.7	11.4	12.1^{E}	13.3	19.4	13.4	11.5^{E}	13.2	17.0^{E}	13.4
Participation and activity limitation, sometimes or often	30.1	26.1	24.2	..	41.7	30.9	26.3	29.2	32.7	29.9
Current smoker, daily or occasional	51.9	21.1	55.2	20.4	51.5	20.6	57.1	19.6	58.1	18.5
Exposure to second-hand smoke at home	F	6.0	F	5.7	9.3^{E}	4.8	5.5^{E}	4.6	F	4.0
Exposure to second-hand smoke in the past month, in vehicles and/or public places	F	15.8	F	17.8	30.4^{E}	17.6	17.8^{E}	17.2	14.9^{E}	18.1
Heavy drinking	..	..	..	..	..	..	17.2^{E}	20.2	14.9^{E}	19.2
Fruit and vegetable consumption, 5 times or more per day	22.2	43.6	19.4	40.7	25.8	40.9	22.8	41.1	22.8	39.8

Table 5.31 Nunavut Health Indicator Profile, Nunavut and Canada, 2010 to 2014

Indicators	Year									
	2010		2011		2012		2013		2014	
	Nunavut	Canada	Nunavut	Canada	Nunavut	Canada	Nunavut	Canada	Nunavut	Canada
Physical activity during leisure-time, moderately active or active	44.2	53.1	33.2	54.8	47.5	54.7	43.5	56.3	36.9	54.6
Physical activity during leisure-time, inactive	55.8	46.9	66.8	45.2	52.5	45.3	56.5	43.7	63.1	45.4
Body mass index, self-reported, adult (18 years and over), overweight or obese	63.1	50.6	63.6	50.4	52.7	50.7	60.0	51.7	50.8	52.1
Sense of belonging to local community, somewhat strong or very strong	88.4	64.9	83.5	64.3	85.5	65.5	86.1	65.2	86.4	65.6
Has a regular medical doctor	16.6[E]	83.1	21.0	83.1	18.8	83.5	15.7[E]	82.8	20.1	83.3
Contact with a medical doctor in the past 12 months	55.5	79.3	..	..	63.5	77.1	54.0	76.9	49.2	77.1
Influenza immunization, less than one year ago	52.7	23.5	45.6	27.9	31.2	26.4	33.4	26.6	39.6	29.5
Breastfeeding initiation	61.3[E]	87.1	79.7	88.2	83.5	90.3	70.2	..	77.4	..
Exclusive breastfeeding, at least 6 months	F	27.9	34.4[E]	28	F	24.4	31.2[E]	..	F	..
Mood disorder	5.7[E]	6.4	F	6.8	5.8[E]	6.9	F	7.5	F	7.6
Injuries in the past 12 months causing limitation of normal activities	18.6[E]	15.7	..	..	..	..	12.9	16.9	9.2[E]	16.4
Chronic obstructive pulmonary disease (COPD)	F	4.1	F	3.8	F	3.9	F	4.0	F	3.6

NOTES:
F = data is too unreliable to be published
[E] = there is a level of uncertainty with data. Use with caution

SOURCE: Statistics Canada (n.d.)

The percentage of residents in Nunavut reporting poor mental health was higher than the rest of Canada, and those reporting good or excellent mental health was lower (see Table 5.31).

Table 5.32 illustrates the leading causes of death within Nunavut. According to the most recent information available (2013); external causes of mortality were the highest cause of death (31.4%) among Nunavut residents. Of the 61 external causes of death in 2013, 41 (67.2%) were suicides.

Table 5.32 Nunavut Leading Causes of Death—2009 to 2013

Causes of Death	Total Causes of Death				
	2009	**2010**	**2011**	**2012**	**2013**
Certain Infectious and Parasitic Diseases	3	2	4	0	2
Neoplasms	43	26	43	40	40
Diseases of the Blood	2	0	0	0	0
Endocrine, Nutritional and Metabolic Diseases	0	2	1	2	2
Diseases of the Nervous System	0	0	3	0	4
Diseases of the Circulatory System	14	16	19	21	30
Diseases of the Respiratory System	16	14	15	14	13
Diseases of the Digestive System	3	1	0	0	0
Diseases of the Genitourinary System	3	2	0	3	4
Certain Conditions Originating in the Perinatal Period	6	4	9	9	7
Congenital Malformations, Deformations and Chromosomal Abnormalities	4	1	6	3	2
External Cause of Morbidity and Mortality	42	37	42	47	61
Accidents	18	11	13	21	16
Suicides	21	23	23	24	41
Other External Causes	3	3	6	2	4
Other Causes of Death	26	27	29	22	29
Total	**162**	**132**	**171**	**161**	**194**
SOURCE: Government of Nunavut (2017e)					

Table 5.33 illustrates the suicide rate in Nunavut by age group. Between 2012 and 2016, the highest percentages of suicides occurred with individuals ages 30 and under. During 2016, 53.1% of all suicides occurred by individuals between the ages of 20 and 29. Within the different geographic regions, the highest proportion of suicides has historically been within the Qikiqtani Region (see Table 5.34). Historically, the highest percentage of suicide deaths occurred in Inuit men (Government of Nunavut n.d.-a).

Table 5.33 Nunavut Suicide Percentage by age group, 2012 to 2016

Age Range	Year				
	2012	2013	2014	2015	2016
Under 20	40.7	24.4	39.3	31.3	25.0
20 to 29	37.0	44.4	28.6	31.3	53.1
30 to 39	14.8	17.8	14.3	18.8	12.5
40 to 49	3.7	6.7	14.3	9.4	9.4
50 and over	3.7	6.7	3.6	9.4	0.0
Total	100	100	100	100	100
SOURCE: Government of Nunavut (n.d.-a)					

Table 5.34 Nunavut Suicide Rates by Region

Location	Year				
	2012	2013	2014	2015	2016
Nunavut	27	45	28	32	32
Qikiqtani Region	16	26	18	16	18
Kivalliq (Keewatin)	8	12	7	9	8
Kitikmeot	3	7	3	7	6
SOURCE: Government of Nunavut (n.d.-a)					

5.6.1.1 Indicators and determinants of health and well-being

Well-being, and perceived well-being, can be influenced by several social and economic factors, and the sense of well-being is linked to the demographic and economic setting that an individual is living in. For example, the birth rate among teenagers and young women in Nunavut between 2002 and 2011 was higher than the rest of Canada (Government of Nunavut: Department of Health 2016). This increased birth rate can potentially affect the perceived well-being of mothers if it impacts their ability to obtain further education, which can then translate into impacts on children's well-being. Below are some indicators that have been highlighted as linkage with perceived mental, physical, and psychological well-being.

EDUCATION AND EMPLOYMENT

Education is something that is needed to successfully obtain employment in the growing wage economy in Nunavut. This includes aspects such as literacy and numeracy skills. Education is associated with employment and income security, which can help provide individuals with a greater sense of control over their own life, and the pride or confidence that they will be able to provide for their family (National Collaborating Centre for Aboriginal Health 2017). It can help contribute to a better sense of overall wellbeing and mental health. According to the 2013 Programme for the International Assessment of Adult Competencies, adults in Nunavut had the lowest rates of literacy and numeracy in the country (Government of Nunavut: Department of Health 2016). The percentage of residents in Nunavut and the Qikiqtani Region that had no certificate, diploma or degree, were also high (see Table 5.34), and well above the Canadian average of 18.3% (Statistics Canada 2017). The lack of these skills may make it difficult for Nunavut residents to find work in the growing wage economy, which can further affect their physical and mental health if they feel they are not able to provide for themselves or their families.

HOUSING

A person's living arrangement can also influence their mental and physical well-being. According to the Nunavut Housing Needs survey in 2009/2010, approximately 20% of occupied dwellings in the Qikiqtani Region were classified as needing major repairs, while approximately 30% of dwellings were considered overcrowded. Within these crowded dwellings, approximately half of respondents indicated that they regularly used the living room for sleeping (Nunavut 2011). Approximately 44% of occupied dwellings were classified as below housing standards, with public housing having the highest proportion at 59% (Nunavut 2011). This issue of housing condition can partially explain the high level of renovations that make up the majority of value for residential housing construction (see Table 5.22).

The lack of suitable housing and overcrowding of homes can have a negative effect on both the physical and mental health of residents. Living in crowded conditions takes a toll on health in many ways. Most problems reported in overcrowding housing is individuals not having time alone, noisy conditions, trouble sleeping, and a higher prevalence of anger in homes. All of these issues have the potential to affect mental, physical, and psychological well-being (Minich et al. 2011).

EMPLOYMENT

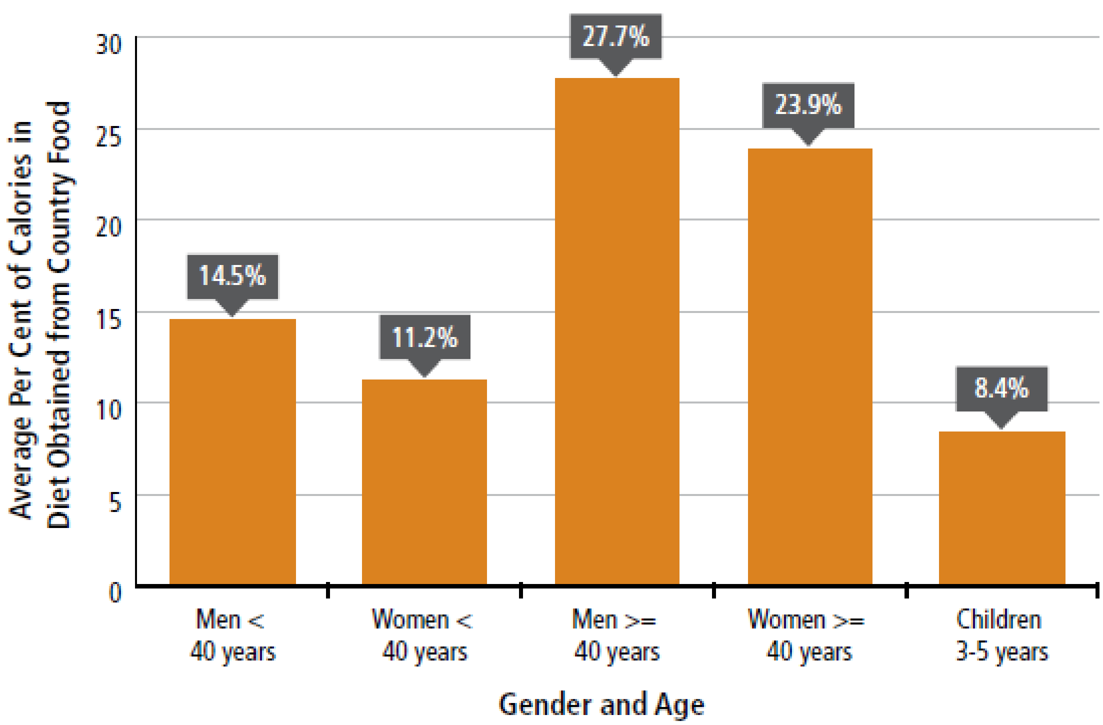
Employment, and job satisfaction can be a determinant of perceived health and well-being and has been linked to mental health (Government of Nunavut: Department of Health 2016). Employment provides a sense of purpose and accomplishment for individuals, and a source of income for individuals to support themselves and their families, including providing the means to purchase supplies and equipment to participate in traditional hunting activities. If individuals feel they cannot support themselves or their families, the inability to obtain employment in the wage-based or traditional economy can have adverse implications on mental health and confidence. Section 5.3 and 5.5 discuss both the existing conditions of employment and education in Nunavut and the Qikiqtani Region. Nunavut's lower literacy and numeracy rates, lower educational achievement levels, and higher rates of unemployment all play a role in the perceived health and well-being of residents.

5.6.2 Nutrition and Nutritional Requirements

5.6.2.1 Country Foods

Hunting, harvesting, and sharing of traditional / country foods plays an essential role in Nunavut society, and is an important component of the economy. Country food harvesting also is of cultural importance to Inuit. Despite the presence of market food in the contemporary northern diet, country food is central to the identity and well-being of Inuit.

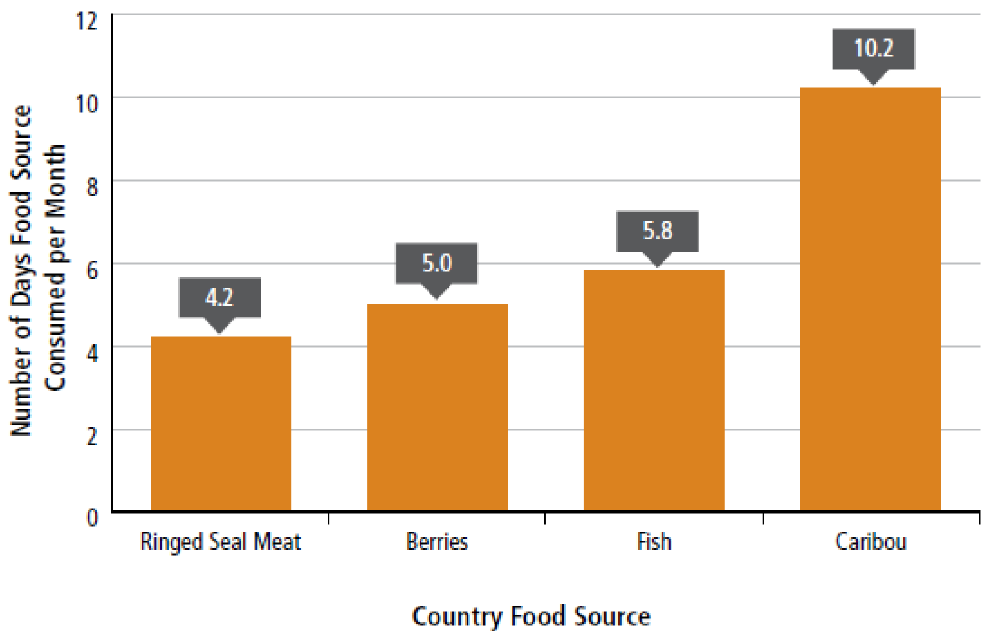
Rates of country food consumption vary according to a wide variety of factors, including age, gender, level of education, community size and region (Council of Canadian Academies 2014). For example, the International Polar Year (IPY) Health Survey (2007-2008) indicated that women in Nunavut consume less country food than men (Council of Canadian Academies 2014). Older adults derived more calories from country food than did younger adults, and children's diets had the lowest percentage of calories from country food sources (Council of Canadian Academies 2014). Figure 5.4 below illustrates the rate of country food consumption among Inuit adult men, women, and children in Nunavut.



SOURCE: Council of Canadian Academies (2014)

Figure 5.4 Percentage of Calories Inuit Men, Women, and Children Derived from Country Food in Nunavut

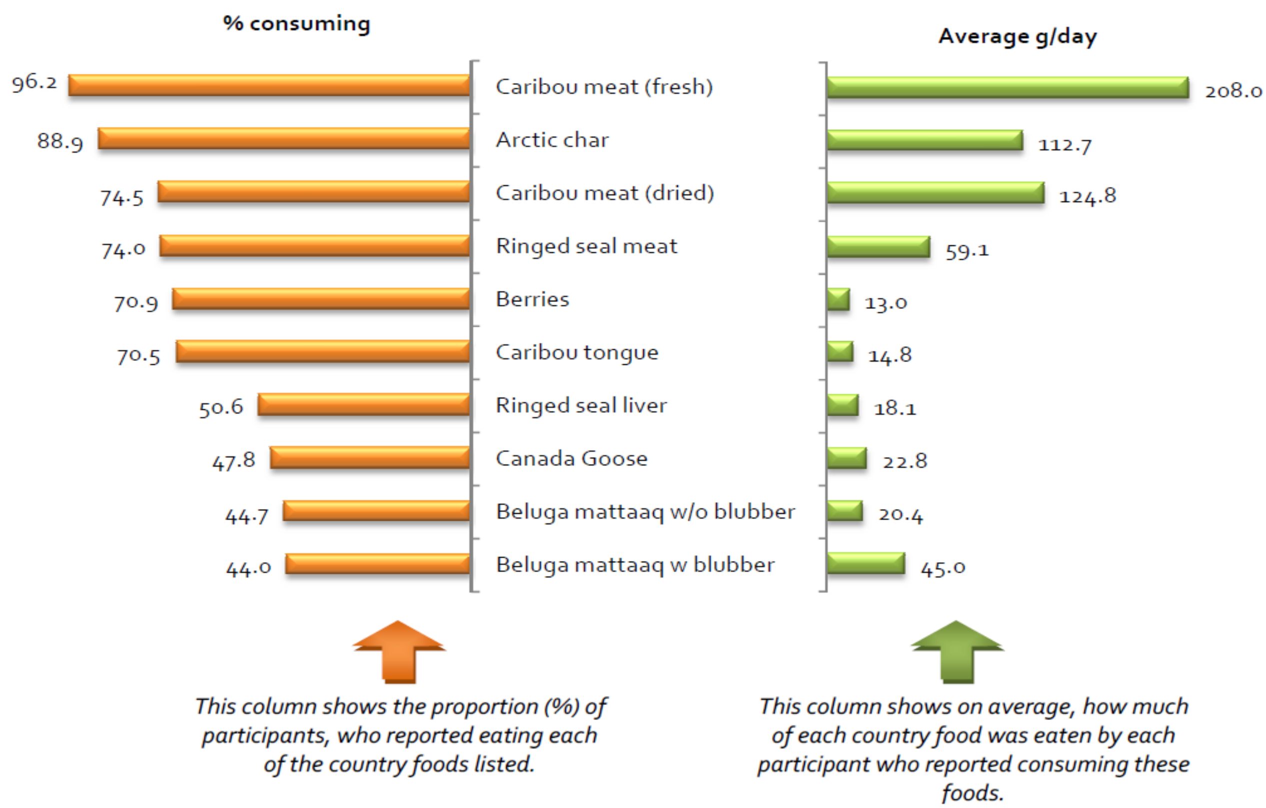
Inuit children are eating country food; however, only 8.4% of calorie intake among Nunavut's children came from country food in 2007–2008 (Council of Canadian Academies 2014). The Nunavut Inuit Child Health Survey, 2007–2008 revealed that nearly all children (99%) ate country food in the month prior to the survey, and about one-third (33%) ate country food an average of 30 times or more during the same period (Council of Canadian Academies 2014) (Figure 5.5).



SOURCE: Council of Canadian Academies (2014)

Figure 5.5 Average Number of Days Inuit Children in Nunavut Consumed Country Food in One Month.

Across Nunavut, caribou meat and Arctic char were the most often consumed country food, and in the largest quantities (Council of Canadian Academies 2014) (Figure 5.6). Ringed seal meat was also eaten often, but in smaller quantities (Nunavut Steering Committee and the Centre for Indigenous Peoples' Nutrition and Environment 2010) (Figure 5.6). In addition, narwhal is found to be a key component of the harvest among households in Arctic Bay, Pond Inlet, and to a lesser degree, Clyde River (Nunavut Impact Review Board 2014).



SOURCE: Nunavut Steering Committee and the Centre for Indigenous Peoples' Nutrition and Environment (2010)

Figure 5.6 Most Commonly Consumed Country Food in Nunavut

Some limited research on nutrition in Nunavut households was carried out under the federal food mail program. In 1997, a study commissioned by INAC estimated that country food accounted for over half of the protein, and more than one-third of Vitamin A consumed by residents of Pont Inlet (Baffinland Iron Mines Corporation 2010). This source of nutrition also added only 6% of sodium and less than one-quarter of the saturated fat of local diets (Baffinland Iron Mines Corporation 2010).

The harvesting sector in Nunavut has thrived on the cultural strength of Inuit harvesting and food use traditions, rather than through the encouragement of subsidy programs. The primary causes limiting country food intake in Nunavut include not having an active hunter in the home; lack of access to transportation; unable to take time off wage-earning employment when animals are near communities and in season; and the high cost of gas and hunting and fishing supplies (Council of Canadian Academies 2014). Because harvesting is largely reliant on modern technologies involving snow machines, boats, fuel and ammunition, high costs associated with these harvesting inputs have continued to limit the ability of many Inuit harvesters to continue harvesting activities (Baffinland Iron Mines Corporation 2010). This has the potential to result in adverse changes in well-being, if Inuit feel they are not taking part in their traditional way of living.

As the food produced does not generally generate monetary returns to the harvesters, cash resources come largely from transfers from the wage economy (Baffinland Iron Mines Corporation 2010). This includes allocation for wages earned by family / extended family members toward harvest inputs, as well as the sale of seal skins through a territorial government program (Baffinland Iron Mines Corporation 2010).

5.6.2.2 Market Food

Market food is more expensive in northern communities than in southern Canada. The IPY Inuit Health Survey results from Nunavut found that the average monthly cost for groceries in Nunavut in 2007-2008 was $1,317 per month, or $19,760 per year (Council of Canadian Academies 2014). In comparison, the average Canadian household spent $609 per month in 2007 (Council of Canadian Academies 2014). The Revised Northern Food Basket, which comprises 67 standard market food items that would meet the recommended daily nutritional amounts in Canada's Food Guide for a family of four, cost, for the year 2010, a total of $398 a week in Iqaluit, $395 in Kimmirut, and $460 in Pangnirtung. The same items, for the same time period, cost $226 total in Ottawa (Council of Canadian Academies 2014; Government of Canada 2017a).

The shift to purchased food is particularly evident among younger generations, women and communities with more access to market foods (Council of Canadian Academies 2014). While food consumption and diet of Inuit residents still contains a balance of both country food and market food, commercially produced food has now become more prevalent in in these younger generations (Myers 2004).

5.6.2.3 Food Security

Food security is "when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (Statistics Canada 2014). Food insecurity is a well-documented contributing factor to poor health, as it is associated with restricted mobility, multiple chronic conditions, and depression and distress. Food insecurity is a growing challenge across Nunavut. Results from the 2007–2008 IPY Inuit Health Survey, revealed that Nunavut has the highest documented rate of food insecurity for any Indigenous population living in a developed country (Council of Canadian Academies 2014). In 2012, 56% of Inuit in Nunavut lived in households that experienced food insecurity (Statistics Canada 2014).

A variety of federal programs supplement income support benefits that provinces and territories provide to residents who require support. Since the early 1960s, the federal Government has subsidized food in northern communities through initiatives such as the Food Mail Program, which was later replaced by Nutrition North Canada in 2011. The objective of Nutrition North Canada is to help make perishable food more accessible and affordable to residents of isolated northern communities, particularly those without year-round road, rail or marine access (Indigenous and Northern Affairs Canada 2016). Nutrition North Canada directly subsidizes retailers, suppliers, and country-food processors who meet program requirements. These groups are then required to pass on the full amount of the subsidies to consumers (Indigenous and Northern Affairs Canada 2016).

Food security related to climate change has also been a documented concern in Nunavut. A study by Healey et al. (2011) highlighted aspects of climate change affecting food security, such as unpredictable weather patterns affecting the ability to successfully hunt; changes in ice levels affecting the ability to access wildlife; longer travel times to hunt and increased cost; and potential effects on species movements and migrations. These all can potentially affect the ability of Inuit residents to successfully harvest country foods which, in turn, can affect mental and physical well-being. There also is a cost implication if Inuit residents have to purchase more packaged food.

5.7 Community Infrastructure and Services

5.7.1 Transportation

5.7.1.1 Road Infrastructure

Nunavut does not have roads connecting any of its communities, and within communities, most roads are unpaved. In Iqaluit, there is one paved road. The Government of Nunavut is not considering development of any intercommunity or interjurisdictional roads in the Area of Focus.

5.7.1.2 Air Transportation

Air transportation is the primary method of travel in Nunavut. Only air transportation provides year-round access to all communities in Nunavut. Air transportation in Nunavut has developed rapidly, and most communities are served on a daily basis. Nunavut's airport system is centered on regional hubs, providing access to and from other jurisdictions. Regional hubs include Iqaluit, Rankin Inlet, and Cambridge Bay. Airports in these communities are configured for jet aircrafts such as the Boeing 737-200.

The Iqaluit Airport is 1 of 25 airports included in Canada's National Airport System, serving a vital role supporting air transportation in Nunavut, trans-Atlantic air navigation, polar routes and North American Air Defence (Government of Nunavut - Department of Economic Development and Transportation n.d.). The airport is an operational base for specialized activities such as medical evacuations, aerial surveillance, cold weather testing and military servicing and refueling (Government of Nunavut - Department of Economic Development and Transportation n.d.). Iqaluit is also connected to international destinations and includes a Canadian Border Services Agency.

After three years of construction at the Iqaluit International Airport, the $300 million project had resulted in construction of a new terminal, eight times the size of the original—large enough to serve Nunavut for the next 50 years (Canadian Broadcasting Corporation (CBC) 2017d). The new airport terminal officially opened in August 2017 (Canadian Broadcasting Corporation (CBC) 2017d).

The Nunavut Airports Division of the Government of Nunavut is responsible for the operation and maintenance of the 24 public airports outside Iqaluit. Within the Qikiqtani Region, these community airports are found in each of the potentially interested communities. Although each community has an airport, smaller communities are limited in the number and size of aircrafts they can accommodate.

Nunavummiut stated that changes in crosswinds may cause safety concerns, and alternative airstrips may be necessary (Nunavut Tunngavik Inc. 2005).

5.7.1.3 Marine Infrastructure

Marine infrastructure is limited throughout Nunavut. There are currently no deep-water ports in Nunavut. A small craft harbour is in Pangnirtung, constructed to provide protection for local vessels and the off-loading of fish destined for a local fish processing plant. The small craft harbour in Pangnirtung opened in 2013 and includes a fixed wharf, breakwater, and marshalling area. There is also a sea lift ramp and a dredged channel and basin. There is also a dock facility at Nanisivik which was constructed as part of a lead and zinc mine that closed in 2002; it is currently being upgraded as a seasonal naval refuelling facility (slated for completion in summer 2018) (Canadian Broadcasting Corporation (CBC) 2017b).

Limited marine infrastructure hinders the territory’s ability to expand its economy and strengthen its self-reliance. This situation has created delays in sealifts and hazards for small craft users as well as tourists (Mussels 2015). For example, community re-supply ships, unable to dock once they reach a community, must rely on barges to bring cargo to shore. Ice can also prevent barges from reaching the shore, where they are unloaded. In addition, tourism vessels must ferry visitors from larger ships to the shore. These situations can be dangerous and inefficient for boaters (Mussels 2015).

In March 2016, the Government of Nunavut agreed to provide $21 million to launch two new port projects in Nunavut, in addition to the $63.7 million funding commitment from the Government of Canada (Frizzell 2017). This investment will provide for the construction of a marine port and sea lift facilities in Iqaluit and a small craft harbour at Pond Inlet. Preliminary designs for the port in Iqaluit illustrate that the facility will allow for one ship to dock at the wharf, while a second can off-load using a barge-and-ramp method (Frizzell 2017). Construction of the two projects will start in the summer of 2018, with the marine port and sea lift facilities anticipated to be fully operational in 2020 (Frizzell 2017).

5.7.2 Waste Management

Municipalities are responsible for managing wastes within communities. Each community has their own solid waste disposal facility and sewage disposal system. Approximately half of all communities in Nunavut operate historical disposal facilities that were not initially designed by an engineer, with no supporting engineering designs or operation and maintenance plans for the facility (Giroux Environmental Consulting 2014). In addition, there are no municipal solid waste incinerators in Nunavut.

Some municipalities rely on the practice of open burning of solid waste. Open burning of garbage regularly takes place to increase space available at dumps, and disposal sites regularly spontaneously catch fire (Mussels 2015). For example, Iqaluit’s landfill, operating beyond its capacity, burned out of control for several months in the summer of 2014 (Mussels 2015). The city has announced plans to replace its landfill with a site 8.5 km from town. Nunavummiut Elders reported that permafrost is melting, which may have an effect on the infrastructure used to encapsulate waste (Nunavut Tunngavik Inc. 2005).

5.7.3 Potable Water and Waste Water

Municipalities are responsible for the delivery of water and sewage services in their respective communities and are accountable to residents for the quality and cost of water and sewage services. Each community has their own water supply and water treatment plant.

Source water used in Nunavut's municipal water systems is typically drawn from lakes or rivers and piped to a central holding reservoir where it undergoes chlorination treatment prior to delivery to residents for domestic use (Daley et al. 2014). Some homes in Nunavut have piped services; however, a trucked water delivery system is employed in most homes (Daley et al. 2014). This system involves tanker trucks delivering potable water to storage tanks inside homes each day. Water use in communities serviced by truck delivery systems is approximately three times lower than the Canadian national average (Daley et al. 2014).

Most communities in Nunavut use passive technologies to treat wastewater that require minimal operational, chemical, and energy inputs (Jamieson 2016). In most communities, wastewater is trucked to wastewater stabilization ponds or wetlands for treatment which can either be natural or engineered systems (Jamieson 2016). Wastewater stabilization ponds in Nunavut are designed as single-cell retention ponds with storage capacities to accommodate wastewater accumulated over a one-year period. Wastewater is stored for approximately nine months, with discharge typically occurring during the ice-free, summer months of July to September. Wastewater from homes is stored in tanks within the dwelling and pumped out by truck which delivers the wastewater to the retention pond.

In May 2017, the Nunavut Minister of Community and Government Services announced over $230 million in joint funding for 9 projects across 19 communities to upgrade solid waste management, and water and wastewater systems throughout the territory (Canadian Broadcasting Corporation (CBC) 2017e). The Government of Canada committed to providing over $30 million through the Clean Water and Wastewater Fund and over $100 million through the Small Communities Fund toward these projects (Canadian Broadcasting Corporation (CBC) 2017e). The Government of Nunavut will provide the remaining funding.

This investment is intended to support projects such as the design and construction of upgraded wastewater infrastructure in Kimmirut and upgrading existing landfills to improve waste management and recycling services in Grise Fiord (Canadian Broadcasting Corporation (CBC) 2017e). Once complete, these projects will better protect the environment by bringing wastewater treatment systems up to modern health and regulatory standards and improving the capacity to manage solid waste and recyclables.

5.7.4 Electricity

Qulliq Energy Corporation is the publicly owned utility which generates and distributes electrical power to consumers in each of Nunavut's communities. Qulliq Energy Corporation operates standalone diesel electric generators in each of the potentially interested communities.

5.8 Traditional Use and Practices

> Historically, the survival of the Inuit depended solely on the land and waters and the wildlife that they provide. The relationship between the Inuit and the land was one, like a newborn baby to her mother…It is evident that Inuit are still connected to their roots though. When the opportunity arises, Inuit leave their communities and live out on the land for a time. (Aglukark n.d.)

Connection to the land, its resources, and the environment is essential for the maintenance of traditional use and practices for the residents of communities in the Area of Focus. This section will discuss traditional practices, hunting, historical and current techniques, resource use, ancestral sites and travelways, cultural transmission, as well as current trends affecting traditional use and practices related to resources available in the Area of Focus.

5.8.1 Traditional Harvesting Practices

Inuit Qaujimaningit holds that wildlife populations will remain healthy and abundant if harvested and treated with respect. Disrespect during harvesting or not harvesting (a sign of disrespect) may result in population declines, or disappearance of a species all together. Offensive practices include arguing or fighting over wildlife, talking badly about wildlife, mistreatment and/or abuse of wildlife, and allowing wildlife to suffer; such practices may lead to a decline in animal populations (NWMB 2000).

> …We used to be told that if we fight over certain animals and talk about animals in a derogatory way, that the animal that we hunted would no longer be around, or there would not be enough to hunt any more…(Nutaralak, L. 2000 [Qkikqtarjuaq] as cited in NWMB 2000)

Respect for animals manifests in multiple ways, including harvesting, limiting harvesting to only what was needed, and sharing.

> Back then the law was not to waste food, and to never leave the meat behind, but they used to leave meat behind to be picked up on a later date. We would cache the meat when we were leaving it behind even in the spring time. The dogs can usually eat aged meat, so that is how we saved the meat for dog food… They cached most of it, even the part that is not too good to eat, for human and dog use later on, the bowhead whale meat was never thrown away (Nutaraaluk, L. 2000 [Iqaluit] as cited in NWMB 2000).
>
> Traditionally, all parts of an animal were used, for consumption, and everyday items ranging from lamp oil to sled runners (Nunavut Wildlife Management Board (NWMB) 1998; NWMB 2000): The blubber of the bowhead whale is very excellent. If we were to go out on the land and build two igloos, and my igloo had seal oil for my lamp, and your igloo had bowhead oil for your lamp, in the morning when we start to get ready to go again on our trip my igloo would have blackened snow. Your igloo would remain pure white. This is the reason why the oil from the bowhead is an excellent oil. As long as the

> lamp is lit properly smoke will not rise from the oil lamp of a bowhead whale. The light also is very high (Awa, M. 2000:52, as cited in NWMB 2000).

Fat from the lower jaw bone was also used to oil rifles; throat cartilage was used to make whistles; and blubber was used as fuel for stoves and mixed with gasoline to run motors (Nunavut Wildlife Management Board (NWMB) 1998).

Philip Qamarnirq of Arctic Bay explained that harpoons were constructed of local resources: "the harpoon head would be made out of caribou antler or walrus tusk or narwhal tusk, and the sharp part of the harpoon head would be made out of stone, this is how it used to be" (Qamanirq 2000:53, as cited in NWMB 2000). Lazarus Aola indicated that "suggaq (baleen) used to have significant uses and it was used for ties (for harpoons, drags, and floats) and other hunting equipment. The jawbones were used for the sled runners …The ribs were used for the structure of sod houses and tents. The meat was also used by humans and dog teams" (Aola, 2000:52, as cited in NWMB 2000). P. Angmarlik states that "the bones were also very useful. They were utilized to make various tools such as the ulu (semi-circular woman's knife), scraper, scraping platform and skin softener (Angmarlik, P. 2000:52 [Pangnirtung] as cited in NWMB 2000). Fox bait was also made from butchered bones or eaten by the Inuit in times of scarcity (Nunavut Wildlife Management Board (NWMB) 1998).

Making sled runners from bowhead bones was preferable to sled runners made of plastic, which tends to wear out quickly (John Tongak). (Tongak, J. 2000, as cited in NWMB 2000). Whale bones, especially elements that are large such as the head could also be used by carvers, after they had dried for a few years (Nunavut Wildlife Management Board (NWMB) 1998; Ezekial, A. and Tongak, J. as cited in NWMB 2000).

A strip of muktuk was cut from head to the back, creating flexible, strong rope. This strip could be fashioned into rope for luring seal pups, made into the base of whips, as well as the "Sulujaq" (thin end of the whip), or simply manufactured into an all-purpose rope (Nunavut Wildlife Management Board (NWMB) 1998). Tendons could be used to make thread, and the skin was used to manufacture the base of whip handles. Sinew selected from specific parts of the beluga were used for certain types of women's work (NWMB 2000). Rope was fashioned by cutting the top part of the muktuk (Nunavut Wildlife Management Board (NWMB) 1998). This rope, which would turn white with use, and not freeze, was used to lure seal pup's mothers to the hole. Nauja Tassugat of Clyde River indicated "that baleen could be used to tie up husky dog booties in the spring" (Tassugat, N. as cited in NWMB 2000). Baleen was used to make harpoon lines, drags, and floats, and baleen ties were used to secure kayak frames and dog sleds (NWMB 2000). Floats, such as the commonly used avataq, could be made of baleen or sealskin, and were used as markers or to slow down bowhead whales during harvest (NWMB 2000). P. Kooneeliusie (as cited in NWMB 2000) notes that the "avataq was made of sealskin [usually from a yearling seal] and was attached to the harpoon line. The line was short so the float would not reach the tail."

In the past, whale stomach was boiled and considered a delicacy, while meat was turned into jerky or used for dog food (Nunavut Wildlife Management Board (NWMB) 1998). Pangnirtung Elders noted that useable meat cuts, including those parts considered a delicacy or useable for traditional tool making such as sinew, were removed with care, with the remaining meat used mostly as dog food (NWMB 2000). Meat was also fermented: “when it [aged meat] looks really yucky, when it starts to seep old blood and oil, that’s when it tastes the best” (Qappik, M. as cited in NWMB 2000). One Elder described the process for fermentation:

> In order to age the meat, it was stored in a closed seal bag which was left in a cache for several months. …By storing it [bowhead maktak and meat] into these [seal] skins they [Inuit] would age the meat and make it fermented. When the people would come and get the meat out of the skin bags, they would say that it looked very much like cooked meat being taken out of the pot, and they say this makes very good food and very good meat. (Nutaralak, L. as cited in NWMB 2000)

Meat was also cached: “We would cache the meat when we were leaving it behind even in the spring time. The dogs can usually eat aged meat, so that is how we saved the meat for dog food“ (Nutaraaluk, L. [Iqaluit] as cited in NWMB 2000). Most of the animal was used. Of the bowhead whale, for example, the only parts not consumed or used were the kidneys, the anal passage, and the front part of the whale head, which would cause dizziness and sickness in both people and dogs (Nunavut Wildlife Management Board (NWMB) 1998; Nutaraaluk, L. [Iqaluit], as cited in NWMB 2000).

Adherence to Inuit laws and understanding animal behaviour are required for a successful harvest. During the summer months, Inuit hunters used kayaks and umiat to harvest bowhead whales in the open waters of Baffin Bay (NWMB 2000). Josephee Keenainak of Pangnirtung (as cited in NWMB 2000), recalls camps being established at the location of the whale kill site, sometimes having to move from a previous location. These camps are reflected in the archaeological record along the islands and mainland in old sod houses (qarmait), which still contain whale bones (NWMB 2000).

When whales arrived in the Clearwater Fiord near the outpost camps, their breathing could be heard all night. Enoosilk Nashalik, an elder/hunter who used to live at Sauniqtuuradyuk, explained that in the spring, the whales would follow newly forming cracks in the ice near the camp and would be hunted there in the cracks. But even in the event of numerous whales in the area, hunting would not occur unless there was certainty of clean shot, given the scarcity of ammunition, and the desire to ensure no animal was wasted (Nunavut Wildlife Management Board (NWMB) 1998).

Although killer whales are not themselves hunted, Inuit reported sometimes relying on the help of killer whales to drive sea mammals closer to shore (Westdal and Ferguson 2009). Before the use of motorized boats, hunters would bang on their kayaks or make noise with rocks to steer whales toward the land where hunters with rifles or harpoons or anguvigaq were waiting (Nunavut Wildlife Management Board (NWMB) 1998). Harpoons were also used from kayaks, but hunters had to take care to harpoon a line to the whale on a certain side, so that the whale wouldn’t strike the kayak and capsize it (Nunavut Wildlife Management Board (NWMB) 1998). One Elder described the process of harpooning a whale:

> Once the whale was harpooned with floats and drags, it could go under water for a long time. When it surfaced, the hunters used penetrating lances, called anguvigaq, qalugiaq or iputujuq, to kill the animal. The hunters would walk on top of the whale and lance it through the vital organs…Then when the bowhead had already been harpooned with floats and the draggers put on, then it would go under water for a long time, then when it

> comes up for air, it will not go down again, for sure. Then the people who would do the kill would prepare themselves, they would go to the bowhead whale, which had already been struck with floats; when they reached it, the kayaks would gather together to tie the bowhead whale using their oars throwing the ropes on top of the bowhead, and some of the Inuit would be walking on top of the bowhead whale to kill the bowhead, at first they would tie their kayaks to themselves before they killed the bowhead whale, by using penetrating lances to stab it…They would kill them through the vital organs, like through the lungs, because even if you stab it all over the meat it will not die quickly unless you hit it on the lungs…by making holes on them you kill them, like when you shoot a beluga through the lungs, they die. (Kooneeliusie, P. 2000, as cited in NWMB 2000)

Nets are also used when the water is free of ice in the summer and fall (Nunavut Wildlife Management Board (NWMB) 1998; Westdal and Ferguson 2009). Elders report that there are noticeable differences in the meat depending on how a whale is killed. Those caught in nets tend to be saltier, with more blood in the blubber, and a different texture to the muktuk. If the whale becomes bloated, it will not be edible, so nets are checked frequently (Westdal and Ferguson 2009).

Nets are effective for harvesting beluga whales, but not for bowhead.[17] Two Elders reported how bowhead whales destroy the beluga nets without even seeming to notice them.[18] Noise is also a factor when hunting for bowhead whale:

> Bowheads may be disturbed by snowmobile noise at the floe edge or in the breaking ice: We know that the noise from the ski-doos are disturbing to bowheads. That is why they do not come here. Before the ski-doo when we lived down there, when people spotted the narwhals, everyone was careful not to make any holes in the ice so that they would not make any noise. As well, the first narwhal they saw, they would not kill them. They would only kill the ones that came after the first ones had appeared…so that they will not go back to where they came from for a while…if some hunter tried to kill [the first group of migrating narwhals] the rest of the narwhals would not follow, knowing there is danger. They would come around again only after a long period of time had passed. That is what the Inuit have come to know in the Inuit way. Right now they [sea mammals] are staying away because of the ski-doos. The sea mammals in particular are very easily frightened; all of them. (Akpaliapik, S. cited in NWMB 2000)
>
> Since motorized boats have been introduced bowhead whales that used to be around and in the [Pangnirtung] Fjord seemed to have moved into deeper waters and the floe edge—this is the results of noise made by motorized boats. (Evic 2000, as cited in NWMB 2000)

[17] One Elder reported that “the bowhead whales have been caught in fish nets or tangled with fish nets” (Qiyuakjuk, M. cited in NWMB 2000).
[18] Bowhead whales just destroy beluga nets without even seeming to notice them. The nets are usually attached to the floe edge, at the beginning of June (Veevee, A. as cited in NWMB 2000). An elder was saying that he used to set nets for beluga at the floe edge but the bowhead whales used to destroy them. The net [mesh] size was 16” x 32”. (Keeniainak, J. as cited in NWMB 2000)

Residents who use Frobisher Bay explained that the presence of motorized boats has created a considerable difference in the number of whales encountered on the west side of Frobisher Bay compared to previously. Both the decline in numbers of some species in Cumberland Sound, compared to numbers observed in the 1960s, and a change in the behaviour of whales is attributed to the noise caused by motorized boats (Nunavut Wildlife Management Board (NWMB) 1998).

Hunting whales close to the camps occurred because the whales needed to be killed in shallower waters where there was less risk of them sinking (Nunavut Wildlife Management Board (NWMB) 1998; Westdal and Ferguson 2009). An Elder described one such event:

> [As a child] we were still living in our outpost camp near Pangnirtung called “Iqalulik” [on outer headland between Kangilo and Nettilling Fiords]…when we were near Pangnirtung, they saw a bowhead calf [no mother] from the land…the men left the women on the land and the men went rowing down to the calf by the boat, it was really close…it was a very small calf…the Inuit tried to catch the calf, by shooting it but it just sank…it died right away when it was shot. (Qappik, M. 2000, as cited in NWMB 2000)

Whale hunting also occurred and continues to take place in the spring at the floe edge, where whales would go to feed. Previously, when dog teams were used, hunters would walk to the edge of the ice to avoid frightening the whales away. Before motorized vehicles, sharp shooters equipped with 22 long rifles were appointed to shoot from high lookout spots. High powered rifles are preferred to avoid unnecessary injury or damage to the whale and resulting wastage (Nunavut Wildlife Management Board (NWMB) 1998). Harpoons are now used less frequently at the floe edge, but hooks, which can be thrown further and require less accuracy, are used to secure the kill and bring it in (Westdal and Ferguson 2009).

The introduction of new equipment, motorized boats and snowmobiles, allows hunters to chase the whales, which has resulted in hunters spending less time at the camps (Nunavut Wildlife Management Board (NWMB) 1998). The introduction of new equipment, including rifles, knives, binoculars, ammunition, or other non-local commodities, such as tobacco, flour, needles, clothing, and later, motorized vehicles began in the commercial whaling era, when Inuit were paid for their guidance and knowledge on the hunt with equipment (NWMB 2000).

Changes in hunting techniques and approaches are attributed in part to the introduction of this new equipment, but also to the quota system. Some hunters avoid using nets so that whales are not accidentally taken after the quota has been reached but hunts also have a new sense of urgency that was not present previously. The quota limits the number of hunters who can bring in a whale and has resulted in rushed hunts with a greater number of hunters, up to three times the number of hunters than the quota number could support. The rush to bring in a whale before the quota is filled has resulted in more scarred whales and has increased the safety risk to hunters (Nunavut Wildlife Management Board (NWMB) 1998).

Hunters are careful when in boats in the presence of whales. One Elder explained the fear of driving over the whales, while another described the potential for the boat to be turned over:

> When we travel by boat they [bowheads] don't seem to be bothered at all. Some of them get very close to us. We get scared at times because there are so many of them, because we think that we might drive over them with our boats. They are not very fierce animals and they are usually very close to our boats. That's the way they are. (Nutaralak, L. as cited in NWMB 2000)
>
> I have seen many bowhead whales, down in front of Qikiqtan/Kekerten, more to the west of Qikiqtan. We had to get out of the water, on to a piece of ice for safety, for there were too many bowhead whales around, for it was getting too dangerous to keep on boating. They were passing us by all day long, so we literally stayed on the piece of ice all day for safety. There was more than one boat, so the other crew, Etuangat and his stepson, Palluq, had to go to safety too on to a different piece of ice. (Anon. 24, PA. as cited in NWMB 2000)

Hunters also describe reading a whale's body for characteristic signs of aggressiveness (Angmarlik, P., Maniapik, T., Nutarak, Sr., K., Akpaliapik, S., Audlakiak, M. as cited in NWMB 2000):

> [According to my father]...when the bowhead whale has a pointy nose [blowhole], and roundish body, it would be very hard to catch [and aggressive], and sometimes lost; even when they put many lines to it, the bowhead whale would not even slow down with a heavy drag, and the boats would not be able to catch up to them, for they are very fast swimmers. The more docile ones, would require only two lines, then it would slow down…Then they would use a penetrating lance or exploding dart to kill it. (Anon. 26, PA, as cited in NWMB 2000)

Mother whales with young are protective, but some whales are not pursued because of the sound of their breathing and the potential for that sign to indicate an aggressive nature (NWMB 2000)[19]:

> If its breath is a cracking sound with breaks in between, this is an indication that the bowhead whale is warning [the hunters], as the bowhead whales are capable of striking at the kayaks or umiat [large skin boats]. The hunters were able to detect the mood of the bowhead whale by the way it was breathing. (Pitsiulak, L. as cited in NWMB 2000)

One Elder recalled that "during the time of the whalers…some bowhead whales would face the ships, these would be aggressive whales. Their flippers can reach up to the corner of their mouths. There was one incident where one of these aggressive bowhead whales attacked [a whaling vessel]" (Nutarak, Sr., K. as cited in NWMB 2000).

[19] "People say that they [some bowheads] breathe differently.... They say that the bowhead whales that make a lot of noise would be very difficult to kill. I guess they would be fierce, vicious" (Nutaralak, L. as cited in NWMB 2000).

Because of the ban on hunting bowhead whale, some residents fear that Inuit knowledge of the whale and how to harvest the whale is being lost:

> The Inuit are not studying the bowhead today, even the elders are not paying attention to them, because we do not even deal with them today; because we were not allowed to hunt them, we did not even pay attention to the population growth, because we were not allowed to hunt them period, even when we still wanted to hunt them. (Ell, B. as cited in NWMB 2000)
>
> Perhaps in some ways we are getting behind with our knowledge on bowhead whales, simply because we have not been involved with bowhead whale harvesting for a long time and we don't talk about it often enough…Inuit who are knowledgeable in whaling are no longer with us—they could have relayed information on what is needed and what needs to be done when actually harvesting a bowhead whale. As there was a special technique when harvesting a bowhead whale unlike when hunting for common wildlife. Because of their large size and [as] they were hunted traditionally where it could not be killed just like that, there were specific areas in the body that were targeted to kill the bowhead whale. (Evic, J. as cited in NWMB 2000)

The ability to transmit knowledge between generations is key to Inuit traditional practices and use. "If you don't know the traditional knowledge, you won't last very long: you will freeze to death if you don't know how to survive" (Kalluk, D. as cited in Ford et al. 2006). Knowledge of traditional navigation, building snow shelters, predicting weather, reaction to dangerous situations, manufacture, repair and use of equipment, and appropriate attire have historically been acquired through cultural transmission (Ford et al. 2008). However, shifts away from traditional knowledge transfer, in large part due to the school system, has resulted in a younger generation with less "adaptive capacity for hunting" (Ford et al. 2008). One resident explained, "We show our sons by sketching on the sand on where to shoot the whale" (Noshuttaq as cited in Nunavut Wildlife Management Board (NWMB) 1998). Hunters and Elders noted that there was no traditional material on Baffin belugas in the local school programs and without experience out on the land, youth would not be able to distinguish whales by size, behaviour, colour, or other bodily characteristics that are necessary for successful harvesting but also hunter safety (Nunavut Wildlife Management Board (NWMB) 1998).

Bans and restrictions on hunting are resulting in changes in intergenerational knowledge exchange, but also affect local wildlife population numbers and resident safety. Regarding the quota on polar bear, one Clyde River resident explained, "We have many problems and there are many youths who want to catch their first polar bear. There are many people. Sometimes there are people in their 50s who never caught a polar bear. It's very important to get your first bear. It brings you up in your life (Clyde River community consultation participant, Dowsley and Taylor 2006).

Several residents within the Area of Focus also describe fluctuating populations in relation to the quota:

> We can't have all the bears that there are. So, it has increased the population of bears, it's like that all around. Before people would get all the bears. The population will decrease since we can only catch males, so soon the population of males will be so little. (Dowsley 2005)
>
> There are people still here from the 1930s and they know where the bears used to be. There used to be few bears at that time. The people that you interviewed did you include them? My first recollection from then is that nobody would catch a polar bear; it would be a surprise if someone did. There were no limits back then. More polar bears seem to be showing up since I moved to the community. (Panikpakoochoo, E. as cited in Government of Nunavut 2017g)
>
> A few years ago, I thought the quotas were not useful, but then they increased the number of tags so I'm okay with it now. We wouldn't even need quotas now because people see bears and don't even try to get them. If we stopped using quotas we could probably manage. The fur value is decreasing so people don't even try to catch them. Soon the only money from them will be from sport hunt guiding. (Dowsley 2005)

There are concerns that the quota on polar bears is resulting in an increase in the population that is dangerous for residents.

> There have been more polar bears these days. There were some by these houses, and also by cabins. We always need "watch person" while berry picking. We always hear polar bears are decreasing, but that's not true. We like berry picking and walking in summer, but we need rifles to protect ourselves. If you are going to talk about the past, there were fewer then than there are today. This is the time of the most polar bears. (Clyde River community consultation participant, Dowsley and Taylor 2006)

If the quota system is to be maintained, some residents would like to see the number increased:

> There are too many bears. Before, when we went dog teaming for hunting we didn't come across many bears. We were getting 45 a year anyway. The government says that's too many. We should be able to get more now since we were able to get that when they were scarce (Dowsley 2007).

For some residents, the quota system is in conflict with Inuit knowledge:

> It's not right for animals to be chased away with a rifle [when there is no available hunting tag]. It must be recognized that this is wrong. We should try going back to Inuit knowledge for 4 or 5 years and see the effect. (Pond Inlet consultation participant, Dowsley and Taylor 2006).

5.8.2 Traditional Sites and Travelways

Much of the land and marine use in the Area of Focus is focused in the coastal lowlands, along shores, and into adjacent and surrounding marine areas. The Nunavut Atlas displays clusters of campsites, archaeological sites, sites of archaeological interest, and travelways throughout these areas of high intensity usage (Riewe 1992b). Residents of Qikiqtarjuaq, for example, described numerous ancestral sites along the coast line of Qikiqtarjuaq, some of which had been occupied by Thule inhabitants, predecessors to modern Inuit, including traditional habitations, meeting places, and burial sites (Nunavut Department of Environment 2010). Iqaluit residents identified areas used for camping in the summer on Lower Savage, Edgell, and northern Resolution islands (Riewe 1992b).

Travelways identified in the Nunavut Atlas for the Area of Focus, as well as the communities associated with them, are described in Table 5.35 (Riewe 1992b).

Table 5.35 Travelways in Strategic Environmental Assessment Area of Focus

Community	Nature of Travelway	Location	Time of Year Used
Arctic Bay	snowmobile routes, north-south and west-east, to southeast Devon Island for muskox and marine mammals	Lancaster Sound	winter spring
Pond Inlet, Clyde River	skidoo travel route between Pond Inlet and Clyde River	Baffin Bay shore and sea ice	Not indicated
Pond Inlet	northernmost extent of travel by Pond Inlet hunters	northeast coastal area of Bylot Island (up to approx. 73.5 degrees latitude)	Not indicated
Grise Fiord, Resolute Bay	main snowmobile route between Grise Fiord and Resolute	Jones Sound, through Bear Bay	not indicated
Qikiqtarjuaq, Clyde River	travelway—travel corridor for Clyde River and Broughton Island residents	Henry Kater Peninsula and lowlands north of Isabella Bay	winter spring
Qikiqtarjuaq, Pangnirtung	snowmobile travelway between Pangnirtung and Broughton Island	Kingnait Fiord	winter
Clyde River, Pond Inlet	snowmobile and dog team route	along coast between Pond Inlet and Clyde River	Not indicated
Pangnirtung	travelways to Netilling Lake—previously travelled by kayak, but now by motorboat or freighter canoe	Nettilling Fiord	Not indicated
Pangnirtung, Iqaluit	main snowmobile (formerly dog team) route between Pangnirtung and Frobisher Bay	North-south route from Cumberland Sound	Not indicated
Pangnirtung	travelway by boat for hunting area at Lemieux Islands	east side of Frobisher Bay and east coast of Hall Peninsula	Not indicated
Pangnirtung	Travelway	west coast of Cumberland Sound	year round
Iqaluit, Kimmirut	travelway by boat between Iqaluit to Kimmirut	southeast coast of Meta Incognita Peninsula	Not indicated

Table 5.35 Travelways in Strategic Environmental Assessment Area of Focus

Community	Nature of Travelway	Location	Time of Year Used
Iqaluit	travelway—used to reach outpost camps and hunting areas at the mouth of Frobisher Bay, as well as the Allen, Brevoort, and Lemieux Islands areas	east side of Frobisher Bay and east coast of Hall Peninsula	summer—boat winter—skidoo
Resolute Bay, Arctic Bay	travelway—main snowmobile routes between Arctic Bay and Resolute and Creswell Bay Outpost Camp	northeast tip of Somerset Island	Not indicated

5.8.3 Changes in Traditional Use and Practices

The literature review for the Area of Focus highlights several events, in addition to the quota system, that are causing changes to traditional practices. Changes in local weather and environmental conditions is affecting harvesting practices, as well as the timing of traditional activities.

> It is very obvious that spring is a lot earlier than before. The month of April is one where I can cite an example of the changes, perhaps by many other Inuit. The month is generally used for the Toonik Time spring festivities. It was towards the end of the month when the festivities were held prior to the new century, but these last few years, due to earlier spring, the festivities have to be moved up by two weeks (Peter, J. as cited in Nunavut Department of Environment 2005).

Ice conditions have always been a challenge: thin ice is a risk to hunters, while heavy ice packs in the summer can make it harder to harvest game and travel. Heavy ice packs at the floe-edge; however, can be advantageous when hunting whales (Nunavut Wildlife Management Board (NWMB) 1998). One resident described changes to previous ice conditions:

> The ice thickness has changed. I do not go out as much as before, so I can only tell you what I have heard from those who are still fishing in the winter. From their words, the ice is way thinner than the normal levels. When we used to fish the lakes for food, when we were chipping away at the ice, sometimes it would be over our heads. That is how thick it was. Luckily, no one ever drowned in one of the holes. It used to be really thick in those days when all we had were hand chippers. As well, when we lived in a camp near Kimmirut, the ice used to be really thick. Up there, the Inuit living in the shadows apparently required steps to climb out of the holes they were chipping for their nets. That is how thick they were. (Boaz 2002, as cited in Nunavut Department of Environment 2005)

Climate change has made traditional practices such as hunting more dangerous and the Inuit of Nunavut have changed and adapted in response to these increased risks. Some Inuit hunters reduce potential hazards by being more vigilant during day to day activities including: avoiding dangerous areas, avoiding travelling at dangerous times of the year, and returning quickly if out on the land when the weather changes. Some hunters have stopped conducting certain traditional practices such as the floe-edge narwhal hunt altogether (Ford et al. 2006).

Pangnirtung residents have also observed changes in the formation of snow, which has made igloo building more difficult (Nunavut Department of Environment 2005). To adjust to changing conditions, hunters pack extra supplies, pre-identify shelters in the event of getting stranded, and take small row boats to avoid being stranded on detached ice (Ford et al. 2006; Ford et al. 2008).

There is concern voiced in the literature regarding accidents leading to pollution of waters. One resident explained that "if there are too many activities in the waters inhabited by sea mammals, there is a good possibility that accidents could easily occur in the ocean and pollute the water and that would for sure destroy the wildlife" (Nashalik, I. as cited in NWMB 2000). A resident of Qikiqtarjuaq expressed concern about effects of pollution in addition the effects of externally imposed wildlife management practices:

> ...if the bowhead whale is wiped out by any kind of pollution while we are still not allowed to hunt them, (there are so many chemicals nowadays that are pollutants to the world), if the animals are killed by, like any kind of pollutant spills, like oil, I would be very sorrowful. (Qappik, M. as cited in NWMB 2000)

5.9 Traditional Harvest

> During the time of their ancestors, the survival and well-being of Inuit depended on wildlife. The Inuit believed that all animals were put on earth for them to harvest and utilize. They had strict guidelines and rules regarding harvesting wildlife, which were transmitted to subsequent generations through oral culture and traditions. The Inuit have observed and been taught that wildlife tend to have natural cycles of abundance and distribution. These cycles will be reflected in local occurrence and/or number of animals harvested: …the animals vary from one year to the next, sometimes they are more abundant, and sometimes they just seem to disappear, and that is the same with all the animals and that is how it was when I was growing up. Some years the Inuit were starving and some years were plentiful, that is what it was like back then in my time. (Saata, A. as cited in NWMB 2000)

Land and marine use intensity, including harvesting sites, camping areas, areas of archaeological interest and archaeological sites, and travelways, is greatest along the coast of Baffin Island, its fiords, bays, islands, and inlets. Resources are harvested year-round in the terrestrial lowlands, along the shores, on fast ice, at the floe edge, and in open water (Riewe 1992a). The following section outlines the species harvested in the Area of Focus, areas where harvesting occurs, months and seasons in which specific species are harvested, as well as the mean number of species harvested as recorded by the Nunavut Wildlife Harvest Study (Priest and Usher 2004). This information is organized by community. Current trends in harvesting are also discussed under each community; those trends focus largely on changes in local weather and environmental conditions that are affecting access to traditional resources.

Much of the traditional harvest information for the Area of Focus comes from the Nunavut Wildlife Harvest Study published in 2004 (Priest and Usher 2004) and the Nunavut Atlas, published in 1992 (Riewe 1992a), which was based largely on the Inuit Land Use and Occupancy Project, published in 1976 (Freeman 1976). There are additional online sources of information,[20] but permission to use the harvesting information had not been received at the time of writing.

5.9.1 Arctic Bay

Table 5.36 shows species harvested, harvesting locations, months or seasons in which species are harvested, as well the mean number of any given species harvested annually for the period 1996 to 2001 by Arctic Bay and Nanisivik hunters. The table combines results primarily from the Nunavut Wildlife Harvest Study and the Nunavut Atlas. Results from the Nunavut Wildlife Harvest Study were collected from a total of 310 registered Arctic Bay and Nanisivik harvesters out of total approximate populations of 627 and 23 respectively.

[20] For example, the Nunavut Coastal Resources Inventory and the Pikialasorsuaq Atlas.

Table 5.36 Harvesting by Residents of Arctic Bay[21]

Species/Umajuin[22]	Yearly Mean Harvested[23]	Harvesting Locations Within SEA Area of Focus[24]	Seasons and Months Harvested[25]
caribou/tuktut	778	• Shores of southern Admiralty Inlet • Beringuet Inlet • Northern Steensby Peninsula • Milne Inlet • Eclipse Sound	• January to December[26]
musk-ox/umingmait	1	• Croher Bay, including inland, of Lancaster Sound, accessible when Lancaster Sound freezes enough for snowmobile travel	• May, August, September
wolf/amagut	13	Not indicated	• February, March, April, May, August, September, November
Arctic fox/tigiganiat	114	Admiralty Inlet, the entire coastline and adjacent to northern Steensby Peninsula	• January, February, March, April, June, November, December; winter along the coastline
coloured fox/kalaliit tigiganiat	1	Not indicated	• February, November, December
Arctic hare/ukalik	136	Not indicated	• January, February, March, April, May, June, August, September, October, November, December

[21] Information from (Priest and Usher 2004) related to Arctic Bay includes information for residents from Nanisivik.
[22] Priest and Usher (2004)
[23] Priest and Usher (2004)
[24] Riewe (1992b). In some cases, locations have been generalized from the maps contained within The Nunavut Atlas.
[25] (Priest and Usher 2004).
[26] Caribou are harvested on northern Steensby Peninsula and west of Milne Inlet in spring and summer (Riewe 1992b).

Table 5.36 Harvesting by Residents of Arctic Bay[21]

Species/Umajuin[22]	Yearly Mean Harvested[23]	Harvesting Locations Within SEA Area of Focus[24]	Seasons and Months Harvested[25]
polar bear/nanuit	11	• Large area, primarily on the ice of Admiralty Inlet, Adams and Strathcona sounds • Admiralty Inlet • Admiralty Inlet adjacent to northern Steensby Peninsula • Beringluet Inlet • Lancaster Sound (when frozen enough for snowmobile travel) • Southeastern Devon Island	• January, March, June, October, November, December[27]
ringed seal/natiinat	1,450	• Most of Admiralty Inlet • Admiralty Inlet adjacent to northern Steensby Peninsula • Victor Point important sealing area	• January to December • In winter taken at breathing holes in ice • In spring taken while basking on ice
bearded seal/ukyuk	14	• Part of Lancaster sound • Admiralty Inlet adjacent to northern Steensby Peninsula • Victor Point important sealing area	• March, April, May, June, July, August, September, October, December • Late spring at floe edge • Summer in open water
harp seal/qairulik	10	• Lancaster Sound	• April, July, August, September, October • Summer in open water
seal (species not indicated)	NA[28]	• Admiralty Bay • Berlinguet Inlet • Bell Bay • Lancaster Sound (when frozen enough for snowmobile travel in late winter and spring) • Borden Peninsula • Navy Board Inlet	• January to December • Winter at breathing holes • Summer in open water

[27] Polar bear are harvested in Lancaster Sound and southeastern Devon Island in late winter and spring and in Admiralty Inlet adjacent to northern Steensby Peninsula in winter (Riewe 1992b).
[28] NA= not available.

Table 5.36 Harvesting by Residents of Arctic Bay[21]

Species/Umajuin[22]	Yearly Mean Harvested[23]	Harvesting Locations Within SEA Area of Focus[24]	Seasons and Months Harvested[25]
walrus/akvik	3	• Southern shore of Adams Sound • Giants Castle—Turner Cliffs area • Strathcona Sound • Victor Bay • Cape Crawford • Lancaster Sound (when frozen enough for snowmobile travel)	• April, May, July, August, September, October • In late spring at the floe edge • Summer in open water
narwhal/tuugaak	74	• Admiralty Inlet, as far south as Easter Sound • Western shore of Admiralty Inlet • Admiralty Inlet adjacent to northern Steensby Peninsula • Lancaster Sound (when frozen enough for snowmobile travel)	• May, June, July, August, September, October • From spring into June and July, at floe edge [29]
beluga/kilalugak	14	Not indicated	• May, June, July, August, September, October
snow goose/kanguq	390	• Northern Steensby Peninsula • Wetlands of southern Admiralty Inlet • Steensby Peninsula	• May, June, July, August, September; nesting period
Canada goose/nikliknik	1	Not indicated	• June, July, September
brant goose/nirlirnaq	5	Not indicated	• May, June, July, August, September
old squaw/aahangik	1	Not indicated	• September, October
eider duck/kingalik	16	Not indicated	• April, June, August, September, October
common loon/tuulik	<1	Not indicated	• June, September
Arctic loon/maliriq	<1	Not indicated	• June
red-throated loon/qaqhuaq	1	Not indicated	• August, September
black guillemot/black guillemot	1	Not indicated	• August, October

[29] Narwhal are hunted in Admiralty Inlet adjacent to northern Steensby Peninsula in summer (Riewe 1992b).

Table 5.36 Harvesting by Residents of Arctic Bay[21]

Species/Umajuin[22]	Yearly Mean Harvested[23]	Harvesting Locations Within SEA Area of Focus[24]	Seasons and Months Harvested[25]
goose and duck (species not indicated)	NA	• North shore Strathcona Sound—favoured location • Western shore of Admiralty Inlet across from Arctic Bay—favoured location • Along shores of Admiralty Inlet	Not indicated
thick-billed murre/thick billed murre	2	Not indicated	• June
ptarmigan/akilgik	571	Not indicated	• January to December
Sandhill crane/tatilgaq	1	Not indicated	• May, June
goose eggs/uluaguliit manniit	556	Not indicated	• June
duck eggs/tinmiat manniit	<1	Not indicated	• July
seagull eggs/nauyat manniit	33	Not indicated	• June, July
Arctic char/ikaliviit	10,237	Not indicated	• January to December
lake trout/ikaliviit	8	Not indicated	• May
cod/ugak	152	Not indicated	• June, July
sculpin/kanayuk	34	Not indicated	• June, July, August
clams/uviluq	51	Not indicated	• July, August

In addition to the species listed in Table 5.36, Arctic Bay hunters also report harvesting bowhead whales (NWMB 2000).

Changes in the ability to access hunting areas continue to alter harvest timing and location (Ford et al. 2008). The ability to access harvesting areas is changing for numerous reasons:

- Melting permafrost creates hazardous muddy conditions in spring and summer (Ford et al. 2006)
- Thinner snow cover than previously can result in damage to snowmobiles and sleds (Ford et al. 2006)
- Changing climatic conditions have lessened residents' ability to predict safe harvesting conditions and sudden changes in weather exacerbate the risk (Ford et al. 2006)
- There are new areas of open water, thin ice, and the location of leads (crevices, channels, or breaks in a mass of sea ice) (Ford et al. 2006)
- Access to nearshore hunting grounds by boat is limited by unpredictable winds, which have become stronger and more unpredictable (Ford et al. 2006)

David Kalluk (2004–2005; as cited in Ford 2006) of Arctic Bay indicates that Inuit hunters must make additional preparations prior to departing in anticipation of getting stranded. "Since the weather is unpredictable now you have to take extra everything, extra grub and extra gas."

Some hunters avoid travelling on the land or water altogether during dangerous times of the year or when there is a possibility of changes in weather. Unfortunately, this has resulted in fewer hunters taking part in, for example, floe-edge narwhal hunts, which has important cultural and social implications for residents of Arctic Bay (Ford et al. 2006; Ford et al. 2008).

Traditional harvest remains an important practice for Arctic Bay Hunters and youth continue to participate in harvesting activities, but fewer are displaying the same degree of commitment or interest in harvesting as previously (Ford et al. 2008).

5.9.2 Cape Dorset

Table 5.37 shows species harvested, the months in which harvesting occurs, as well as the mean number of any given species harvested annually for the period of 1997 to 2001 by Cape Dorset harvesters. The table is based on the results of the Nunavut Wildlife Harvest Study (Priest and Usher 2004). Harvesting locations were not identified in the Nunavut Wildlife Harvest Study; as such, it is unknown where the species listed in Table 5.37 were procured, and if those areas overlap the Area of Focus. Results from the Nunavut Wildlife Harvest Study were collected from a total 510 registered Cape Dorset harvesters out of a total approximately population of 1,130, current as of 1999

Information from the Nunavut Atlas was not included because the harvesting area identified for Cape Dorset does not overlap the Area of Focus.

Table 5.37 Harvesting by Residents of Cape Dorset

Species/Umajuin	Yearly Mean Harvested	Seasons and Months Harvested
Caribou/tuktut	508	January to December
Polar bear/nanuit	7	January, February, March, April, October, November, December
Wolf/amagut	4	January, February, March, April, May, June, November
Arctic fox/tigiganiat	66	January, February, March, April, May, September, October, November, December
Coloured fox/ kalaliit tigiganiat	2	February, April, May, November, December
Wolverine/kalvik	<1	May
Arctic hare/ukalik	110	January to December
Seal (unspecified)/natiit	1	November
Ringed seal/natiinat	1,060	January to December
Bearded seal/ukyuk	71	January to December
Harp seal/qairulik	15	June, July, September, October, November, December
Harbour seal/qanigiaq	1	February, March, October, November
Hooded seal/nahakakaktutu ittut natiit	1	October, November
Walrus/akvik	43	January to December
Narwhal/tuugaak	1	October
Beluga/kilalugak	50	June, July, August, September, October, November
Snow goose/kanguq	3,156	April, May, June, July, August, September
Canada goose/nikliknik	221	May, June, July, September
Ross's goose/kakat	1	May, September
Brant goose/nirlimaq	1	May, June
Old squaw/aahangik	4	May, June
Eider duck/kingalik	787	January to November
Tundra swan/kukyuk	<1	May
Common loon/tuulik	1	August
Red-throated loon/qaqhuaq	2	July, September

Table 5.37 Harvesting by Residents of Cape Dorset

Species/Umajuin	Yearly Mean Harvested	Seasons and Months Harvested
Black guillemot/black guillemot	4	January, March, April, September, November
Thick-billed murre/thick-billed murre	194	January to October
Ptarmigan/akilgik	1,522	January to December
Eggs (unspecified)	<1	June
Goose eggs/uluaguliit manniit	7	June
Duck eggs/tinmiat manniit	3,241	June, July
Seagull eggs/nauyat manniit	16	June
Eider down/mitiit qiviungit	10	July
Arctic char/ikaliviit	13,695	January to December
Lake trout/ikalukpik	25	January, September, November, December
Cod/ugak	67	April, May, June
Sculpin/kanayuk	42	February, May, June, July, August, September, December
Clams/uviluq	7,624	June, July, August, September, October
Mussels/uviluvaloet	175	July

While Inuit from Cape Dorset report that they have not harvested bowhead whale in recent years due to the moratorium, opportunistic harvesting has occurred.

> There was a dead bowhead whale near a lake or on a lake near Cape Dorset. I had seen this and taken some of the meat out of the lake so the dogs had some of it for food...I had brought it up on the land but the dogs started eating it and I had let it sink again in the lake*…*(Kellypalik, M. as cited in NWMB 2000)

5.9.3 Clyde River

Table 5.38 shows species harvested, harvesting locations, months or seasons in which species are harvested, as well as the mean number of any given species harvested annually for the period 1996 to 2001 by Clyde River hunters. The table combines results primarily from the Nunavut Wildlife Harvest Study and the Nunavut Atlas. Results from the Nunavut Wildlife Harvest Study were collected from a total of 245 registered Clyde River harvesters out of a total approximate population of 737, current as of 1999.

Table 5.38 Harvesting by Residents of Clyde River

Species/Umajuin[30]	Yearly Mean Harvested[31]	Harvesting Locations Within SEA Area of Focus[32]	Seasons and Months Harvested[33]
Caribou/tuktut[34]	349	• Northwest side of Scott Inlet • Head of Clyde Inlet • Head of Eglinton Fiord	January to December[35]
Polar bear/nanuit	9	• Marine area and all fiords around Clyde River • All adjacent fiords, bays, and inlets (Baffin Bay/Clyde River) • Home Bay, especially Isabella Bay • Northern part of Home Bay and adjacent fiords • Alexander Bay (favoured harvesting location)	January, March, April, May, June, October, December
Wolf/amagut	3	Not indicated	February, March, April, May, December
Arctic fox/tigiganiat	36	• Coast of Isabella Bay and its islands	January, February, March, April, May, August, September, October, November, December
Coloured fox/kalaliit tigiganiat	3	Not indicated	January, February, March, August, October, November, December
Arctic hare/ukalik	55	Not indicated	January to December
Seals (species not indicated)	2	• Eglinton Fiord • Mouth of Clyde Inlet • Cape Christian (popular sealing area)	March, October Fall and winter

[30] (Priest and Usher 2004); (Riewe 1992a)
[31](Priest and Usher 2004).
[32] (Riewe 1992a). In some cases, locations have been generalized from the maps contained within The Nunavut Atlas.
[33] (Priest and Usher 2004); (Riewe 1992a).
[34] It is unknown which herd of caribou were harvested, but one resident of Clyde River explained that caribou from the Porcupine herd could be identified because they have a “longer body, shorter legs, eyelashes, and whiskers. And they taste better" (Jenkins and Goorts 2013).
[35] Clyde River residents hunt caribou at the heads of Clyde Inlet and Eglinton Fiord in the summer (Riewe 1992a).

Table 5.38 Harvesting by Residents of Clyde River

Species/Umajuin[30]	Yearly Mean Harvested[31]	Harvesting Locations Within SEA Area of Focus[32]	Seasons and Months Harvested[33]
Ringed seal/natiinat	2,004	• Marine area and all fiords around Clyde River (mainly for silver jars in spring) • All adjacent fiords, bays, and inlets (Baffin Bay/Clyde River) • Sam Ford Fiord (incl. Walker Arm) for pups • Scott Inlet for pups • Clark Fiord • Gibb Fiord • Home Bay, especially Isabella Bay • Northern part of Home Bay and adjacent fiords	January to December Spring for pups
Bearded seal/ukyuk	19	• All adjacent fiords, bays, and inlets (Baffin Bay/Clyde River) • Marine area and fiords around Clyde River • Home Bay, especially Isabella Bay	January, June, July, August, September, October, November, December December to June on fast ice and at floe edge[36]
Harp seal/qairulik	13	• Clark Fiord • Gibb Fiord • Marine area and fiords around Clyde River • Clyde Inlet and Inugsuin Fiord	January, April, July, August, September, October, November[37]
Hooded seal/nahakakaktutut ittut natiit	<1	Not indicated	May
Walrus/akvik	<1	• Clark Fiord • Gibb Fiord • Alexander Bay	July Spring[38]

[36] Clyde River residents sometimes hunt bearded seal in the marine areas around Clyde River in the summer, while in Home Bay and Isabella Bay, hunting is undertaken in both winter and spring (Riewe 1992a).
[37] Clyde River residents sometimes hunt harp seal in the marine area around Clyde River in the summer, while hunting in Clyde Inlet and Inugsuin Fiord is undertaken in late summer and fall (Riewe 1992a)
[38] Clyde River residents hunt walrus in Alexander bay in the spring (Riewe 1992a).

Table 5.38 Harvesting by Residents of Clyde River

Species/Umajuin[30]	Yearly Mean Harvested[31]	Harvesting Locations Within SEA Area of Focus[32]	Seasons and Months Harvested[33]
Narwhal/tuugaak	20	• Marine area and all fiords around Clyde River • Near the head of Clyde Inlet • Clyde Inlet and Inugsuin Fiord • Buchan Gulf • Feachem Bay (favoured harvesting location) • Clark Fiord • Gibb Fiord	May, July, August, September, October, November[39]
Beluga/kilalugak	<1	• Near the head of Clyde Inlet	August Summer
Snow goose/kanguq	88	Not indicated	May, June, July, August, September
Canada goose/nikliknik	39	Not indicated	May, June, July, August, September
Brant goose/nirlirnaq	1	Not indicated	June, September
Old squaw/aahangik	1	Not indicated	September
Eider duck/kingalik	133	• Inugsuin Fiord	May, June, July, August, September, October, November, December
Common loon/tuulik	<1	Not indicated	October
Red-throated loon/qaqhuaq	7	Not indicated	June, July, August, September
Black guillemot/black guillemot	<1	Not indicated	October
Thick-billed murre/thick billed murre	1	Not indicated	October
Ptarmigan/akilgik	1,214	Not indicated	January, February, March, April, May, June, August, September, October, November, December
Sandhill crane/tatilgaq	<1	Not indicated	May

[39] Clyde River residents hunt narwhal near the head of Clyde Inlet in the summer, within Clyde Inlet and Inugsuin Fiord in late summer and fall, and in Buchan Gulf and Feachem Bay throughout open-water season (Riewe 1992a).

Table 5.38 Harvesting by Residents of Clyde River

Species/Umajuin[30]	Yearly Mean Harvested[31]	Harvesting Locations Within SEA Area of Focus[32]	Seasons and Months Harvested[33]
Eggs (unspecified)	<1	Not indicated	July
Goose eggs/uluaguliit manniit	323	Not indicated	June, July
Arctic tern eggs	9	Not indicated	July, August
Duck eggs/tinmiat manniit	8	Not indicated	July
Seagull eggs/nauyat manniit	33	Not indicated	June, July
Fish (unspecified)	NA	• Fishing occurs in coastal areas around Clyde River, particularly along extensive tracts of low-relief headlands	Not indicated
Arctic char/ikaliviit	8,463	• Inugsuin Fiord (favoured for fishing by gill netting)	January to December[40]
Burbot/tiktaaliq	<1	Not indicated	June
Arctic cisco/kapihilik	9	Not indicated	October, November
Least cisco/eetuuk	<1	Not indicated	February
Cod/ugak	292	Not indicated	March, May, June, July, August, September, December
Sculpin/kanayuk	1,778	Not indicated	February, March, April, May, June, July, August, September, November, December
Turbot/nataarnak	88	Not indicated	January, February, March, April, May
Clams/uviluq	9,311	Not indicated	June, July, August, September, October, November, December

[40] Clyde River residents fish for Arctic char at Inugsuin Fiord in the summer (Riewe 1992a).

In addition to the species listed in Table 5.38, Clyde River hunters also reported harvesting bowhead whales (NWMB 2000). Hunters from Clyde River noted that there are two types of bowhead whales. Bowheads with flat heads tend to be docile and are harvested, while bowheads with high pointed protuberances near their blow holes are very aggressive and are not sought (NWMB 2000). Nauja Tassugat and Martha Kitiutikku note that when harvesting a calf, the mother must be killed first, though mother and calf pairs are not typically harvested (Tassugat, N. and M. Kutiutikku as cited in NWMB 2000).

Clyde River participants indicated that bears can now be hunted within or close to town. This change in harvesting location is attributed to climate change (Dowsley 2007).

Maintaining access to resources is an important part of harvesting. This includes travelling across land-fast ice, harvesting along the flow edge, monitoring changes in weather, understanding the timing of break-up and freeze-up, as well as other environmental changes that can create constraints on travel. In Clyde River, changes in local ice conditions have noted consequences for access to harvesting activities.

> "In the past, we could hunt for different animals further. Now we can't go further, we have to hunt nearby on the ice. I am experiencing it. In winter, there are usually cracks from the points of land and I can put my [fishing] net under water. But now there are hardly any cracks so I can't fish for char anymore." (Clyde River Participants, as cited in Dowsley 2007).

The changes in ice conditions described by residents of Clyde River:

- The ice is thinner now, with more snow on the ice, it is insulated and prevented from becoming thicker (Dowsley 2007)
- Ice quality is variable, with no discernible patterning (Dowsley 2007)
- "The ice is sharper now, not as hard as before. In the past the ice was really thick. The cracks were very narrow, deep and tapered down like a 'V'. Now they have straight edges." (Clyde River participants as cited in Dowsley 2007)
- "The salt water doesn't freeze as hard as before. Every year we chip the ice at seal breathing holes; today it is not as hard, not as brittle. Now in June the bottom of puddles (on the ice) is not slippery, it's not melting from the top, it's melting from everywhere through the ice, like the inside of a bone. Today the ice is also thinner. People used to say when the leads opened they looked tapered going down in them because of the thickness. They no longer look tapered" (Clyde River participants as cited in Dowsley 2007)
- Ice cracking is variable, ranging from no observed changes by Clyde River residents, to observations of more cracks (Dowsley 2007)
- Changes in floe edge is variable, ranging from observations by Clyde River residents that the floe edge was closer, to the flow edge extent being the same as previous years (Dowsley 2007)
- Changes in ice texture is variable, ranging from residents of Clyde River observing no changes in ice texture, to observations of more rough ice now (Dowsley 2007)

- Changes in timing of spring break-up, which, generally, is being observed earlier now than in the past, and winter freeze-up, which, generally, is being observed a couple of weeks later than in the past (Dowsley 2007)

Melting glaciers and changes in wind patterns also affect local conditions, for example: “We used to only have wind from the north. Three or four years ago the wind started coming from the south too,” and “seems like there is more wind. Seems to be more strong winds. It was soft snow in the south, less blowing snow. Now the snow is harder there (from being blown more)” (Dowsley 2007)

5.9.4 Grise Fiord

Table 5.39 shows species harvested, harvesting locations, months or seasons in which species are harvested, as well the mean number of any given species harvested annually for the period 1996 to 2001 by Grise Fiord hunters. The table combines results primarily from the Nunavut Wildlife Harvest Study and the Nunavut Atlas. Results from the Nunavut Wildlife Harvest Study were collected from a total of 73 registered Grise Fiord harvesters out of total approximate populations of 145, current as of 1999.

Table 5.39 Harvesting by Residents of Grise Fiord

Species/Umajuin[41]	Yearly Mean Harvested[42]	Harvesting Locations Within SEA Study Area[43]	Seasons and Months Harvested[44]
Caribou/tuktut	41	Not indicated	February, March, April, May, June, July, August, September, October, November, December
Musk-ox/umingmait	7	• Northeast coastal lowlands of Devon Island	February, March, April, May, August, October
Polar bear/nanuit	19	• Smith Sound/Baffin Bay at Ellesmere Island • Nearshore marine area from just north of Smith Bay, out into Baffin Bay and south to and including Glacier Bay • Jones Sound when it freezes • Jones Sound through Bear Bay	January, February, March, April, May, October, November, December[45]
Wolf/amagut	1	Not indicated	March, April, May, November
Arctic fox/tigiganiat	20	• Heavy trapping between Cape Sparbo and Cape Hardy	January, February, March, April, November, December
Arctic hare/ukalik	28	Not indicated	February, March, April, May, June, July, August, September, October, December
Seals (unspecified)	<1	• Jones Sound • Nearshore marine area from just north of Smith Bay, out into Baffin Bay, and south to and including Glacier Bay	September Winter and early spring
Ringed seal/natiinat	653	Not indicated	January to December
Bearded seal/ukyuk	20	Not indicated	February, March, May, June, July, August, September, October, November
Harp seal/qairulik	46	• Jones Sound	July, August, September, October When encountered

[41] Priest and Usher (2004); Riewe (1992b)
[42] Priest and Usher (2004)
[43] Riewe (1992b) In some cases, locations have been generalized from the maps contained within The Nunavut Atlas.
[44] Priest and Usher (2004); Riewe (1992b)
[45] Grise Fiord residents hunt polar bear in Jones Sound in between March and May in years when it freezes (Jones Sound is part of North Water Polynya) (Riewe 1992b).

Table 5.39 Harvesting by Residents of Grise Fiord

Species/Umajuin[41]	Yearly Mean Harvested[42]	Harvesting Locations Within SEA Study Area[43]	Seasons and Months Harvested[44]
Walrus/akvik	7	• Jones Sound	February, March, April, May, July, August, September, October, November
Narwhal/tuugaak	5	Not indicated	July, August, September, October,
Beluga/kilalugak	8	Not indicated	July, August, September, October
Greater snow goose	NA	• Northeast coastal lowlands of Devon Island	Occasionally in summer
Snow goose/kanguq	26	Not indicated	May, June, July, August, September
Canada goose/nikliknik	9	Not indicated	June, August
Brant goose/nirlirnaq	1	Not indicated	June
Old squaw/aahangik	<1	• Northeast coastal lowlands of Devon Island	June Occasionally in summer
Eider duck/kingalik (also king eider)	18	• Northeast coastal lowlands of Devon Island	June, July, August, September, October Occasionally in summer
Red-throated loon/qaqhuaq	<1	Not indicated	September
Seabirds (e.g., kittiwake, fulmar, glaucous gull, thayer`s gull)	NA	• Coburg Island	Not indicated
Black guillemot/black guillemot	1	• Coburg Island	June, October
Thick-billed murre/thick-billed murre	<1	• Coburg Island	June
Ptarmigan/akilgik	277	Not indicated	February, March, April, May, June, August, September, October, December
Arctic char/ikaliviit	488	Not indicated	March, April, May, June, July, August, September, October, November

Table 5.39 Harvesting by Residents of Grise Fiord

Species/Umajuin[41]	Yearly Mean Harvested[42]	Harvesting Locations Within SEA Study Area[43]	Seasons and Months Harvested[44]
Cod/ugak	108	Not indicated	April
Sculpin/kanayuk	43	Not indicated	June, July, August, September
Clams/uviluq	30	Not indicated	August

The geographic area identified by interviewees as the normal range of their hunting and fishing activities extends throughout Jones Sound. This area extends into Norwegian Bay, Baumann Fiord, Vendom Fiord, and Makison Inlet (Nunavut Department of Environment n.d.). During the NCRI, hunters and fishers from Grise Fiord indicated that they depend on a broad array of animals to supply their traditional diets. Continued, reliable access to and availability of traditional foods is of importance and concern to the community (Nunavut Department of Environment n.d.).

5.9.5 Iqaluit

Table 5.40 shows species harvested, harvesting locations, months or seasons in which species are harvested, as well the mean number of any given species harvested for the period 1996 to 2001 by Iqaluit hunters. The table combines results primarily from the Nunavut Wildlife Harvest Study[46] and the Nunavut Atlas. Results from the Nunavut Wildlife Harvest Study were collected from a total of 540 registered Clyde River harvesters out of a total approximate population of 2,956, current as of 1999.

[46] Note that no data was collected for Iqaluit during year one of the five-year study, and no data was collected during the months of June and July during year two (NWMB 2004).

Table 5.40 Harvesting by Residents of Iqaluit

Species/Umajuin[47]	Yearly Mean Harvested[48]	Harvesting Locations Within SEA Study Area[49]	Seasons and Months Harvested[50]
Caribou/tuktut	1,834	• Northwest coast and inland area of Frobisher Bay • Coastal region of Meta Incognita Peninsula] • Coastal region of Hall Peninsula, adjacent to long bays and fiords and Blunt Peninsula, occasionally on Loks Land • Eastern half of Beckman Peninsula, both Brevoort and Lemieux Islands • Historically, Meta Incognita Peninsula along Hudson Strait coast	January to December[51]
Moose	1	Not indicated	January
Polar bear/nanuit	16	• Around Hozier Island (traditional polar bear hunting area) • Davis Strait by Lemieux Islands • Central Frobisher Bay, from Gabriel Island to Fletcher and Bruce Islands • Eastern half of Beckman Peninsula, both Brevoort and Lemieux Islands • Near Everett Mountain, Meta Incognita Peninsula coast along Frobisher Bay • Historically, coastal area adjacent to Meta Incognita Peninsula	January, February, March, April, May, August, December[52]r
Wolf/amagut	14	• Coastal region of Hall Peninsula, adjacent to long bays and fiords and Blunt Peninsula	January, February, March, April, May, June, August, September, November, December[53]
Arctic fox/tigiganiat	25	• Between the Armshow River, Sylvia Grinnel Lake to the north, and Ward Inlet to the east • Historically, Meta Incognita Peninsula along Hudson Strait coast	January, February, March, April, May, October, November, December

47 (Priest and Usher 2004); (Riewe 1992a).
48 (Priest and Usher 2004).
49 (Riewe 1992a). In some cases, locations have been generalized from the maps contained within The Nunavut Atlas.
50 (Priest and Usher 2004); (Riewe 1992a).
51 Iqaluit residents hunt caribou along the northwest coast and inland areas of Frobisher Bay in winter, and the coastal regions of Meta Incognita, Hall, and Blunt peninsulas in summer (Riewe 1992a).
52 Iqaluit residents hunt polar bear around Gabriel, Fletcher, and Bruce islands from January to March (Riewe 1992a).
53 Iqaluit residents hunt wolf along Hall and Blunt peninsulas in the summer (Riewe 1992a).

Table 5.40 Harvesting by Residents of Iqaluit

Species/Umajuin[47]	Yearly Mean Harvested[48]	Harvesting Locations Within SEA Study Area[49]	Seasons and Months Harvested[50]
Coloured fox/ kalaliit tigiganiat	4	Not indicated	January, March, April, October, November, December
Arctic hare/ukalik	79	Not indicated	January to December.
Seal (unspecified)	1	• Historically, coastal area of Meta Incognita Peninsula, Annapolis and Gabriel straits	November
Ringed seal/natiinat	1,975	• All of Frobisher Bay • Intensively along west side of central Frobisher Bay, Chase Island and Hamlen Bay • Historically in Davis Strait [around Lady Franklin Island and Monumental Island] • Southern coast of mouth of Frobisher Bay and further south to areas adjacent to Potter, Gross, and Palmer islands • Coastal area of Meta Incognita Peninsula, Annapolis and Gabriel straits	January to December
Bearded seal/ukyuk	50	• All of Frobisher Bay • Southern coast of mouth of Frobisher Bay and further south to areas adjacent to Potter, Gross, and Palmer islands • Historically in Davis Strait around Lady Franklin Island and Monumental Island • Coastal area of Meta Incognita Peninsula, Annapolis and Gabriel straits	January, June, July, August, September, October, November, December[54]
Harp seal/qairulik	185	• All of Frobisher Bay • Southern coast of mouth of Frobisher Bay and further south to areas adjacent to Potter, Gross, and Palmer islands • Historically in Davis Strait around Lady Franklin Island and Monumental Island • Coastal area of Meta Incognita Peninsula, Annapolis and Gabriel straits	January, July, August, September, October, November, December[55]

[54] Iqaluit residents hunt bearded seal in Frobisher Bay mostly in the summer (Riewe 1992a).
[55] Iqaluit residents hunt harp seal in Frobisher Bay mostly in the summer (Riewe 1992a).

Table 5.40 Harvesting by Residents of Iqaluit

Species/Umajuin[47]	Yearly Mean Harvested[48]	Harvesting Locations Within SEA Study Area[49]	Seasons and Months Harvested[50]
Harbor seal	4	• Cyrus Field Bay, Lupton Channel, Beare Sound, and north, west, and east coasts off Loks Land (harbour seal uncommon in this area, opportunistically hunted while waterfowl hunting) • Near Lefferts Island and the coast of Loks Land • Coastal and mouth area of Frobisher Bay (harbour seal uncommon in this area, opportunistically hunted while waterfowl hunting) • Southeast Meta Incognita Peninsula, Savage and Edgell islands, northern Resolution Island, and Gabriel Strait (harbour seals uncommon in area, opportunistically hunted while waterfowl hunting)	June, July, August, October, December
Hooded seal	8	• Southern coast of mouth of Frobisher Bay and further south to areas adjacent to Potter, Gross, and Palmer islands • Occasionally, coastal area of Meta Incognita Peninsula, Annapolis and Gabriel straits	July, August, September, October, November, December
Walrus/akvik	20	• Ward Inlet • Hamlen Bay • Between Gabriel Island and Sharko Peninsula • Southern coast at mouth of Frobisher Bay and further south to areas adjacent to Potter, Gross, and Palmer islands • Historically, coastal area adjacent to Meta Incognita Peninsula	March, April, June, July, August, September, October, November, December[56]
Whale (unspecified)	NA	• Historically, coastal area adjacent to Meta Incognita Peninsula	Not indicated
Narwhal/tuugaak	1	• Entire head of Frobisher Bay (occasionally seen and hunted in this area) • Between Gabriel Island and Sharko Peninsula	April, May, June, July[57]

[56] Iqaluit residents hunt for walrus between Gabriel Island and Sharko Peninsula in April and May at the floe-edge, and at Ward Inlet and Hamlen Bay in the fall (Riewe 1992a).
[57] Iqaluit residents hunt narwhal between Gabriel Island and Sharko Peninsula in April and May at the floe-edge (Riewe 1992a).

Table 5.40 Harvesting by Residents of Iqaluit

Species/Umajuin[47]	Yearly Mean Harvested[48]	Harvesting Locations Within SEA Study Area[49]	Seasons and Months Harvested[50]
Beluga/kilalugak	45	• Central Frobisher Bay, along west side	June, July, August, September, October, November Spring[58]
White whale	70[59]	• Entire head of Frobisher Bay • Between Gabriel Island and Sharko Peninsula	April-May, July-October[60]
Waterfowl (unspecified)	NA	• Southern head Frobisher Bay • Coastal and mouth area of Frobisher Bay • Along York River, Meta Incognita coast along Frobisher Bay • Kendall Strait and near Gross and Potter islands (waterfowl and eggs) • Gabriel and Graves straits (waterfowl and eggs) • Historically, Meta Incognita Peninsula along Hudson Strait coast • Historically, waters of York and Jackman sounds, adjacent streams and lakes	Nesting season Summer
Goose (unspecified)	4	Not indicated	May
Snow goose/kanguq	16	Not indicated	May, June
Canada goose/nikliknik	16	Not indicated	April, May, June, August, September
Eider duck/kingalik	127	• Southern head Frobisher Bay • Islands in central Frobisher Bay “a portion of Iqaluit annual take of up to 500 eiders may come from this harvest area” (Riewe 1992a) • Kendall Strait and near Gross and Potter islands • Gabriel and Graves straits	March, April, May, June, July, August, September, October, November

[58] Iqaluit residents hunt beluga on the west-central side of Frobisher Bay in the spring (Riewe 1992a).
[59] (Riewe 1992a).
[60] Iqaluit residents hunt white whale between Gabriel Island and Sharko Peninsula in April and May at the floe-edge; hunting in Frobisher Bay is undertaken from July through October (Riewe 1992a).

Table 5.40 Harvesting by Residents of Iqaluit

Species/Umajuin[47]	Yearly Mean Harvested[48]	Harvesting Locations Within SEA Study Area[49]	Seasons and Months Harvested[50]
Red-breasted merganser/ red-breasted merganser	1	Not indicated	October
Black guillemot/black guillemot	9	Not indicated	May, August, September, October
Thick-billed murre/thick billed murre	2	Not indicated	November
Ptarmigan/akilgik	2,960	• Northwest coast and inland area of Frobisher Bay	January to December
Goose eggs/uluaguliit manniit	1	Not indicated	June, July
Duck eggs/tinmiat manniit	1,294	• Southern head Frobisher Bay • Islands in central Frobisher Bay • Kendall Strait and near Gross and Potter islands • Gabriel and Graves straits	June, July
Eider down/mitiit qiviungit	60	Not indicated	June, July
Fish (unspecified)	NA	• Historically, Meta Incognita Peninsula along Hudson Strait coast	Not indicated

Table 5.40 Harvesting by Residents of Iqaluit

Species/Umajuin[47]	Yearly Mean Harvested[48]	Harvesting Locations Within SEA Study Area[49]	Seasons and Months Harvested[50]
Arctic char/ikaliviit	6,264	• Jordan River, at the head of Foul Inlet • Entire head of Frobisher Bay, from Foul to Tarr Inlet • Heads of Ward Inlet and Cormack Bay • Mouth of Armshow River, several lakes along west shore of Frobisher Bay • Frenchman Cove • Small lake on Oogah River, upstream of river mouth at Ney Harbour head, Meta Incognita coast along Frobisher Bay • Waters of York and Jackman sounds, adjacent streams and lakes • Lakes along Meta Incognita coast along Frobisher Bay (for land-locked Arctic char)	January to December[61]
Cod/ugak	53	• Tidal lake at head of Ney Harbour, Meta Incognita coast along Frobisher Bay	January, June, August, December
Sculpin/kanayuk	68	Not indicated	July, August, September, October
Clams/uviluq	6,147	Not indicated	July, August, September, October, November

[61] Iqaluit residents fish for Arctic char in York and Jackman sounds, its adjacent streams and lakes in late summer (Riewe 1992a).

Changes in local weather and environmental conditions are affecting the ability of Iqaluit residents to access traditional resources. There were numerous comments in the publicly available literature regarding the unpredictability of the weather:

> It is getting more unpredictable as to what will happen, because the signs are misleading the Inuit who are used to weather that follows these signs. (Joamie, S. as cited in Nunavut Department of Environment 2005)

> The weather seems to be a little less sure, but all I can say is that the weather always changes and is unpredictable year to year, because some days, some seasons and years do not behave exactly as the years before them. (Boas, H. as cited in Nunavut Department of Environment 2005)

> [It] feels like summer already during springtime, during what we traditionally call spring… (Boaz, H. as cited in Nunavut Climate Change Centre n.d.)

> We are experiencing very short springs where the snow melts right away. This affects our ability to hunt in the spring with snowmobiles. Before, we used to be able to snowmobile on the land and ice until late spring around late June. Nowadays, the ice is always melting and we cannot go camping for as long as we want. (Mike as cited in Nunavut Department of Environment 2005)

> Back then, snow would not melt until late June, but today snow melts way earlier. As a matter of fact, the ice is late and we can boat until the end of November, even me, I went boating during this period. If this were the old days, we would not need a boat at that time. As a matter of fact, these last couple years we have been boating until the end of November and even into December, Inuit were still boating around in the bay hunting seals…I guess there are drawbacks, but for the Inuit who like boating, it is right up their alley. It is beneficial to them. But the people who do not have boats are affected in that they cannot go hunting until the ice forms. (Joamie, S. as cited in Nunavut Department of Environment 2005)

Changes in winter temperatures have also been observed. Iqaluit residents reported to the Nunavut Climate Change Centre that temperatures in winter were rising, while others reported that they were dropping (Nunavut Tunngavik Inc. 2005).

Changes in temperature affect traditional harvesting conditions such as ice thickness and texture:

> The lakes and rivers are starting to get mushy earlier and they become impassable in only a few days. Even before the traditional time of ice melting, the ice is getting dangerous to traverse. The lakes have thinner ice and does not hang around. These days the ice melts earlier and becomes crystallized way earlier where you cannot stand on it. (Mike, E. as cited in Nunavut Department of Environment 2005).

> The ice thickness has changed. I do not go out as much as before, so I can only tell you what I have heard from those who are still fishing in the winter. From their words, the ice is way thinner than the normal levels. When we used to fish the lakes for food, when we were chipping away at the ice, sometimes it would be over our heads. That is how thick it was. Luckily, no one ever drowned in one of the holes. It used to be really thick in those days when all we had were hand chippers. As well, when we lived in a camp near Kimmirut, the ice used to be really thick. Up there, the Inuit living in the shadows apparently required steps to climb out of the holes they were chipping for their nets. That is how thick they were. (Boaz, H. as cited in Nunavut Department of Environment 2005)

Changes in wind patterns are also affecting residents of Iqaluit, creating potentially unsafe conditions for harvesting:

> The upcoming wind is harder to predict and the fact that the winds are now not as steady in their direction is noticeable, such as the fact that the winds are now very shifty and continually move. (Joamie, S. as cited in Nunavut Department of Environment 2005)

> Nowadays we are getting wind from everywhere. The winds are shifty and constantly changing their point of origin. The weather signs point towards a clear calm day, but the winds suddenly whips up and that is how it seems to operate in this day and age. (Mike, E. as cited in Nunavut Department of Environment 2005)

> Every time I go along on a trip, I am scared of the wind because I do not know from when it will come now. (Koomarjuk, J. as cited in Nunavut Department of Environment 2005)

5.9.6 Kimmirut

Table 5.41 shows species harvested, harvesting locations, months or seasons in which species are harvested, as well the mean number of any given species harvested annually for the period 1996 to 2001 by Kimmirut hunters. The table combines results primarily from the Nunavut Wildlife Harvest Study and the Nunavut Atlas. Results from the Nunavut Wildlife Harvest Study were collected from a total of 114 registered Kimmirut harvesters out of a total approximate population of 408, current as of 1999.

Table 5.41 Harvesting by Residents of Kimmirut[62]

Species/Umajuin[63]	Yearly Mean Harvested[64]	Harvesting Locations Within SEA Study Area[65]	Seasons and Months Harvested[66]
Caribou/tuktut	333	• South inland coast of Meta Incognita Peninsula • Coastal and mouth area of Frobisher Bay • Meta Incognita Peninsula and adjacent coastal waters	January to December
Polar bear/nanuit	10	• Entire southern coast and adjacent waters/ice of Meta Incognita Peninsula • Middle Savage Islands—Thompson Island area (favoured) • Historically, coastal area adjacent to Meta Incognita Peninsula • Meta Incognita Peninsula and adjacent coastal waters	January, October, November, December
Wolf/amagut	9	Not indicated	January, February, March, April, May, December
Arctic fox/tigiganiat	25	• Shores of Big Island • South inland coast of Meta Incognita Peninsula • Historically, coastal area adjacent to Meta Incognita Peninsula	January, February, March, April, May, October, November, December
Coloured fox/ kalaliit tigiganiat	11	Not indicated	January, February, April, October, November, December
Arctic hare/ukalik	67	Not indicated	January, February, March, April, May, June, August, September, October, November, December
Seal (unspecified)	NA[67]	• Historically, coastal area of Meta Incognita Peninsula, Annapolis and Gabriel straits • Coastal and mouth area of Frobisher Bay	Mostly summer In winter and spring at the floe edge

[62] The Nunavut Atlas uses the former name of Lake Harbour to refer to residents of Kimmirut (Riewe 1992a).
[63] (Priest and Usher 2004); (Riewe 1992a).
[64] (Priest and Usher 2004).
[65] (Riewe 1992a). In some cases, locations have been generalized from the maps contained within The Nunavut Atlas.
[66] (Priest and Usher 2004); (Riewe 1992a).
[67] Riewe reported that the annual harvest of seals for residents of Kimmirut ranged from one to several thousand a year (Riewe 1992a).

Table 5.41 Harvesting by Residents of Kimmirut[62]

Species/Umajuin[63]	Yearly Mean Harvested[64]	Harvesting Locations Within SEA Study Area[65]	Seasons and Months Harvested[66]
Ringed seal/natiinat	865	• Entire southern coast & adjacent waters/ice of Meta Incognita Peninsula • Coastal area of Meta Incognita Peninsula, Annapolis and Gabriel straits	January to December
Bearded seal/ukyuk	38	• Entire southern coast and adjacent waters of Meta Incognita Peninsula • Coastal area of Meta Incognita Peninsula, Annapolis and Gabriel straits	January, February, March, April, May, June, July, August, September, October, November[68]
Harp seal/qairulik	33	• Entire southern coast and adjacent waters of Meta Incognita Peninsula • Coastal area of Meta Incognita Peninsula, Annapolis and Gabriel straits	January, March, June, July, August, September, October, November, December[69]
Harbor seal/qanigiaq	3	• Entire southern coast and adjacent waters of Meta Incognita Peninsula • Coastal and mouth area of Frobisher Bay (harbour seal uncommon in this area, done in conjunction with waterfowl hunting)	July, August, September, October, November
Hooded seal	1	• Coastal area of Meta Incognita Peninsula, Annapolis and Gabriel straits	July, August, October, November
Walrus/akvik	2	• Entire southern coast & adjacent waters/ice of Meta Incognita Peninsula • Historically, coastal area adjacent to Meta Incognita Peninsula	March, April, August, September, November Winter and spring at the floe edge
Whale (unspecified)	NA	• Entire southern coast & adjacent waters/ice of Meta Incognita Peninsula • Historically, coastal area adjacent to Meta Incognita Peninsula	Not indicated
Narwhal	NA	• North Bay	Summer (rarely)
Beluga/kilalugak	15[70]	• South and east of Big Island • Coast between Shaftsbury Inlet and Cape Wight • Markham Bay (sometimes)	April, May, June, July, August, October, November April to June at the floe edge[71]

[68] Kimmirut residents hunt bearded seal along the southern coast and adjacent waters of Meta Incognita Peninsula in the summer (Riewe 1992a).
[69] Kimmirut residents hunt harp seal along the southern coast and adjacent waters of Meta Incognita Peninsula in the summer (Riewe 1992a).
[70] In the 1970s, Kimmirut residents harvested up to 100 beluga annually (Riewe 1992a).
[71] Kimmirut residents hunt beluga at Big Island between April and June, along the coasts between Shaftsbury Inlet and Cape Wight from September to October, and sometimes in Markham Bay in the fall (Riewe 1992a).

Table 5.41 Harvesting by Residents of Kimmirut[62]

Species/Umajuin[63]	Yearly Mean Harvested[64]	Harvesting Locations Within SEA Study Area[65]	Seasons and Months Harvested[66]
Waterfowl	NA	• Entire southern coast and adjacent waters of Meta Incognita Peninsula • South inland coast of Meta Incognita Peninsula • Kendall Strait and near Gross and Potter islands • Historically, coastal area adjacent to Meta Incognita Peninsula	Summer
Snow goose/kanguq	31	Not indicated	May, June, August, September
Canada goose/nikliknik	206	Not indicated	April, May, June, July, August, September, October,
Brant goose/nirlimaq	<1	Not indicated	May
Old squaw/aahangik	1	Not indicated	January, December
Pintail/arnaviaq	<1	Not indicated	August, September
Eider duck/kingalik	286	• Middle Savage Islands • Along shores of Big Island • Along shores of Markham Bay • Kendall Strait and near Gross and Potter islands	March, May, June, July, August, September, October, November
Common loon/tuulik	1	Not indicated	July, August
Black guillemot/black guillemot	8	Not indicated	January, September, October, November
Thick-billed murre/thick billed murre	83	Not indicated	March, April, June, July, August, September, October, November
Ptarmigan/akilgik	1,989	Not indicated	January, February, March, April, May, June, August, September, October, November, December
Eggs (unspecified)	41	Not indicated	June

Table 5.41 Harvesting by Residents of Kimmirut[62]

Species/Umajuin[63]	Yearly Mean Harvested[64]	Harvesting Locations Within SEA Study Area[65]	Seasons and Months Harvested[66]
Duck eggs/tinmiat manniit	249	• Middle Savage Islands • Along shores of Big Island • Along shores of Markham Bay • Kendall Strait and near Gross and Potter islands	June, July
Seagull eggs/nauyat manniit	14	Not indicated	June
Eider down/mitiit qiviungit	<1	Not indicated	June
Fish	NA	• South inland coast of Meta Incognita Peninsula	Not indicated
Arctic char/ikaliviit	4,174	• Entire southern coast and adjacent waters of Meta Incognita Peninsula	January to December
Inconnu/aanakhiik	3	Not indicated	February, June, December
Cod/ugak	631	Not indicated	January to December
Sculpin/kanayuk	15	Not indicated	February, July, September, November
Clams/uviluq	6,947	Not indicated	June, July, August, September, October, November, December
Mussels/uviluvaloet	355	Not indicated	June, July, August, September, October

It was noted that, despite a decline in the populations of migrating whales, harvesting by Kimmirut residents occurs in the same general areas as previously in the spring, summer, and fall and is conducted primarily from the floe edge (Westdal and Ferguson 2009).

5.9.7 Pangnirtung

Table 5.42 shows species harvested, harvesting locations, months or seasons in which species are harvested, as well the mean number of any given species harvested for the period 1996 to 2001 by Pangnirtung hunters. The table combines results primarily from the Nunavut Wildlife Harvest Study and the Nunavut Atlas. Results from the Nunavut Wildlife Harvest Study were collected from a total of 224 registered Pangnirtung harvesters out of a total approximate population of 1,354, current as of 1999.

Table 5.42 Harvesting by Residents of Pangnirtung

Species/Umajuin[72]	Yearly Mean Harvested[73]	Harvesting Locations Within SEA Study Area[74]	Seasons and Months Harvested[75]
Caribou/tuktut	2,098	• Occasionally along travel routes inland from Ujuktuk Fiord and Kumlein Fiord • Leybourne and Lemieux islands, and vicinity of Lemieux Islands • Hoare Bay, along fiord heads and river valleys (historically) • Kingnait Fiord, shores and head • Highlands inland from Ptarmigan Fiord • Entire west coast of Cumberland Sound used intensively • Nettilling Lake and Cumberland Sound considered main location • Adjacent to Nettilling and Kangilo fiords (by boat)	January to December[76]
Polar bear/nanuit	12	• Exeter Sound • Totnes Road • Coast of Cumberland Peninsula from Nijadluk Harbour to Kingnait Fiord (intensively used) • Cumberland Sound, fiords adjacent to the northern part of Cumberland Sound, area between Hoare and Exeter bays • Hoare Bay area (50-75% of annual quota from here) • Occasionally along travel routes inland from Ujuktuk Fiord and Kumlein Fiord • Leybourne Islands • Around Hozier Island (traditional polar bear hunting area) • Davis Strait by Lemieux Islands	January to May, December[77]

[72] (Priest and Usher 2004); (Riewe 1992a).
[73] (Priest and Usher 2004).
[74] (Riewe 1992a). In some cases, locations have been generalized from the maps contained within The Nunavut Atlas.
[75] (Priest and Usher 2004); (Riewe 1992a).
[76] Pangnirtung residents hunt caribou along west coast of Cumberland Sound year-round, but particularly when travel by snowmobile is possible in late fall, winter and early spring. Caribou are hunted in areas adjacent to Nettilling and Kangilo fiords by boats in summer and fall (Riewe 1992a).
[77] Pangnirtung residents hunt polar bear in Exeter Sound, Exeter Bay, and Totnes Road in winter and spring and in Cumberland Sound from April to June at the floe-edge (Riewe 1992a).

Table 5.42 Harvesting by Residents of Pangnirtung

Species/Umajuin[72]	Yearly Mean Harvested[73]	Harvesting Locations Within SEA Study Area[74]	Seasons and Months Harvested[75]
Wolf/amagut	9	Not indicated	January to May, June, August, September
Arctic fox/tigiganiat	7	Not indicated	January to March, November, December
Coloured fox/ kalaliit tigiganiat	8	Not indicated	January, February, November, December
Arctic hare/ukalik	76	Not indicated	January to April, August to December
Sea mammal (unspecified)	NA	• Mouth of Cumberland Sound (used infrequently)	Not indicated
Seals (unspecified)/natiit	39	• Cumberland Sound • Vicinity of Lemieux Islands • Traditionally, Hoare Bay	April, May, June, October, November[78]
Ringed seal/natiinat	6,098	• Exeter Sound • Exeter Bay • Totnes Road • Cumberland Sound (up to 5400 annually) • Coast of Cumberland Peninsula from Nijadluk Harbour to Kingnait Fiord (intensively used) • Most taken from northern part of Cumberland Sound and adjacent fiords • Recurring polynyas off Shomeo Point, mouth of Kingnait Fiord, and Littlecote Channel • Hoare Bay • Miliakdjuin Island (favoured for newborn pups)	January to December[79]
Bearded seal/ukyuk	84	• Coast of Cumberland Peninsula from Nijadluk Harbour to Kingnait Fiord (intensively used) • Northern part of Cumberland Sound and adjacent fiords	January to December

[78] Pangnirtung residents hunt seal in Cumberland Sound from April to June at the floe edge (Riewe 1992a).
[79] Pangnirtung residents hunt ringed seal in Exeter Sound, Exeter Bay, and Totnes Road in winter and spring (Riewe 1992a).

Table 5.42 Harvesting by Residents of Pangnirtung

Species/Umajuin[72]	Yearly Mean Harvested[73]	Harvesting Locations Within SEA Study Area[74]	Seasons and Months Harvested[75]
Harp seal/qairulik	331	• Cumberland Sound (up to 4800 annually until pelt market collapsed) • Coast of Cumberland Peninsula from Nijadluk Harbour to Kingnait Fiord (intensively used) • Most taken from northern part of Cumberland Sound and adjacent fiords	May to December
Hooded seal / nahakakaktututittut natiit	33	Not indicated	September to December
Walrus/akvik	16	• Coast of Cumberland Peninsula from Nijadluk Harbour to Kingnait Fiord (intensively used) • Cumberland Sound • Lemieux Islands and vicinity • Hoare Bay	April to September Winter, spring, summer[80]
Narwhal/tuugaak	34	• Vicinity of Clearwater Fiord, a traditional whaling area, most of quota taken from here annually • Cumberland Sound and its fiords	April to November[81]
Beluga/kilalugak	35[82]	• Vicinity of Clearwater Fiord, a traditional whaling area • Cumberland Sound and its fiords (approximately 50[83] taken per year)	Year round[84]
Bowhead/aivik	<1	Not indicated	July
Waterfowl (unspecified)		• Northern part of Cumberland Sound and adjacent fiords	Not indicated
Snow goose/kanguq	1	Not indicated	June
Canada goose/nikliknik	91	Not indicated	May to August

[80] Pangnirtung residents hunt walrus in Cumberland Sound from April to June at the floe-edge and in Hoare Bay in winter, spring, and summer (Riewe 1992a).
[81] Pangnirtung residents hunt narwhal in Cumberland Sound from April to June at the floe-edge and around Clearwater Fiord in summer (Riewe 1992a).
[82] (Priest and Usher 2004).
[83] (Riewe 1992a)
[84] Pangnirtung residents hunt beluga in Cumberland Sound from April to June at the floe-edge and around Clearwater Fiord in summer (Nunavut Wildlife Management Board (NWMB) 1998; Riewe 1992b). The greatest intensity of hunting occurs in Cumberland Sound in the summer (Nunavut Wildlife Management Board (NWMB) 1998).

Table 5.42 Harvesting by Residents of Pangnirtung

Species/Umajuin[72]	Yearly Mean Harvested[73]	Harvesting Locations Within SEA Study Area[74]	Seasons and Months Harvested[75]
Eider duck/kingalik	1,297	• Northern part of Cumberland Sound and adjacent fiords (most hunted here)	May to December
Thick-billed murre/thick billed murre	1	Not indicated	September
Ptarmigan/akilgik	1,422	Not indicated	January to May, August to December
Eggs (unspecified)/manniit	78	Not indicated	July
Duck eggs/tinmiat manniit	2,274	Not indicated	June, July
Arctic char/ikaliviit	35,065	• Coastal areas of Cumberland Sound, fiords in northern part of Cumberland Sound, and all rivers at head of Cumberland Sound	January to December
Cod/ugak	566	Not indicated	February to May, August, December
Sculpin/kanayuk	33	Not indicated	February, July
Turbot/natnaarnak	5,315	Not indicated	February to May
Clams/uviluq	1,001	Not indicated	July to September

Changes in local weather and environmental conditions are affecting the ability of Pangnirtung residents to access traditional resources. IQ in publicly available literature highlights the change in the predictability of the weather, changes in wind patterns, and changes in snow and ice conditions, all of which affect the ability of Pangnirtung residents to access traditional resources safely.

> Nowadays, the weather is quite different according to my observations as I said I am no academic professor, but the wind seems to spring out of nowhere and when the clouds start to change, it is immediate and the wind springs up right away, even during the spring. (Uniuqsaagaq, I. 2002, as cited in Nunavut Department of Environment 2005)

> The weather is completely different now. The winter is a lot shorter in terms of timing and months. The changes are quite obvious and the way spring arrives now, with a rush and the way the snow has melted off the land so quickly, including all of the ice on the water, these are changes that are different from the past…The weather changes all of a sudden, without the weather preparing a warning. The wind picks up, the storm starts and once it starts to go, then it proceeds right away these days. It is not as ambivalent as in the past. (Novaqilk, M. 2002, as cited in Nunavut Department of Environment 2005)

> The winter is seemingly a shadow of its former self. It is quite short now and the dark period is when we had ice to travel on, at least starting from November we would be traveling by dog team on the ice. Nowadays, it is right up to December and even right up to Christmas that Inuit are out boating in the fiord. That is how much it has changed since my youth. You can now boat during the twelve days of Christmas. It was unheard of in the old days. (Qarpik, J. 2002, as cited in Nunavut Department of Environment 2005)

> The changes I've seen on ice are that before 1962 the ice conditions were good those years. The ice condition changed after 1962. As a hunter, I started noticing that ice was starting to form very late. Around 1960 the ice used to form early. When it had formed the ice conditions were good those days, but after 1960's even though the ice has formed, it was still not good to use. Those days the ice used to form completely during January. The ice at that time is completely formed as we can go just about everywhere to hunt/camp. The other changes I've seen on the ice condition is that during April, the ice seems like it would be good to use but it usually started breaking earlier. There was even a time when it was May the ice wasn't useable. It wasn't like that before. We even used to come to Pangnirtung with our dog teams in June those years but these days it's impossible. We even have started boating around May. That's how it had changed since before, with the paths we used when we go hunting/camping. (Keenaiak, A. 2002, as cited in Nunavut Department of Environment 2005)

> Sea ice does not form in places where it used to, as if there were strong currents there, but these have not changed, ice forms about two months behind and breaks up earlier than usual…polynyas all over the place now and polynyas occurring in April, that never happened in the past…it's too early… (Novaqilik, M. 2002, as cited in Nunavut

Department of Environment 2005)(see also Nunavut Department of Environment (n.d.) for concerns regarding effects of changing sea ice on fishing practices)

The area where I live, the ice condition is good, lots of snow. But those days the path used to be easy to use as a routine but these days we have to use the area close to the beach because the conditions gets dangerous. These areas weren't dangerous before. There is this island close to my camp that I can use an example. The path is usually good to use in winter seasons but these days, it's kind of impossible to use. The point of the island's ice condition used to be useable but these days the ice condition is usually thin, even during winter season. If you don't know the area, it is considered dangerous because you don't know the area. (Qijuaqjuk, M. 2002, as cited in Nunavut Department of Environment 2005)

The way snow forms these days is a lot lesser than before. We used to get lots of snow, but nowadays we get less. The snow on the ground melts quicker these days. Those days the snow didn't melt that quick like today. It is probably due to not enough snow on the ground. It used to be good for our sleds, when the snow was good for longer periods of time. These days, it is still good but only for a shorter period of time. (Nauyk 2002, as cited in Nunavut Department of Environment 2005)

5.9.8 Pond Inlet

Table 5.43 shows species harvested, harvesting locations, months or seasons in which species are harvested, as well the mean number of any given species harvested annually for the period 1996 to 2001 by Pond Inlet hunters. The table combines results primarily from the Nunavut Wildlife Harvest Study and the Nunavut Atlas. Results from the Nunavut Wildlife Harvest Study were collected from a total of 408 registered Pond Inlet harvesters out of a total approximate population of 1,240, current as of 1999.

Table 5.43 Harvesting by Residents of Pond Inlet

Species/Umajuin[85]	Yearly Mean Harvested[86]	Harvesting Locations Within SEA Study Area[87]	Seasons and Months Harvested[88]
Caribou/tuktut	1,828	• Northern Steensby Peninsula • Milne Inlet, coastal area[89] • Eclipse Sound • Large area southwest of Pond Inlet • Bylot Island, including Button Point[90]	January to December[91]
Musk-ox/umingmait	1	Not indicated	March, April
Polar bear/nanuit	18	• Borden Peninsula, coastal area • Navy Board Inlet, coastal area • Bylot Island, coastal area • All marine areas through Eclipse Sound and out into Baffin Bay, except south of Emerson Island • Eclipse Sound • Offshore Baffin Bay fast ice • Marine area and all fiords around Clyde River	January to May (near-shore-fast ice and at floe edge), August to December[92]
Wolf/amagut	13	• Large area southwest of Pond Inlet (hunted when encountered, in tandem with caribou hunting)	January to June, August, November, December

[85] (Priest and Usher 2004); (Riewe 1992a).
[86] (Priest and Usher 2004).
[87] (Riewe 1992a). In some cases, locations have been generalized from the maps contained within The Nunavut Atlas.
[88] (Priest and Usher 2004); (Riewe 1992a).
[89] Jenkins and Goorts (2013). “Always in the summer we used to get caribou, every year. Along the beach. Didn't have to go inland, just go by boat and get what we want. Along the beach. Anyone looking for caribou could spot one by boat. It was easy ... From the 60's to the 1990's by boat” (Elijah Panipakoocho, as cited in Jenkins and Goorts 2013).
[90] Jenkins and Goorts (2013). Caribou were harvested near Pond Inlet and Bylot Island starting in the 1990s.
[91] Pond Inlet residents hunt caribou on northern Steensby Peninsula and west of Milne Inlet in spring and summer, and the area southwest of Pond Inlet in the fall, winter, and spring (Riewe 1992a).
[92] Pond Inlet residents hunt polar bear on the northeast coast of Bylot Island from January through March, while the period of March and April allows for polar bear hunting in the offshore Baffin Bay area because the growth of new fast ice is encouraged by grounded icebergs and a reduction in the current (Riewe 1992a).

Table 5.43 Harvesting by Residents of Pond Inlet

Species/Umajuin[85]	Yearly Mean Harvested[86]	Harvesting Locations Within SEA Study Area[87]	Seasons and Months Harvested[88]
Arctic fox/tigiganiat	38	• Borden Peninsula, coastal area • Navy Board Inlet, coastal area • Bylot Island, coastal area • Pond Inlet, coastal area • Shores of Eclipse Sound • Shores of Milne Inlet	January to May, October to December
Coloured fox/ kalaliit tigiganiat	17	Not indicated	January to April, September to December
Arctic hare/ukalik	105	Not indicated	January to December
Seals (species not indicated)	0	• Borden Peninsula • Navy Board Inlet • Inlets and fiords off Eclipse Sound, including Tay Sound, Paquet Bay, and North Arm • South of Cape Walter Bathurst • Offshore Baffin Bay fast ice (reduced current and grounded icebergs in March and April create new fast ice for seal hunting)	November Winter at breathing holes Summer in open water
Ringed seal/natiinat	2,113	• Navy Board Inlet • Eclipse Sound • Milne Inlet • All marine areas through Eclipse Sound and out into Baffin Bay used intensively • Marine area and all fiords around Clyde River (mainly for silver jars in spring)	January to December
Bearded seal/ukyuk	28	• Navy Board Inlet • Eclipse Sound • Milne Inlet • All marine areas through Eclipse Sound and out into Baffin Bay used intensively	January, May, July to December

Table 5.43 Harvesting by Residents of Pond Inlet

Species/Umajuin[85]	Yearly Mean Harvested[86]	Harvesting Locations Within SEA Study Area[87]	Seasons and Months Harvested[88]
Harp seal/qairulik	29	Not indicated	July to November
Hooded seal/nahakakatutut ittut natiit	2	Not indicated	June to October
Walrus/akvik	5	• Wollaston Islands, which has one haul-out site • Eastern end of Pond Inlet • Northern part of Milne Inlet • Eclipse Sound • Entire coastal area of northeastern Bylot Island	February, May, June to September Spring at floe edge Summer in open water and at haul-Out sites Winter
Narwhal/tuugaak	119	• Navy Board Inlet • Southern Lancaster Sound • All marine areas through Eclipse Sound and out into Baffin Bay, except Oliver Sound and Paquet Bay • Eclipse Sound • Milne Inlet • South of Cape Walter Bathurst • Marine area and all fiords around Clyde River • Buchan Gulf • Feachem Bay (favoured harvesting location)	May to September[93]
Beluga/kilalugak	1	• Eclipse Sound • Milne Inlet	July, September, October
Waterfowl (unspecified)	NA	• Shores of Navy Board Inlet	Not indicated

[93] Pond Inlet residents hunt narwhal at Navy Board Inlet, southern Lancaster Sound, all marine areas through Eclipse Sound, and all marine areas around Clyde River in spring and summer, Milne Inlet in summer, and Buchan Gulf and Feachem Bay throughout open-water season (Riewe 1992a).

Table 5.43 Harvesting by Residents of Pond Inlet

Species/Umajuin[85]	Yearly Mean Harvested[86]	Harvesting Locations Within SEA Study Area[87]	Seasons and Months Harvested[88]
Goose (unspecified)	NA	• Ipitalik Peninsula • Mouth of Tugaat River • Southwest end of Pacquet Bay • Wet lowland tundra of southwest Bylot Island	Spring to fall[94]
Snow goose/kanguq	536	• Major hunting area is southwest Bylot Island • Southwest side of Tay Sound	May to September
Canada goose/nikliknik	3	Not indicated	April, May, June, September
Brant goose/nirlimaq	<1	Not indicated	August
White-fronted goose/nirlivik	11	Not indicated	June
Duck (unspecified)	NA	• Coastal waters of Bylot Island • Marine area by southeast Bylot Island • Waters of Guys Bight • Erik Harbour • Tay Sound	Not indicated
Old squaw/aahangik	<1	Not indicated	June
Eider duck/kingalik	30	Not indicated	April to November
Red-breasted merganser/ red-breasted merganser	<1	Not indicated	August
Red-throated loon/qaqhauq	1	Not indicated	July, August
Black guillemot/black guillemot	2	Not indicated	August to October

[94] Residents of Pond Inlet hunt geese at the southwest end of Pacquet Bay from late spring into summer, and in the lowlands of southwest Bylot Island from spring into fall (Riewe 1992a).

Table 5.43 Harvesting by Residents of Pond Inlet

Species/Umajuin[85]	Yearly Mean Harvested[86]	Harvesting Locations Within SEA Study Area[87]	Seasons and Months Harvested[88]
Thick-billed murre/thick billed murre	3	Not indicated	May to July, October
Ptarmigan/akilgik	926	Not indicated	January to December
Sandhill crane/tatilgaq	2	Not indicated	May, June, August
Goose eggs/uluaguliit manniit	1,494	Not indicated	June, July
Duck eggs/tinmiat manniit	1	Not indicated	June, July
Seagull eggs/nauyat manniit	2	Not indicated	June
Thick-billed murre eggs/thick-billed murre eggs	2,601	Not indicated	June, July
Arctic char/ikaliviit	12,114	Not indicated	January to December
Cod/ugak	6	Not indicated	June, August
Sculpin/kanayuk	47	Not indicated	June, July, October
Clams/uviluq	1	Not indicated	August

As with residents elsewhere in the Area of Focus, residents of Pond Inlet have observed changes in the local weather and environmental conditions, including changes in the quality of ice, cracks in land-fast ice, ice break-up and freeze-up timing, iceberg numbers, the extent of the floe edge, the state of glaciers, and amount of snow. Responses reported in Dowsley (2005) varied. For example, regarding the ice around the Button Point hunting area, residents of Pond Inlet described the ice as thinner, non-existent, and smoother, a quality which now allows for the use of snowmobiles, which had not been possible before (Dowsley 2005).

5.9.9 Qikiqtarjuaq

Table 5.44 shows species harvested, harvesting locations, months or seasons in which species are harvested, as well the mean number of any given species harvested annually for the period 1996 to 2001 by Qikiqtarjuaq hunters. The table combines results primarily from the Nunavut Wildlife Harvest Study and the Nunavut Atlas. Results from the Nunavut Wildlife Harvest Study were collected from a total of 192 registered Qikiqtarjuaq harvesters out of a total approximate population of 508, current as of 1999.

Table 5.44 Harvesting by Residents of Qikiqtarjuaq

Species/Umajuin[95]	Yearly Mean Harvested[96]	Harvesting Locations Within SEA Study Area[97]	Seasons and Months Harvested[98]
Caribou/tuktut	120	• Formerly hunted in Exeter Sound and Exeter Bay, but caribou here are scarce now • West and north of Broughton Island, as well as the valleys at the heads of some fiords, caribou are scarce here99 • From the heads of Nudlung and Confederation fiords inland	January to October[100]
Polar bear/nanuit	13	• All fiords, inlets, bays from Broughton Island to Cape Dyer • Southeast of Cape Hooper • Maktak, Coronation, and North Pangnirtung fiords • Kivitoo area • Hoare Bay, traditional polar bear hunting area, used infrequently now	January, October to December Winter and spring[101]
Wolf/amagut	<1	Not indicated	June
Arctic fox/tigiganiat	9	• Maktak Fiord	January to March
Coloured fox/ kalaliit tigiganiat	1	Not indicated	January, February, November, December
Arctic hare/ukalik	24	Not indicated	January to June, August to December
Seal (unspecified)	NA	• Hoare Bay, traditional seal hunting area, used infrequently now	Not indicated

[95] (Priest and Usher 2004); (Riewe 1992a).
[96] (Priest and Usher 2004).
[97] (Riewe 1992a). In some cases, locations have been generalized from the maps contained within The Nunavut Atlas.
[98] (Priest and Usher 2004); (Riewe 1992a).
[99] Qikiqtarjuaq residents reported wanting to transplant caribou to this area in the future (Riewe 1992a).
[100] Caribou are hunted by residents of Qikiqtarjuaq in Nudlung and Confederation fiords, as well as inland, year round (Riewe 1992a).
[101] Polar bear are hunted by residents of Qikiqtarjuaq in marine areas from Broughton Island and Cape Dyer, as well as southeast of Cape Hooper in the winter and spring. Near Kivitoo, polar bear are also hunted at the floe-edge in spring, up to 50 miles out from Kivitoo (Riewe 1992a).

Table 5.44 Harvesting by Residents of Qikiqtarjuaq

Species/Umajuin[95]	Yearly Mean Harvested[96]	Harvesting Locations Within SEA Study Area[97]	Seasons and Months Harvested[98]
Ringed seal/natiinat	2,950	• Exeter Sound • Exeter bay • Totnes Road • All fiords, inlets, bays from Broughton Island to Cape Dyer • Merchants Bay (highly productive) • Throughout Home Bay, intensively hunted, especially for silver jars • Throughout the marine nearshore and all fiords of Davis Strait coast north and west of Broughton Island • Kivitoo area • East of Broughton Island • Home Bay, intensive hunting, especially of silver jars	January to December Spring at floe-edge[102]
Bearded seal/ukyuk	22	• All fiords, inlets, bays from Broughton Island to Cape Dyer • Mouth of Alexander Bay • Maktak, Coronation, and North Pangnirtung fiords • Okoa Bay	January, February, June to November Summer
Harp seal/qairulik	35	• All fiords, inlets, bays from Broughton Island to Cape Dyer • Mouth of Alexander Bay • Maktak, Coronation, and North Pangnirtung fiords • Kivitoo area	June to November Summer Spring at floe-edge[103]
Walrus/akvik	4	• All fiords, inlets, bays from Broughton Island to Cape Dyer • Mouth of Alexander Bay • Maktak, Coronation, and North Pangnirtung fiords	June to November[104]

[102] Ringed seal are hunted by residents of Qikiqtarjuaq in Exeter Sound, Exeter bay, and Totnes Road in winter and spring, while the marine areas from Broughton Island to Cape Dyer and Merchants Bay are intensively use year round. Near Kivitoo, ringed seals are hunted at the floe-edge in spring, up to 50 miles out from Kivitoo (Riewe 1992a).
[103] Near Kivitoo, harp seals are hunted at the floe-edge in spring, up to 50 miles out from Kivitoo (Riewe 1992a).
[104] Qikiqtarjuaq residents hunt walrus in marine areas between Broughton Island and Cape Dyer when the fast ice breaks up in summer, and hunt from the mouth of Alexander Bay in summer (Riewe 1992a).

Table 5.44 Harvesting by Residents of Qikiqtarjuaq

Species/Umajuin[95]	Yearly Mean Harvested[96]	Harvesting Locations Within SEA Study Area[97]	Seasons and Months Harvested[98]
Narwhal/tuugaak	25	• East of and around Broughton Island • Home Bay and in vicinity of Cape Hooper • Merchants Bay • Padle Fiord • Near Paugnang Island • Ekalugad and Pitchforth fiords • Mouth of Alexander Bay • Maktak, Coronation, and North Pangnirtung fiords • Kivitoo area	June to October[105]
Beluga/kilalugak	1	• Padle Fiord	September Spring at floe edge Summer
Waterfowl (unspecified)	NA	• All fiords, inlets, bays from Broughton Island to Cape Dyer	Spring at floe edge Open water season in fiords
Snow goose/kanguq	6	• Padle River	May to August Nesting season
Canada goose/nikliknik	58	• Padle River	April to October Nesting season
Eider duck/kingalik	128	• Maktak, Coronation, and North Pangnirtung fiords	January, April to November
Tundra swan/kukyuk	<1	Not indicated	June
Yellow-billed loon/tuulik	1	Not indicated	July
Black guillemot/black guillemot	1	Not indicated	June, November
Murre (unspecified)	NA	• Maktak, Coronation, and North Pangnirtung fiords	Not indicated

[105] Qikiqtarjuaq residents hunt narwhal east of Brought Island, at Home Bay, Cape Hooper, and Kivitoo in spring at the floe edge. On open water season, hunting occurs in Home Bay, near Cape Hooper, at Merchants and Alexander bays, Broughton and Paunang islands, and in Padle, Ekalugad, and Pitchforth fiords (Riewe 1992a).

Table 5.44 Harvesting by Residents of Qikiqtarjuaq

Species/Umajuin[95]	Yearly Mean Harvested[96]	Harvesting Locations Within SEA Study Area[97]	Seasons and Months Harvested[98]
Thick-billed murre/thick billed murre	3	Not indicated	July, October
Ptarmigan/akilgik	260	Not indicated	January to August, October to December
Goose eggs/uluaguliit manniit	28	• Padle River	May, June Nesting season
Duck eggs/tinmiat manniit	144	• Small outer islands in Home Bay	June to August
Arctic tern eggs/emitkutailat manniit	113	• Small outer islands in Home Bay	June, July Summer
Seagull eggs/nauyat manniit	41	Not indicated	June
Arctic char/ikaliviit	8,350	• All fiords, inlets, bays from Broughton Island to Cape Dyer, especially fiords, notably Padle Fiord • River valleys, mountain passes, coastal and inland lowland areas between Broughton Island and Cape Dyer • Narpaing Fiord	January to December
Cod/ugak	22	Not indicated	June, August, November
Sculpin/kanayuk	35	Not indicated	June to August
Clams/uviluq	20,353	Not indicated	March, June to December
Mussels/uviluvaloet	571	Not indicated	August

In a Nunavut Environment report published in 2010, Qikiqtarjuaq residents described the geographic range of hunting and fishing activities as approximately 80,000 km^2, centered along the coastline and following the major polynya in the region (Nunavut Department of Environment 2010).

Qikiqtarjuaq residents, as with residents elsewhere in the Area of Focus, have observed changes in local weather and environmental conditions, including less snow, thinner ice, earlier break-up, and warmer temperatures. “[Climate change] has affected our area. In the past we could hunt for different animals further. Now we can’t go further, we have to hunt nearby on the ice” (Dowsley 2005). These changes can affect residents’ ability to harvest traditional resources. For example, early ice break-up challenges the timing of hunting on ice; however, early break-up also means that boats can be used earlier (Dowsley 2005; Nunavut Department of Environment 2010). “I am experiencing [climate change]. In winter there are usually cracks from the points of land and I can put my net under water. But now there are hardly any cracks, so I can’t fish for char anymore” (Dowsley 2005).

5.9.10 Resolute Bay/Qausuittuq

Table 5.45 shows species harvested, harvesting locations, months or seasons in which species are harvested, as well the mean number of any given species harvested annually for the period 1996 to 2001 by Resolute Bay hunters. The table combines results primarily from the Nunavut Wildlife Harvest Study and the Nunavut Atlas. Results from the Nunavut Wildlife Harvest Study were collected from a total of 75 registered Resolute Bay harvesters out of a total approximate population of 174, current as of 1999.

Table 5.45 Harvesting by Residents of Resolute Bay

Species/Umajuin[106]	Yearly Mean Harvested[107]	Harvesting Locations Within SEA Study Area[108]	Seasons and Months Harvested[109]
Caribou/tuktut	17	• Shores of Thomas Lee Inlet, in Jones Sound[110]	January, March, May, July, August, October, November
Musk-ox/umingmait	7	• Shores of Thomas Lee Inlet, in Jones Sound[111]	March, April, May, October, November, December
Polar bear/nanuit	18	• Western end of Jones Bay • Marine area between Devon Island and Somerset Island[112]	January, March, April, May, October, November, December
Wolf/amagut	1		January, March, April, June, November, December
Arctic fox/tigiganiat	31		January, February, March, April, May, October, November, December
Arctic hare/ukalik	4		April, May, June, September, October, December
Seal (unspecified)	NA	• Marine area between Devon Island and Somerset Island	Year round
Ringed seal/natiinat	562		January to December
Bearded seal/ukyuk	20		February, March, April, May, June, July, August, September, October, December
Harp seal/qairulik	7		July, August, September, October
Walrus/akvik	5		January, June, July, August
Narwhal/tuugaak	8		July, August, September

[106] (Priest and Usher 2004); (Riewe 1992a).
[107] (Priest and Usher 2004).
[108] (Riewe 1992a). In some cases, locations have been generalized from the maps contained within The Nunavut Atlas.
[109] (Priest and Usher 2004); (Riewe 1992a).
[110] Resolute Bay residents occasionally hunt caribou along the shores of Thomas Lee Inlet, not necessarily in these locations during all of the months listed (Riewe 1992a); (Priest and Usher 2004).
[111] Resolute Bay residents occasionally hunt muskox along the shores of Thomas Lee Inlet, not necessarily in these locations during all of the months listed (Riewe 1992a); (Priest and Usher 2004).
[112] Resolute Bay residents occasionally hunt polar bear at the western end of Jones Bay and in the marine area between Devon Island and Somerset Island, not necessarily in these locations during all of the months listed (Riewe 1992a).

Table 5.45 Harvesting by Residents of Resolute Bay

Species/Umajuin[106]	Yearly Mean Harvested[107]	Harvesting Locations Within SEA Study Area[108]	Seasons and Months Harvested[109]
Beluga/kilalugak	21		July, August, September
Snow goose/kanguq	17		June, July, August, September
Canada goose	<1		May, June
Brant goose/nirlirnaq	9		June, July, August, September
Old squaw/aahangik	<1		July, August
Eider duck/kingalik	48		June, July, August, September, October
White-winged scoter	<1		June
Common loon/tuulik	<1		July
Red-throated loon/qaqhuaq	<1		July
Thick-billed murre	1		July
Ptarmigan/akilgik	378		February, March, April, May, June, August, September, October
Eggs (species unspecified)/manniit	<1		July
Goose eggs/uluaguliit manniit	3		June, July
Duck eggs/tinmiat manniit	36		June, July
Arctic tern eggs/emitkutailat manniit	9		June, July
Seagull eggs/nauyat manniit	25		June, July
Arctic char/ikaliviit	741		April, May, June, July, August, September, October
Arctic cisco/kapihilik	69		June, July, August
Inconnu/aanakhiik	19		July
Cod/ugak	13		September

Table 5.45 Harvesting by Residents of Resolute Bay

Species/Umajuin[106]	Yearly Mean Harvested[107]	Harvesting Locations Within SEA Study Area[108]	Seasons and Months Harvested[109]
Sculpin/kanayuk	1		May
Turbot/nataarnak	<1		April
Clams/uviluq	163		July, August, September

5.9.11 Changes in Traditional Harvest

Climate change, decreases in cultural transmission, and advances in technology have recently altered the practice of traditional harvest. Nunavummiut stated that language retention and cultural transmission are important tools necessary to adapt to climate change (Nunavut Tunngavik Inc. 2005). In Iqaluit, fishing is an important traditional activity that provides country foods to many residents. Iqaluit fishers are familiar with the history and characteristics of nearby lakes and rivers, and the majority report that the lake ice is thinner in recent years and that lakes freeze later than usual (See Boaz 2002, Mike 2002, Kownirq 2002, and Tiglik 2002 as cited in Nunavut Department of Environment 2005). Nunavummiut have observed unusual plants overtaking the shallow areas of lakes and have attributed it to warming temperatures (Milortuk. 2001, as cited in Nunavut Tunngavik Inc. 2001). Char have been observed having difficulties heading upstream to spawn in certain rivers reducing the harvest yields (Nunavut Tunngavik Inc. 2005). Climate change has also affected traditional harvesting areas, which yield less berries than in the past, and traditional weirs can no longer be used due to changes in water levels. Access to harvesting areas has also been altered due to changes in climate. "Our traditional camp around Committee Bay is mainly gravel interspersed with sandy areas and rocky patches. It is now covered by a diversity of plant growth and it is hard to see the gravel now. We used to travel via boat using a sail and some of the routes we used to navigate are no longer navigable due to some of the areas becoming too shallow," (Qaunaq 2001 as cited in Nunavut Tunngavik Inc. 2001).

Youth are not as involved in traditional harvest as in the past due to risks resulting from climate change and loss of cultural transmission (Tatatuopik 2004 as cited in Ford et al. 2006). Joseph (2004 as cited in Ford et al. 2006) observes that “It is more dangerous for [the younger generation] because they don’t know the conditions, what to avoid.” Ungalak (2004-2005 as cited in Ford et al. 2007) indicates “I think we have lost the skills so much. I mean, what would have not been dangerous for a man 50 years ago is now dangerous because we have lost so many skills.” “It is a real concern that these general skills and ability to read the weather are not being passed on to the young as they should be,” (Macdonald 2004-2005 as cited in Ford et al. 2007).

Technology has also changed the way traditional harvest is conducted “We go to areas where we wouldn’t normally go because we are assured [by the GPS] we will know where we are…We [also] take more chances,” (Arnatsiaq 2004-2005 as cited in Ford et al. 2007). “The dog teams know the ice and the thicker ice so [people] know that they can walk through thin ice. Snowmobile doesn’t say ‘Alert! This is thin Ice.’ So it’s more dangerous [by snowmobile] than by dog team,” (Paniaq 2007-2005 as cited in Ford et al. 2007).

5.10 Traditional Foods

Traditional foods in the Baffin Bay and Davis Strait area continue to be a vital part of the local diet and culture, essential to the identity, health and wellbeing of Inuit.

Despite the cost, rates of market food consumption are increasing. According to the Nunavut Food Security Coalition, the percentage of Inuit receiving daily energy from traditional foods dropped from 23% in 1999 to 16% in 2008, and yet 80% of Inuit prefer a mix of store-bought and traditional food (Nunavut

Food Security Coalition 2016). The Council of Canadian Academies reported that the percentage of calories from country foods for Inuit in Nunavut for 2007 to 2008 was nearly 27.7% for men and 23.9% for women 40 or older, but 14.5% and 11.2% respectively for men and women under the age of 40. For children aged three to five in that year, the percentage of daily calories from country food was 8.4% (Council of Canadian Academies 2014).

As Inuit communities transition towards a greater reliance on market foods, risk rates for "diet-sensitive chronic diseases and micronutrient deficiencies" may also increase (Council of Canadian Academies 2014).

> I believe my Elders and Milortuk's words as well. Our people were always outside in the old days and they had very healthy blood from eating only the traditional diet. Perhaps it is this sedentary lifestyle that is causing Inuit to lose their health and the fact that we are eating more and more of our food from the stores. I believe our blood is not as healthy as our forefathers because we do not have the same lifestyle and diet anymore. Our ancestors were never sitting still and that is why they were extremely healthy. (Qarpik 2001 as cited in Nunavut Tunngavik Inc. 2001)

Traditional foods are associated with higher densities of protein, vitamins, minerals, higher omega fatty acid ratio, and lower densities of carbohydrates, saturated fats, and sugar (Sheehy et al. 2015). "Narwhale is very important part of our vitamin C intake, [especially] from the mattak of the animal" (Audlaluk 2013 as cited in The Association of Fishers and Hunters in Greenland 2013). An Inuit participant in a NWMB study from the Baffin Bay area also explained that "the sea mammals and all the animals are good for us. They are good nutritious food for us. They give us good blood, and they keep us healthy" (NWMB 2000).

In addition to being more nutrient dense, country foods are an essential component of Inuit identity and community. A Clyde River participant in a NWMB Study in 2000 explained,

> Many elders who were involved in bowhead whaling in the past crave to eat bowhead maktak once again. In Inuit culture, it is customary to acknowledge and respect elders who have accumulated knowledge and about Inuit cultural values and beliefs, and/or have extensive and detailed knowledge about specific cultural practices. Many informants declared their desire to see bowhead harvesting resumed in order to satisfy the wishes of the elders and as a means of showing renewed respect and affection to the elders in a society whose values and activities have changed greatly in recent decades. (Tassugat, N. 2000, as cited in NWMB 2000)

A Pangnirtung participant in the same study agreed, "Although it does not seem that there were many specific uses of bowhead as a medicine, bowhead food was considered excellent for general health…The older people consider the bowhead whale meat as a delicacy, and they crave for the bowhead whale meat. After the older people have eaten something they have not eaten for a long time, their spirits seem to lift up; and they seem to be more alive" (Keeniainak, J. as cited in NWMB 2000).

There are a number of challenges with securing a supply of country food that had not existed previously, including the effects of development, climate change, wildlife protection measures such as bans and quotas, loss of opportunities for transmission of traditional knowledge, and loss of time available for harvesting activities.

Warmer weather is affecting the ability to cache food. "In the past, we used to be able to cache marine mammals in June and the meat would still be edible during the winter. Now, due to the warming of the weather, the meat gets too rotten or it gets infested with fly larvae. We now have to cache our meat in the fall" (Aqpik 2001 as cited in Nunavut Tunngavik Inc. 2001). Summer used to be time for caching food but caching now has to be done in the fall: "Everything that has been said about the change in the climate is true. Our climate is changing very quickly. We used to cache our meat in August, to ensure that it would be ready by wintertime. Now August is much too warm to cache meat and we have to wait until October to cache our meat" (Milortuk 2001 as cited in Nunavut Tunngavik Inc. 2001). Community freezers have begun to replace traditional caching practices:

> I have noticed over the last few years that the traditional means of preservation of our country foods is affected by the sun's changes in intensity. It used to be perfect in the summer, in terms of preserving and drying our food for the winter. It has become too hot and the fish meat is peeling off of the skin as the fat is melted. When the fish were migrating upriver, it used to be the appropriate time to put away the surplus in our caches. If we do that today, it will be far too rotten by the wintertime when we return to collect it. We cannot attempt this traditional practice anymore. We have to freeze it at the community freezer until later in the fall, when it is cooler to cache it for the winter. (Qaunaq 2001 as cited in Nunavut Tunngavik Inc. 2001)

The practice of caching food is also greatly affected by changes in polar bear behaviour. "We try to cache meat where we know there are fewer bears but polar bears still eat them. We lose money because of lost food caches" (Panikpakoochoo, E. as cited in Government of Nunavut 2017g).

Climate change has also contributed to food insecurity by creating unpredictable hunting conditions.

> I want to discuss the issue of the winds getting stronger and more unpredictable in our areas. We can no longer just accept these changes and make a concerted effort to protect our equipment in the communities in light of the changes to our weather patterns. The wind now whips up out of any direction and this presents a problem for boat owners. I think that NTI should look at financing some sort of hunting equipment insurance coverage for Inuit hunters. I feel that this should be a priority especially as the climate changes. (Milortuk 2001 as cited in Nunavut Tunngavik Inc. 2001)

Inuit rely on weather observations to predict potential hazards before going out on the land, including clouds, their height, form, direction, wind direction, and other environmental clues. As climate change creates more unpredictable conditions, the traditional knowledge that has long been trusted becomes less dependable, resulting in dangerous hunting conditions affecting successful access to country food (Ford et al. 2006). "We should prepare for a time when other communities in Nunavut no longer have the sea-ice to hunt from. Things like community trade in country foods should be considered" (Qarpik 2001 as cited in Nunavut Tunngavik Inc. 2001).

The health of wildlife and concern for contaminated country foods affects food security. Inuit have reported that the taste of some fish has changed (Nunavut Department of Environment 2005).

> I would like to ask if anyone has noticed the change in our char. I have noticed that the lakes are sprouting more and more vegetation underwater. I have also noticed that the flesh of the char, which used to be bright red, is now lighter in colour, almost whitish like the lake trout. I wonder what is affecting them in this manner, maybe their diet or this new vegetation? (Milortuk 2001 as cited in Nunavut Tunngavik Inc. 2001)

Some wildlife relied on for country food have an unhealthy appearance: “Caribou and fish are skinnier, more unhealthy-looking. Some people now buy country foods or have it flown in from relatives living in other communities, but less fortunate others must depend on local wildlife” (Nunavut Tunngavik 2005). As with the taste of fish, Inuit report that caribou taste different: “Caribou meat tastes different now and there are concerns about contaminants and diseases. We send samples out to labs, but never get results back. Caribou hides are thinner” (Nunavut Tunngavik Inc. 2001).

These differences in the taste of country foods and the health of wildlife are attributed partly to the potential for contaminants in the diets of wildlife: "Country foods, such as smaller animals should be researched and other food items should be checked for levels of pollutants. This research should be done so that our people will know what effect eating our country food has on them" (Milortuk 2001 as cited in Nunavut Tunngavik Inc. 2001). An increasing amount of garbage is also a cause for concern. When animals, such as polar bears, lose their hearing due to anthropogenic noise pollution and can no longer hunt, they must resort to scavenging from community dumpsters, ingesting both food and non-food related items.

> More bears are thinner. We know nuisance bears are chased away these days having hearing impairments from the bangers or gun shots. I drove right next to a polar bear on skidoo and it didn't notice me until it turned its head. Hearing impaired bears go to communities more because they don't have the hearing to hunt on the ice. When bears eat from dumps they don't defecate out the garbage bags. We once found a polar bear that had a stomach full of plastic garbage bags. We can't eat that meat. If polar bear hunting is banned outright what are we to survive on? We have to make sure we consider all things when quotas of caribou and bears are cut as some of us can't afford store bought food. If we hunt more bears, the seal population will rise and we can harvest seals. (Panikpakoochoo as cited in Government of Nunavut 2017g).

> Inuit are starting to become very concerned about the health effects of eating their traditional diet. This is due to the inordinate amount of cancer among our people who subsist on an entirely traditional diet. It seems that cancer causing agents are everywhere, in the air, in the water and in the land and these factors have to be analyzed, especially the water. I would like to know if global warming is a contributing factor in the

> incidences of cancer amongst our people. I am very concerned and would like some answers. (Milortuk 2001 as cited in Nunavut Tunngavik Inc. 2001)

Wildlife protection measures also affect the food security of Study Area residents. “Wildlife are critical to the Inuit way of life. People overseas need to know this. The food is our medicine. It has an intimate connection with our culture. This information needs to be given to Greenpeace and other environmental groups” (North Sky Consulting Group 2009). A resident of Arctic Bay explains that the European ban on seal skins compromised the ability to generate income necessary for market foods:

> Seal skin market crash as result of European ban on seal skins will surely affect our ability to finance our hunting trip as gasoline, oil, ammunition and grub are expensive. Those of us who are non-wage earners are already struggling financially even before the seal skin ban took effect. Elders will be affected less than youth because Elders are eating more country food than the youth. It’s the youth who will have less store-bought food to eat because the absence of money from the sale of seal skins will mean less money to buy store-bought foods. (Arctic Bay). (North Sky Consulting Group 2009).

The European ban on seal product trade referenced here was amended to create an Inuit exception in recognition of the contribution of the seal hunt to subsistence and development (European Commission 2017). The quotas on hunting create problems in the attempts to create secure supplies of country food: “Government should listen to Inuit, we should be able to hunt in summer. The quota should be open all year” (Dowsley 2005). An Inuk from Iqaluit asked, “How can we make a guy make a living from being on the land? This is the most important question that economic development must answer if Inuit are going to survive” (North Sky Consulting Group 2009).

Changes in wildlife behaviour that, in turn, affect availability of country food are attributed to development activities, including oil and gas. "We believe that seismic [companies] oil gas exploration is to blame for this. The marine mammals are being disturbed from it. Inuit rely on country food and it will not change. Therefore, we are against any exploration around the north water, if it is in Canada and Greenland" (Simonee 2013 as cited in The Association of Fishers and Hunters in Greenland 2013). "Looking at the map of the study area for the SEA, beluga whales and eider ducks are coming in from the east, from Baffin Bay and Davis Strait, and spend their summers here. Anything that happens in Baffin Bay and Davis Strait will affect Kimmirut, here in Cape Dorset, and west of us." (Nunavut Impact Review Board 2017)

Effects from seismic activity on migrating narwhals has created obstacles to successful hunting:

> Living in High Arctic, I have experienced behaviour of narwhales and other marine mammals. We learned that there was seismic testing in the area of Greenland. Although the seismic testing have to happen yet in the waters in Nunavut, we know that narwhales were acting in different ways than normal behaviour in the past two years. We also learned the past two years the migration of narwhales has changed as well. They are moving more to the west. Some communities that never had narwhales are getting narwhales like Igloolik and Cambridge Bay. Because of migration, our quota system is affected in Nunavut. When we learn that oil companies want to do seismic testing in the

> waters in our area the people were against it and cause court injunction in Qikiqtani Inuit Association. But, this court injunction is only temporary. North Greenland and in Nunavut high arctic share some of the pods of narwhales and this is a great concern to the people in our area because any exploration whether oil exploration or other development will affect our diet on country food. Some of the experience we know happened before Nunavut was created back in late 1980, when Pan Arctic was exploring in high arctic. We have seen and are able to approach narwhales in spring, because the whales were, I guess, hard of hearing. When Pan Arctic finished, the normal behaviour came back until 2008, we learned and know that narwhales are behaving differently again (Barnabas 2013 as cited in The Association of Fishers and Hunters in Greenland 2013).
>
> As hunters, we have now noticed the last two summers from 2011 how narwhale behaviour has changed drastically. The animal is more difficult to hunt as it seems apt to being very nervous, difficult to chase towards shallow area. This summer (2013) it was very difficult to hunt the narwhale once again. Why is this happening? Narwhale is very important part of our vitamin C intake, [especially] from the mattak of the animal. (Audlaluk 2013 as cited in The Association of Fishers and Hunters in Greenland 2013).

Access to and availability of uncontaminated country food is of great importance and concern to members of the community (Nunavut Environment n.d.a). “I am concerned about polar bears, biodiversity, and predator-prey relationships—everything is integrated. Eventually we eat what we catch and there may be impacts to everything in the lifecycle.” (Nunavut Impact Review Board 2017). Some recommendations for mitigating the current effects on secure supply of country foods include investing in community freezers, creating country food markets, and selling country foods on social media. “Presently, all the communities have a small community freezer. Often, it is overflowing with meat and some people have no room for their food. They should be investing in large community freezers, especially as our population is increasing. If the climate keeps changing, the communities will have to buy large freezers” (Qaunaq 2001 as cited in Nunavut Tunngavik Inc. 2001). Although community freezers are seen as beneficial (Nunavut Department of Environment n.d.), not everyone supports the selling of country food. “Traditionally you don’t sell meat, you give it.” (Brenda, as cited in Jenkins and Goorts 2013). To sell country food, the meat would have to be inspected: “But this is not Inuit culture—we know the hunters and trust them, so we don’t need inspection” (North Sky Consulting Group 2009). Rather than selling country foods, a system to trade those foods could be supported (Nunavut Tunngavik Inc. 2001). “Some communities offer if they have caribou for sale, instead of communities asking which communities have caribou for sale. The communities offer caribou, we don’t ask. For Example, we don't ask Coral Harbour for caribou meat, they offer it” (Jobie as cited in Jenkins and Goorts 2013).

5.11 Heritage Resources

5.11.1 Regulatory Setting

Heritage Resources are protected under the *Nunavut Act*, with the Government of Nunavut Department of Culture and Heritage administering the Nunavut Archaeological and Palaeontological Sites Regulations (Nunavut Government 2001). Heritage resources identified in the Nunavut Archaeological and Palaeontological Sites Regulations (Nunavut Government 2001) consist of archaeological artifacts more than 50 years old and palaeontological fossils. Prehistoric archaeological sites are composed of artifacts, features, and residues of Indigenous origin. They predate the arrival of Europeans and are typically characterized by modified bone and stone, and stone structures. Historic sites are characterized by structures, features, and objects of European influence. These sites date back to contact with Europeans, but also include remains of more recent activity (between contact and approximately 1960). Historic sites less than 50 years old are generally associated with contemporary land use; these sites document continued use and occupation of an area to the present time. Cultural landscapes consisting of either natural or man-made features important to a society's sense of place are also heritage resources. Palaeontological sites contain fossils of plants or animals, or fossilized evidence of their existence; type sites for geological formations are also of geological interest.

Heritage resources are nonrenewable and are susceptible to alteration, damage, and destruction by development, as well as changing sea levels and melting permafrost as a result of climate change. The value of heritage resources cannot be measured in terms of individual artifacts or biological specimens; rather, the value of these resources lies in the integrated information which is derived from the relationship of the individual artifacts and fossil specimens, associated features, spatial relationships, and contextual situations. Interpretation of heritage resource materials, and the ability to interpret the significance of particular sites in a landscape, is based on an understanding of the nature of the relationship between individual archaeological and palaeontological materials, as well as the sediments and strata within which they are contained. As such, removal or mixing of cultural or fossil bearing sediments results in the permanent loss of information basic to the understanding of these resources. As a result, heritage resources are susceptible to destruction and depletion through disturbance.

5.11.2 Precontact Setting

The first inhabitants of Baffin Island, Devon Island and Ellesmere Island were the Palaeoeskimos, part of the Arctic Small Tool tradition. These inhabitants represent a relatively rapid and widespread migration of people from Alaska across to Greenland, into previously unoccupied regions starting perhaps 5,000 years ago. The tradition is distinguished into three different complexes: the Pre-Dorset complex refers to occupations in the Central and Eastern arctic, including Baffin Island and Devon Island; the Independence I complex lies further north on Ellesmere Island; and the Saqqaq complex is found on the west coast of Greenland (Schledermann 1996). A cooling climate and subsequent reduction in the abilities to acquire marine mammals around 3000 years ago may have resulted in a decline in population, and set the stage for a new culture, the Dorset.

The Dorset people inhabited the Arctic from approximately 2,500 to 600 years before present (Maxwell 1984). The Dorset people appear to have lived more secure and rich lives than the Palaeoeskimos before them, as evidenced by larger, more permanent, and more complex sites. This may relate to different methods of obtaining marine mammals which involved hunting from sea ice instead of boats. Because of different adaptations, it seems that the Dorset were more suited to the colder climate that prevailed in the Arctic during this time.

Dorset winter houses were large, semi-subterranean, and contained a mid-passage similar to that present at Pre-Dorset sites. Dorset artifact assemblages are dominated by finely made, small, specialized tools, often made from specially selected lithic materials. Most notably, the Dorset are known for their carvings of organic materials such as ivory and antler, possibly suggestive of a shamanic religious belief (McGhee 1990).

Approximately 1,000 years ago, the climate in the Arctic was warming, and resource availability would have changed. At this time, the Dorset culture is suddenly replaced by the Thule culture. Central arctic oral traditions include references to the "Tunit" (Dorset) people, and it is probable that the two groups occupied the Arctic at the same time, although likely briefly. Tradition suggests that the Inuit may have been responsible for chasing the Tunit out of their territories and are partly responsible for the demise of the Dorset culture (McGhee 1996).

The Thule culture has origins in Alaska and the spread of this culture across the Arctic appears to represent a very rapid movement of people (McGhee 1990). The hunting of large whales appears to be a key component of the Thule way of life, supplemented by acquisition of seal, fish, caribou and fowl. Whales were hunted from the sea using kayak and umiak and using floating harpoons. Characteristic Thule winter houses made use of stones and whale bones in a semi-subterranean construction including a cold-trap at the door.

Modern day Inuit are directly related to the Thule people. The expanse of Thule culture across the Arctic likely resulted in the development of widely varying ways of life for the inhabitants based on the varied resources available in the different regions. Different geographic regions were thus inhabited by small bands of occupants with differing language dialects and widely varying ways of life. The Thule people occupied Baffin Island by around 1,200 years ago, likely spreading down the coast from the north and focusing largely on hunting whales (McGhee 1990). During the Little Ice Age, which lasted from around 400 to 150 years ago, the Thule way of life began to break down, and some areas were abandoned. More ephemeral housing, such as tents and snow houses, came into use and delineation of different Inuit groups continued based on availability of resources.

A comprehensive search of the Nunavut Archaeological Sites Database was not conducted as part of the Strategic Environmental Assessment. However, given the coastal focus of lifeways for precontact inhabitants of the Baffin Bay and Davis Strait region, archaeological sites, both recorded and currently unknown, are present along the coastlines. Sites along the coast may date to various occupations over time and may reflect a number of different types of subsistence activities and other types of activities. Archaeological investigation along the Baffin, Devon and Ellesmere Island coastlines has been relatively minimal in terms of coverage, and any potential development along the coast would require pre-impact archaeological investigation to identify and assess heritage resources sites and develop mitigative options to eliminate or reduce adverse effects to identified sites. Coastal sites are also susceptible to effects of erosion related to sea ice and changing ice and sea levels and melting permafrost.

5.11.3 Historic Setting

The first Europeans to make contact with populations in the Canadian Arctic were the Norse, who may have been trading with Dorset people of Baffin Island in the 12th Century AD (McGhee 2005). Beginning in 1575 with Martin Frobisher, numerous explorers spent time in the eastern Canadian Arctic, many searching for the Northwest Passage but also discovering natural resources such as gold and coal. Between 1585 and 1616, explorers who traveled through, and likely landed in the region included Baffin, Davis, and Hudson; no ice-free passage was discovered, and exploration was largely halted for around 200 years. Exploration resumed in 1818 by Ross who investigated Jones and Lancaster Sounds. In 1819 Parry explored the region and more successfully navigated the sounds to reach Melville Island (Schledermann 1996). Subsequent explorers that travelled and occasionally landed in this region included Franklin, Ross and M’Clure, and later Amundson who successfully navigated the Northwest Passage in 1906, and Rasmussen, who traveled through the region during the Fifth Thule Expedition from 1921 to 1924.

By the mid-19th Century, whalers had a major presence along the coasts of Baffin Island and Hudson’s Bay and, beginning around the same time, Christian missionaries began to move into arctic settlements. The establishment of Hudson’s Bay Company posts in Canada began in the mid-1600s; by 1670 the precursor to the Hudson’s Bay Company, the Company of Gentlemen Adventurers Trading into Hudson’s Bay, had a charter to the territory of Rupert’s Land, and posts were established along Hudson’s Bay and James Bay, and soon further west to the Rocky Mountains. Expansion of the fur trade north may have begun as early as the 17th Century (McGhee 2005). Certainly by the late 18th Century, trade was occurring with the Inuit in the northern part of Hudson’s Bay. By the time the Hudson’s Bay Company merged with the North West Company in 1821, trade covered most of Canada, including many areas in Nunavut.

Similar to precontact sites, historic period sites are present along the coastlines of Baffin, Devon and Ellesmere Islands, including both recorded sites and likely also currently unrecorded sites. Potential impacts to these sites from development would need to be mitigated by conducting pre-impact heritage resources studies. In addition, given the long history and numerous expeditions that extended through this region in the search for the Northwest Passage, as well as other expeditions related to search for resources such as minerals and research projects, shipwrecks located within Baffin Bay and David Strait could be subject to impact depending on the location of the vessel and the type of impact. A search for specific shipwreck locations that may be present in Baffin Bay and Davis Strait was not conducted as part of this SEA but could be undertaken via review of the Northern Shipwrecks database and archival research.

5.12 Non-Traditional Use

5.12.1 Tourism

Tourism has been a growing industry for Nunavut and presents an economic development opportunity. The 2015 Nunavut Visitor Exits Survey estimated a total of 16,750 non-resident visitors exiting the territory by air or sea between May and October 2015. Visitors to the Baffin Region comprised 87% of that total, at approximately 14,572 visitors (Insignia Research 2015). While the survey recorded no measurable change in the number of visitors travelling by airplane between 2011 and 2016, it did assume there was an addition of 860 cruise-based visitors to the region. The survey also reported a total spending in the territory (excluding air fare and cruise tickets) of approximately $37.88 million. The cruise-based travelling sector was the one sector that saw a measurable increase in growth, bringing approximately 2,750 passengers to Nunavut in 2015, up from 1,890 in 2011 (Insignia Research 2015). Business travelers make up the majority of visitors to Nunavut, and the Qikiqtani Region is the region most frequently visited by business travelers, at approximately 76% of the territorial total. Within the Qikiqtani Region, hotels and bed and breakfast establishments are the primary form of residence for visitors and tourists (Insignia Research 2015).

The top 10 activities for visitors to the Qikiqtani Region have been identified in the 2015 Nunavut visitor exits survey and include:

- Visiting museums
- Browsing art / carvings
- Hiking
- Visiting parks or rivers
- Cultural experiences
- Birdwatching or wildlife viewing
- Cruise or boat tours
- Viewing the northern lights
- Visiting friends and relatives
- Attending meetings

Other popular tourist activities include dogsledding, floe edge tours, canoeing and kayaking, fishing, and adventure sports such as mountain biking and rock / ice climbing. These activities play a role in some communities during the summer months and makes up a portion of the local economy (see Section 5.2.4). Many of these activities are carried out by licensed outfitters and tour guides. Table 5.46 and Table 5.47 illustrate the number of licensed tour establishments and outfitters that exist within the potentially interested communities in the Area of Focus.

Table 5.46 Licensed Tour Operators, by Community, SEA Area of Focus, 2017

Company Name	Type of Operation	Location	Licensed Outfitter
Arctic Haven Wilderness Lodge	Lodge	Resolute Bay	Yes
Arctic Haven Wilderness Lodge - Outpost Cabin	Outpost camp	Resolute Bay	Yes
Atco Narwhal Airport Hotel	Hotel	Resolute Bay	No
Atco South Camp Inn	Hotel	Resolute Bay	No
Auyuittuq Lodge, Inns North	Hotel	Pangnirtung	No
Black Point Lodge	Hotel	Pond Inlet	No
Dorset Suites	Hotel	Cape Dorest	Yes
Frobisher Inn	Hotel	Iqaluit	No
Grise Fiord Hotel	Hotel	Grise Fiord	No
Kimik Hotel, Inns North	Hotel	Kimmirut	No
Naujaaraaluit Hotel	Hotel	Clyde River	No
Nunattaq Suites	Bed and breakfast	Iqaluit	No
Qausuittuq Hotel, Inns North	Hotel	Resolute Bay	No
Sauniq Hotel, Inns North	Hotel	Pond Inlet	No
Tangmaarvik Inn	Hotel	Arctic Bay	No
The Discovery, Iqaluits Boutique Hotel	Hotel	Iqaluit	No
SOURCE: Government of Nunavut (n.d)			

Table 5.47 Licenced Outfitters, by Community, SEA Area of Focus, 2017

Company Name	Location	Licenced Tourist Establishment	Activities
Alivaktuk Outfitting	Pangnirtung	No	• ATV or Snowmobile • Boating • Park visits • Fishing • Transportation • Floe edge tour • General tours
Arctic Bay Adventures Ltd.	Arctic Bay	No	• Arts and culture • ATV and snowmobile • Birdwatching and wildlife viewing • Eco-tourism • Camping and hiking • Cruise ship • Boating • Park visits • Fishing • Hunting • Transportation • Dogsledding • Food and beverage • General Tours
Arctic Kingdom	Pangnirtung, Pond Inlet, Kimmirut, Igloolik, Resolute Bay, Iqaluit, Grise Fiord, Arctic Bay	No	• Arts and culture • ATV and snowmobile • Eco-tourism • Park visits • Fishing • Transportation • Meetings and Events • General Tours
Arctic Watch Lodge	Resolute Bay, Clyde River	Yes	• Accommodation • ATV or Snowmobile • Birdwatching and wildlife viewing • Canoeing / Kayaking • Fishing • Food and beverage

Table 5.47 Licenced Outfitters, by Community, SEA Area of Focus, 2017

Company Name	Location	Licenced Tourist Establishment	Activities
Huit Tours Ltd.	Cape Dorset	Yes	• Accommodations • Arts and Culture • ATV or snowmobile • Birdwatching and wildlife viewing • Camping and hiking • Cruise ship • Boating • Park visits • Fishing • Transportation • Food and beverage • Meetings and events • Floe edge • General tours
Inuarak Outfitting	Pond Inlet	No	• ATV or Snowmobile • Birdwatching and wildlife viewing • Boating • Fishing • Hunting • Transportation • Dogsledding • Floe Edge • General tours
Inukpak Outfitting	Pangnirtung, Qikiqtarjuaq, Kimmirut, Iqaluit	No	• ATV or snowmobile • Birdwatching and wildlife viewing • Camping and hiking • Cruise ship • Canoeing and kayaking • Park visits • Fishing • Dogsledding • Meetings and events • Floe edges • General tours
Le Soleal, Compagnie Du Ponant	Qikiqtarjuaq, Iqaluit, Arctic Bay	No	• Cruise Ship

Table 5.47 Licenced Outfitters, by Community, SEA Area of Focus, 2017

Company Name	Location	Licenced Tourist Establishment	Activities
National Geographic Explorer, Lindblad Expeditions	Pond Inlet, Qikiqtarjuaq, Resolute Bay, Grise Fiord, Arctic Bay, Clyde River	No	• Accommodations • Eco-tourism • Cruise ship • Park visits • Food and beverage • General tours
NorthWinds Arctic Adventures	Iqaluit	No	• Camping and hiking • Canoeing and kayaking • Park visits • Dogsledding • General tours
Polar Ice Adventures Outfitting	Resolute Bay	No	• Arts and Culture • ATV or snowmobile • Birdwatching and wildlife viewing • Camping and hiking • Boating • Park visits • Fishing • Hunting • Transportation • Food and beverage • Floe edge • General tours
Polar Outfitting	Iqaluit	No	• ATV or snowmobile • Birdwatching and wildlife viewing • Eco-tourism • Camping and hiking • Cruise ship • Boating • Park visits • Fishing Hunting • Transportation • Meetings and Events • Floe Edge • General tours
Silver Explorer, Silversea Cruises	Iqaluit	No	• Cruise ship
Tagak Outfitting Services	Pond Inlet	No	• Eco-tourism • Park visits • Transportation • General tours
SOURCE: Government of Nunavut (n.d.-a)			

The increase that was noted in cruise ship visitors to the Qikiqtani Region can be attributed to the decreasing levels of sea ice and the increasing length of the ice-free season. As access to the Northwest Passage begins to increase and ship movements become more frequent, marine-based tourism, and increased cruise ship visits could be an economic development opportunity for the Qikiqtani Region. Table 5.48 below illustrates the 2017 itinerary for cruise ships in the communities within the Area of Focus. The Government of Nunavut released their Marine Tourism Management Plan for 2016-2019, with a goal of gaining more information and understanding the potential economic benefits of marine tourism to the region, and how to take advantage of these opportunities (Government of Nunavut 2017b). The Plan reported that the number of passenger vessel voyages and the number of passengers visiting Nunavut has increased over the years, rising from 11 voyages and an estimated 1,045 passengers in 2005, to an estimated 40 passenger vessels and 3,680 passengers in 2015 (Government of Nunavut 2017b).

Table 5.48 Master Nunavut Cruise Ship Itinerary 2017 for the Area of Focus

Community / Port	Operator	Estimated Arrival Date	Estimated Passengers
Cape Dorset	Ocean Endeavour, Adventure Canada	21 July 2017	198
	MV Bremen, Hapag-Lloyd	05 September 2017	155
Clyde River	MV Hanseatic, Hapag-Lloyd	06 September 2017	184
	Le Boreal, Compagnie Du Ponant	20 August 2017	245
	Canada 150 C3 Expedition	09 August 2017	60
Grise Fiord	Ocean Endeavour, Adventure Canada	29 August 2017	198
	Akademik Sergey Vavilov, One Ocean Expeditions Inc.	09 August 2017	92
	Akademik Sergey Vavilov, One Ocean Expeditions Inc.	26 August 2017	92
Iqaluit	Ocean Endeavour, Adventure Canada	18 July 2017	198
	Le Soleal, Compagnie Du Ponant	09 September 2017	264
	Akademik Sergey Vavilov, One Ocean Expeditions Inc.	25 July 2017	92
	Akademik Sergey Vavilov, One Ocean Expeditions Inc.	25 July 2017	92
	Akademik Sergey Vavilov, One Ocean Expeditions Inc.	04 September 2017	92
	Silver Explorer, Silversea Cruises	06 September 2017	132
	Ocean Endeavour, Adventure Canada	18 July 2017	198
	Ocean Adventurer, Quark Expeditions	13 September 2017	100
	Ocean Adventurer, Quark Expeditions	13 September 2017	100
	Canada 150 C3 Expedition	29 July 2017	60
Kimmirut	Ocean Endeavour, Adventure Canada	23 July 2017	198
Pangnirtung	Ocean Endeavour, Adventure Canada	25 July 2017	198
	Akademik Sergey Vavilov, One Ocean Expeditions Inc.	27 July 2017	92
	Ocean Adventurer, Quark Expeditions	10 September 2017	100
	Ocean Adventurer, Quark Expeditions	15 September 2017	100

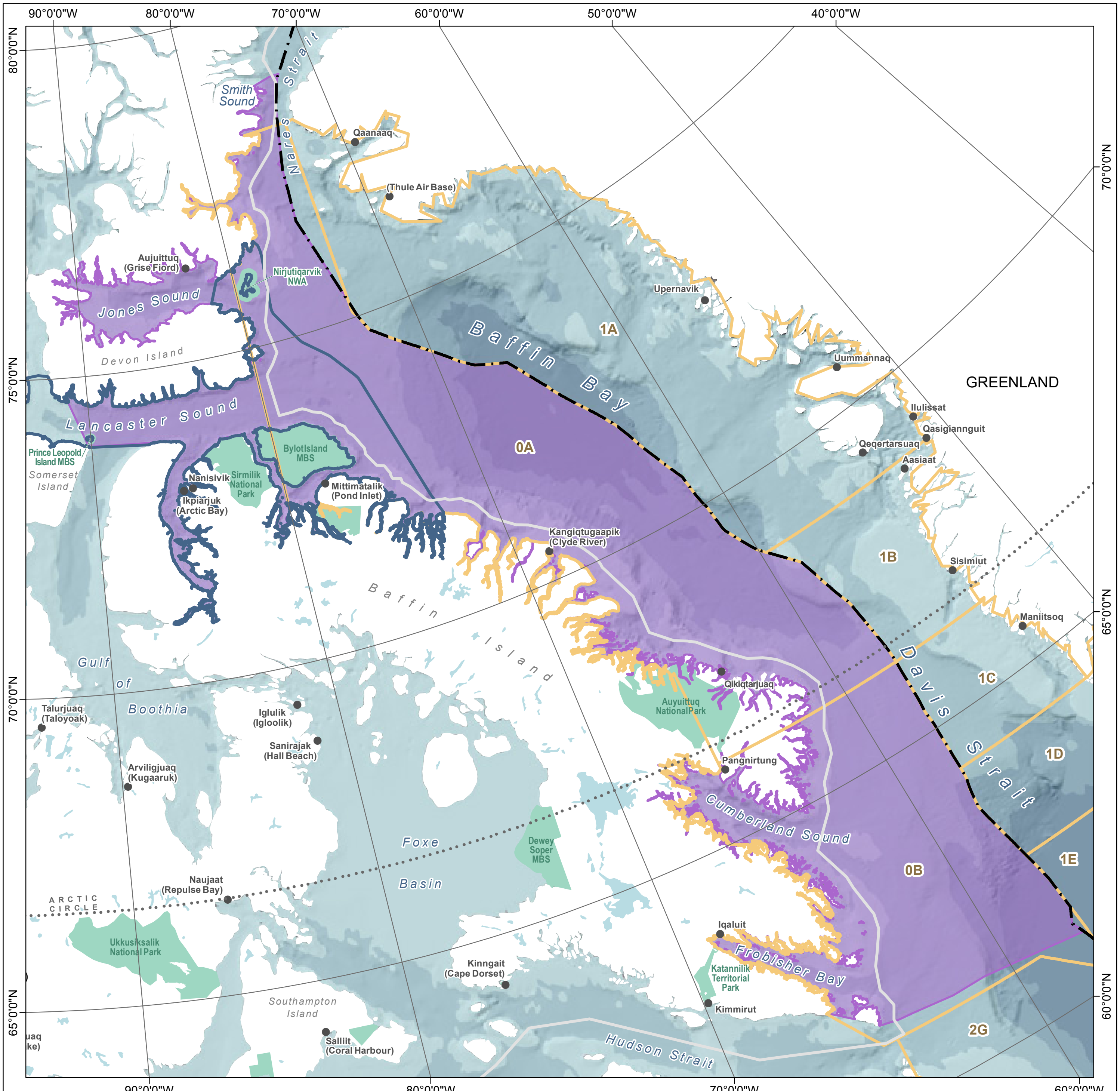
Table 5.48 Master Nunavut Cruise Ship Itinerary 2017 for the Area of Focus

Community / Port	Operator	Estimated Arrival Date	Estimated Passengers
Pond Inlet	Ocean Endeavour, Adventure Canada	05 August 2017	198
	Ocean Endeavour, Adventure Canada	16 September 2017	198
	MV Hanseatic, Hapag-Lloyd	25 August 2017	184
	MV Hanseatic, Hapag-Lloyd	07 August 2017	184
	National Geographic Explorer, Lindblad Expeditions	28 July 2017	148
	National Geographic Explorer, Lindblad Expeditions	18 August 2017	148
	Le Boreal, Compagnie Du Ponant	18 August 2017	245
	Akademik Sergey Vavilov, One Ocean Expeditions Inc.	01 August 2017	92
	Akademik Sergey Vavilov, One Ocean Expeditions Inc.	29 August 2017	92
	Crystal Serenity, Crystal Cruises	03 September 2017	1,070
	Le Boreal, Ambercrombie & Kent	29 August 2017	264
	Canada 150 C3 Expedition	13 August 2017	60
	Ocean Endeavour, Students on Ice	13 August 2017	96
Qikiqtarjuaq	Ocean Endeavour, Adventure Canada	19 September 2017	198
	Le Soleal, Compagnie Du Ponant	23 August 2017	264
	Akademik Sergey Vavilov, One Ocean Expeditions Inc.	29 July 2017	92
	Akademik Sergey Vavilov, One Ocean Expeditions Inc.	01 September 2017	92
	Canada 150 C3 Expedition	06 August 2017	60
Resolute Bay	Ocean Endeavour, Adventure Canada	10 August 2017	198
	Akademik Sergey Vavilov, One Ocean Expeditions Inc.	05 August 2017	92
	Akademik Sergey Vavilov, One Ocean Expeditions Inc.	05 August 2017	92
	Akademik Sergey Vavilov, One Ocean Expeditions Inc.	14 August 2017	92
	Akademik Sergey Vavilov, One Ocean Expeditions Inc.	14 August 2017	92
	Akademik Sergey Vavilov, One Ocean Expeditions Inc.	23 August 2017	92
	Akademik Sergey Vavilov, One Ocean Expeditions Inc.	23 August 2017	92
	Canada 150 C3 Expedition	19 August 2017	60
	Ocean Endeavour, Students on Ice	10 August 2017	96
SOURCE: (Government of Nunavut - Department of Economic Development and Transportation 2017)			

5.13 Commercial Harvest

5.13.1.1 Overview

Commercial fishing and harvesting activity in Nunavut, specifically related to fisheries, is monitored and managed through a co-management agreement that has been legislated through the Nunavut Agreement. The NWMB and DFO have an agreement in place to make management decisions in the absence of fisheries regulations specific to Nunavut. This also involves input from fish harvesters to their respective hunter and trappers organizations, as well as through the Regional Wildlife Organization for the Qikiqtani Region, the Government of Nunavut, and Nunavut Tunngavik Inc. While there is a co-management framework in place, the final decision regarding quota allocation rests with DFO and the Minister. Within the inshore and freshwater commercial fisheries, Arctic char and Greenland halibut (turbot) are the species landed, while turbot and shrimp are the primary species fished commercially offshore. Inuit from Qikiqtarjuaq note that impacts from these fisheries can be very high (Nunavut Impact Review Board 2017). There are also a number of exploratory fisheries that take place inshore for species such as shrimp, whelks, and clams (Government of Nunavut Department of Environment 2016). These exploratory fisheries are designed to determine whether a species is viable to be fished commercially in the future (see Section 5.13.1.5). The Baffin Bay and Davis Strait Area falls within NAFO Divisions 0A and 0B (see Figure 5.7), and within Shrimp Fishing Areas (SFA) 0,1, and 2 (see Figure 5.8).



Base Features

- Community[1]
- Limit of Exclusive Economic Zone[4]
- Nunavut Settlement Area[3]
- Tallurutiup Imanga / Lancaster Sound NMCA[2]
- Protected Area or National Park[4]

Bathymetry[5] Depth (m)

< 200 | 200 - 1000 | 1000 - 2000 | 2000 - 3000 | > 3000

Project Features

- Area of Focus[2]
- NAFO Divisions[6]

1:10,000,000

0 50 100 200 300

Kilometres

References:
[1]Atlas of Canada Base Maps, 2017
[2]NIRB, 2017
[3]Nunavut Planning Commission, 2010
[4]National Framework Canada, 2017
[5]Natural Earth, 2016
[6]Northwest Atlantic Fisheries Organization, 2016

Nunavut Impact Review Board Strategic Environmental Assessment

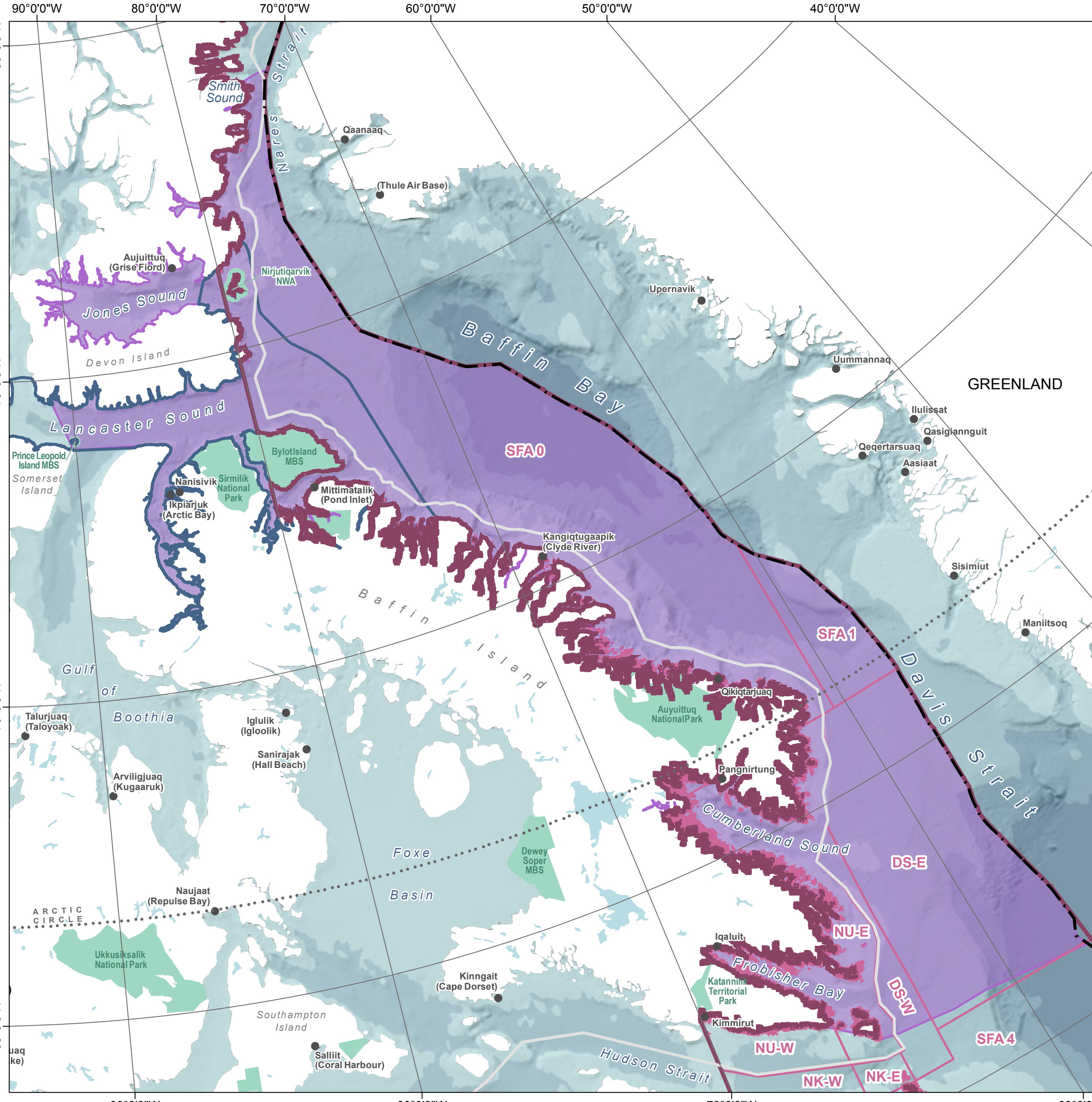
Figure 5.7
NAFO Divisions Around Baffin Island and Davis Strait

NUNAMI STANTEC LIMITED

N.I.R.B.

Prepared By: Nunami Stantec Limited
Projection: Canada Lambert Conformal Conic, North American 1983
Date: Apr 13, 2018
Project Number: 12322100
Produced By: L. Trudell
Verified By: J. Beckett
Revision: 01

Filepath: S:\1232\projects\123221001\figures\report\SEA\fig_123221001_NIRB_SEA_05.7_NAFO_Divisions_Around_Baffin_Island_and_Davis_Strait.mxd



Base Features

- Community[1]
- Limit of Exclusive Economic Zone[4]
- Nunavut Settlement Area[3]
- Tallurutiup Imanga / Lancaster Sound NMCA[2]
- Protected Area or National Park[4]

Bathymetry[5] Depth (m)

< 200 | 200 - 1000 | 1000 - 2000 | 2000 - 3000 | > 3000

Project Features

- Area of Focus[2]
- Northern Shrimp Fishing Area[6]
- Northeast Shrimp Management Units[6]

1:10,000,000

0 50 100 200 300

Kilometres

References:
[1]Atlas of Canada Base Maps, 2017
[2]NIRB, 2017
[3]Nunavut Planning Commission, 2010
[4]National Framework Canada, 2017
[5]Natural Earth, 2016
[6]Fisheries and Oceans Canada, 2009

Nunavut Impact Review Board Strategic Environmental Assessment

Figure 5.8 Northern Shrimp Fishing Areas and Management Units

NUNAMI STANTEC LIMITED

N.I.R.B. NUNAVUMI AVATILIKIYIIN KATIMAYIIN

Prepared By: Nunami Stantec Limited
Projection: Canada Lambert Conformal Conic, North American 1983
Date: Apr 13, 2018
Project Number: 12322100
Produced By: L. Trudell
Verified By: J. Beckett
Revision: 01

Filepath: S:\1232\projects\123221001\figures\report\SEA\fig_123221001_NIRB_SEA_05.8_Shrimp_Fishing_Areas_in_Baffin_Island_and_Davis_Strait.mxd

5.13.1.2 Turbot Fishery

Canada and Denmark (on behalf of Greenland) requested the North Atlantic Fisheries Organization (NAFO) to conduct stock assessments for turbot, including recommendations on total allowable catch for NAFO Divisions 0A and 1A (offshore) and 1B in the north, and Divisions 0B and 1C-F in the south. Canada retains management authority for stocks in NAFO Division 0. In the most recent stock assessment conducted by NAFO, it recommended the total allowable catch (TAC) for turbot in Division 0A and 1AB not exceed 17,150 t for the 2017-2018 season. For Division 0B and 1C-F, the TAC was recommended not exceed 15,150 t (Northwest Atlantic Fisheries Organization (NAFO) 2015). Quota information and landings statistics for turbot is limited for Nunavut. In 2015, the total quota available to Nunavut for turbot was approximately 11,350 t. Of that, 11,150 t were harvested for a value of $78 million to Nunavut (Government of Nunavut Department of Environment 2016). In 2017, the federal government announced an increase in turbot TAC in 0A and 0B by approximately 575 t each. This brought the total quota for Division 0A to 8,575 t, with Nunavut fishers being awarded 100% of the increase. Meanwhile Division 0B saw its TAC increase to 7,575 t, with Nunavut fishers receiving 90% of the increase (Canadian Broadcasting Corporation (CBC) 2017a).

5.13.1.3 Shrimp Fishery

For commercial shrimp harvesting, NAFO provides stock assessments for the coastal shrimp stocks in Shrimp Fishing Areas 0 and 1 and provides recommendations on the TAC for the fishery. Shrimp stocks in SFA 1 are managed through a bi-lateral agreement with Canada and Greenland. Based on the most recent stock assessment by NAFO in 2015 for northern shrimp in SFA 1 and NAFO Subdivision 0A, the TAC was recommended not to exceed 90,000 t. Like turbot, information regarding quotas and fisheries landing information for northern shrimp in Nunavut is not readily available. In 2015, the total quota available to Nunavut was approximately 10,955 t (Northwest Atlantic Fisheries Organization (NAFO) 2015). Of that, approximately 1,879 t were harvested for a value of approximately $6.5 million. In 2016, the federal government announced an increase of approximately 1,084 t to shrimp harvesters in Nunavut (Nunatsiaq News 2016).

5.13.1.4 Arctic Char Fishery

There is limited public information on commercial fishing activity for Arctic Char outside of the Cambridge Bay area, and available information on quota numbers are limited. As mentioned in Section 4.2.3, in 2015, over 72 t of Arctic char were caught commercially in Nunavut, for a total value of $1.8 million. This amount was part of a TAC for char in Nunavut set at approximately 363 t (Government of Nunavut Department of Environment 2016). A processing facility for Arctic char exists in Pangnirtung, operating under Pangnirtung Fisheries Ltd., which can process raw material into packaged food that is shipped across the territory, country, and internationally.

An overview of commercial fish landings information from DFO for the three commercial fisheries operating in waters off Nunavut is provided in Table 5.49 below.

Table 5.49 Commercial Fish Landings Information, Nunavut, 2012 to 2016

Species	Area / Allocation	Weight (t)					Value ($ 000)				
		Year					Year				
		2012	2013	2014	2015	2016	2012	2013	2014	2015	2016
Greenland Halibut	**Total**	**13,363**	**13,415**	**14,892**	**15,439**	**13,782**	**$67,427**	**$69,418**	**$77,562**	**$91,841**	**$85,082**
	0A Fishers	6,355	6,322	7,916	7,925	7,527	$31,196	$33,184	$40,976	$45,453	$46,181
	Nunavut	6,355	6,322	7,916	7,925	7,527	$31,196	$33,184	$40,976	$45,453	$46,181
	0B	7,008	7,092	6,977	7,513	6,255	$36,232	$36,234	$36,586	$46,388	$38,901
	Nunavut	3,438	3,345	3,409	3,478	2,608	$16,877	$17,559	$17,645	$19,947	$16,003
Shrimp	**Total**	**5,359**	**16,359**	**13,515**	**9,800**	**14,742**	**$21,119**	**$56,238**	**$51,992**	**$45,914**	**$72,413**
	Nunavut	1,741	4,467	3,999	1,903	4,404	$5,902	$16,529	$16,997	$9,097	$22,240
	SFA 1	NA	NA	10	6	NA	NA	NA	$41	29.72	NA
	DS-E	NA	215	2	NA	89	NA	$794	$8	NA	$451
	DS-W	NA	275	358	NA	1,247	NA	$1,018	$1,520	NA	$6,297
	NU-E	NA	1,002	347	NA	380	NA	$3,709	$1,474	NA	$1,917
	NU-W	NA	2,975	3,283	32	456	NA	$11,009	$13,954	$153	$2,300
	NK-E	NA	NA	NA	NA	4	NA	NA	NA	NA	$18
	NK-W	NA	NA	NA	1,865	2,229	NA	NA	NA	$8,914	$11,256
Arctic Char	**Total**	**56**	**78**	**64**	**74**	**NA**	**$314**	**$362**	**$309**	**NA**	**NA**
	Cambridge Bay	26	48	48	NA	NA	$185	$241	$241	NA	NA
	Kivalliq	12	13	0	NA	NA	$47	$52	$0	NA	NA
	Pangnirtung Area	19	17	16	NA	NA	$82	$69	$68	NA	NA
	Arctic Char	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

NOTES:
- Numbers may not add due to rounding
- NA indicates that landings information has been either suppressed or is not available for a specific year and/or region.

SOURCE: DFO 2018

5.13.1.5 Future Fisheries

Determining future commercial fishing in Nunavut is conducted primarily through the issuing of licences for exploratory fisheries from DFO to local Hunter Trapper Organizations. Exploratory fisheries are carried out on lakes and rivers that have never been commercially fished before, with the purpose to determine if these rivers would be able to support a commercial fishery. For a new exploratory license, an application would be sent to DFO, and if approved, a target quota would be set, and the waterbody fished for five years under that quota (DFO n.d.). The total harvest for each year is recorded, along with samples collected for age, length, gender, age structure, etc. According to the 2016-2020 Fisheries Strategy, several exploratory fisheries are taking place inshore for species such as shrimp, whelks, and clams (Government of Nunavut Department of Environment 2016). In 2017, DFO issued exploratory licences for Arctic Char to both the local Hunter Trapper Associations in both Pangnirtung and Pond Inlet (DFO 2018a).

5.13.1.6 Harvester Organizations

Currently, the main entity for lobbying for Nunavut's fishing interests in the offshore environment is the Nunavut Offshore Allocation Holders Association. This group consists of the four active fishing entities: Baffin Fisheries (BF), Arctic Fishery Alliance LP (AFA), Qikiqtaaluk Corporation (QC), and Pangnirtung Fisheries and Cumberland Sounds Fisheries Partnership (Government of Nunavut Department of Environment 2016). BF, AFA, and QC are the groups that have capacity to harvest offshore, while Pangnirtung Fisheries and Cumberland Sounds Fisheries Partnership have processing capabilities. These groups have made contributions to the development of offshore and inshore fisheries, including infrastructure and vessels, and training opportunities for Inuit.

BF holds licences offshore for both northern shrimp and turbot. According to their most recent annual report, the BF harvested 100% of its 0A/0B turbot quota allocations in 2015/2016 and purchased additional allocations from a third party (Baffin Fisheries 2016). In 2015-2016, BF was active in harvesting shrimp from SFA 1 and within the Davis Strait, and in 2015 was active in harvesting shrimp from SFA 2,3,4,5, and 6 through royalty arrangements with other allocation holders and through BF's own allocations (Baffin Fisheries 2016).

AFA was established in 2008 with the objective to distribute benefits from the offshore fishery to more communities in Nunavut. The AFA currently operates two vessels and is active in the offshore turbot fishery. In 2013, AFA was awarded an allocation of 1,030 t for turbot in NAFO Division 0A, and 400 t in NAFO Division 0B. These allocations were locked for the next three fishing seasons (Arctic Fishery Alliance 2017).

The QC operates in the offshore fishery through its two subsidiary groups, the Qikiqtaaluk Fisheries Corporation and Unaaq Fisheries. Qikiqtaaluk Fisheries Corporation is a joint venture between QC and Nataaqnaq Fisheries to fish both shrimp and turbot offshore. It harvests QC fishing allocations through its wholly owned vessel and crew, and it also fishes additional turbot quotas allocated to other Nunavut and southern fishing companies through royalty arrangements (Qikiqtaaluk Fisheries Corporation 2017).

Unaaq Fisheries is held equally between QC and Makivik Corporation and holds a licence to harvest shrimp in Canadian waters (Qikiqtaaluk Fisheries Corporation 2017).

5.14 Marine Transportation

5.14.1.1 Overview

Nunavut is highly dependent on marine transportation for community re-supply, construction, local economic activities and cultural livelihoods (Dawson et al. 2017). Shipping in Nunavut has increased substantially over the past decade due to the increase in exploration and extraction of natural resources, cargo trade and transport, tourism industries and community re-supply demands (Dawson et al. 2017). The growth in marine transportation is related to both the changes in ice cover that have resulted in greater access both spatially and temporally to waters of Nunavut, and changes in population growth and economic activity which has subsequently increased the demand for more goods in the north. (Government of Nunavut 2017b). Thinner ice and longer ice-free seasons have allowed for ships to travel more frequently, making the region more accessible. For example, the total annual kilometres traveled by all vessel types in Nunavut has more than doubled over the past 25 years, increasing from 345,567 km in 1990 to 793,684 km in 2015 (Dawson et al. 2017).

Vessel types that constitute the greatest proportion of traffic in Nunavut include general cargo (re-supply vessels), government icebreakers, pleasure crafts, fishing vessels, and tanker ships and tug and barge activity related to community re-supply (Dawson et al. 2017). Within the Area of Focus, between 1990 and 2000 the distribution of vessel traffic by km included 28% general cargo, 25% government icebreakers, 18% bulk carriers, 14% tanker ships, 7% passenger ships, 5% fishing, and 3% tug and barge (Dawson et al. 2017). Between 2011–2015 the distribution of tanker ships, fishing vessels, and pleasure crafts has increased to 16%, 16% and 6% respectively, while the distribution of general cargo, government ice breaking, and bulk carriers has declined to 24%, 18% and 9% respectively (Dawson et al. 2017). The community of Pond Inlet experienced the largest increase in annual traffic of any Nunavut community from 1990 to 2015, with close to a tripling of vessel traffic activity (Dawson et al. 2017). This increase has been attributed primarily to an increase in tourism vessels, along with bulk carrier and tanker traffic related to the Mary River Mine. Resolute and Arctic Bay both experienced declines in ship traffic from 1990-2015, which is likely related to the closures of the Polaris and Nanisivik Mines (Dawson et al. 2017).

Ships travelling from southern Canada usually enter the western portion of the Northwest Passage through a southern route along the main coast—the Amundsen Gulf—or through two northern routes, either north of Banks Island or south-east of Banks Island (Government of Northwest Territories - Environment and Natural Resources 2015). In 2012, a record number of vessels (30) transited through the Northwest Passage (Government of Northwest Territories - Environment and Natural Resources 2015). In 2013, for the first time, a large bulk carrier transited the Northwest Passage (Government of Northwest Territories - Environment and Natural Resources 2015). In 2014, only 17 vessels travelled the Northwest Passage, due to a short and cold summer (Government of Northwest Territories - Environment and Natural Resources 2015).

Voyages through the Northwest Passage have become an annual event. The number of transits increased from 4 per year in the 1980s to 20–30 per year from 2009–2013 (Government of Northwest Territories - Environment and Natural Resources 2015). These transits are largely completed by icebreakers, research vessels, passenger ships for Arctic tourism, and tug and supply vessels. Most ships travelling through the Northwest Passage take a southern route, while only 8% enter and / or leave the Beaufort Sea through northern routes around Banks Island (Government of Northwest Territories - Environment and Natural Resources 2015).

5.14.1.2 Sealift

Sealift is critical for all Nunavut communities and their residents to obtain an annual re-supply of goods and materials required throughout the year (Government of Nunavut - Department of Community and Government Services n.d.). During the ice-free season, ships travel annually from a variety of ports in southern Canada with goods including construction materials, vehicles, heavy equipment, house wares and non-perishable food items (Government of Nunavut - Department of Community and Government Services n.d.).

Sealift typically takes place between June and late October each year. The Government of Nunavut provides organizational and logistical support for dry cargo and bulk fuel requirements through a variety of carriers (Government of Nunavut - Department of Community and Government Services n.d.).

5.14.1.3 Suppliers

NUNAVUT SEALINK AND SUPPLY INC.

Nunavut Sealink and Supply Inc. (NSSI) is an Inuit owned shipping firm with its head office located in Iqaluit. NSSI carries and delivers general cargo and fuel, using roll-on roll-off vessels and dry cargo sealift services. NSSI delivers to all communities within the Area of Focus, including Iqaluit, Cape Dorset, Kimmirut, Clyde River, Pond Inlet, Grise Fiord, Resolute Bay, Pangnirtung, Arctic Bay and Qikiqtarjuaq.

NUNAVUT EASTERN ARCTIC SHIPPING GROUP

Established in 1998, and headquartered in Iqaluit, the Nunavut Eastern Arctic Shipping (NEAS) Group is a majority Inuit owned company that is part of the NEAS Group which includes maritime transportation service providers Nunavut Eastern Arctic Shipping Inc., Nunavik Eastern Arctic Shipping Inc., and NEAS Group.

The NEAS Group uses general cargo and roll-on roll-off vessels and provides dry cargo sealift services. The NEAS Group delivers to all the communities within the Area of Focus, including Iqaluit, Cape Dorset, Kimmirut, Clyde River, Pond Inlet, Grise Fiord, Resolute Bay, Pangnirtung, Arctic Bay and Qikiqtarjuaq.

WOODWARD GROUP OF COMPANIES

Coastal Shipping Limited, a division of Woodward Group of Companies, operates a fleet of oil tankers to provide fuel supply service to the Canadian Arctic and Labrador Coastal ports. The Company was established in 1973 to provide fuel deliveries to coastal Newfoundland and Labrador communities. The Company has since expanded to include service to the Canadian Arctic. The Government of Nunavut buys its petroleum products under existing supply and transportation contracts with Woodward Oil Limited.

GOVERNMENT OF NUNAVUT ANNUAL REPORT ON SHIPPING

The 2015 Dry Cargo Re-supply Programme Activity Summary Report, released by the Government of Nunavut, indicated that the 2015 shipping season saw a reduced amount of cargo being shipped to communities and for mining purposes in Nunavut (Government of Nunavut - Department of Community and Government Services 2016). However, projects in Iqaluit, Repulse Bay, Arctic Bay, Pangnirtung and Pond Inlet resulted in considerable shipping demand. The total estimated cargo shipped in 2015 was 500,000 m^3, of which approximately 200,000 m^3 was mine related and 300,000 m^3 for Nunavut and Nunavik community shipments (Government of Nunavut - Department of Community and Government Services 2016). Shipments to Iqaluit represented roughly one third of community cargo shipped north in 2015, given the construction of the airport during that period (Government of Nunavut - Department of Community and Government Services 2016).

In 2015, 30 dry cargo trips by 2 carriers from the Montreal area occurred within Nunavut. NEAS Group undertook 12 northbound trips from their base at the Port of Valleyfield with 4 ships (Government of Nunavut - Department of Community and Government Services 2016). NSSI undertook 18 northbound trips with 6 ships, plus 3 additional trips from Churchill (Government of Nunavut - Department of Community and Government Services 2016). The company also ran two barges from Les Mechins at the start of the season to Baker Lake, then using the barges to transship cargo through Chesterfield Narrows (Government of Nunavut - Department of Community and Government Services 2016).

NEAS Group and NSSI provided trips in support of mining related activity, with six trips being directly related to mining activities and 12 trips being related to both mining activities and community cargo (Government of Nunavut - Department of Community and Government Services 2016). NSSI dedicated four ship loads in support of Agnico-Eagle’s Meadowbrook mine at Baker Lake, together with trips to Rankin Inlet with cargo for the new Meliadine mine (Government of Nunavut - Department of Community and Government Services 2016). In addition, one full and two-part NSSI cargos also supported Baffinland’s Mary River Iron Ore Project at Milne Inlet; one of these voyages also served Agnico-Eagle’s Meadowbrook via Baker Lake and Nunavik Nickel at Deception Bay. Six of NEAS northbound trips were split between services to communities and mining operations (Government of Nunavut - Department of Community and Government Services 2016).

The 2015 season also saw 10 cruise ships operating in Nunavut, with 18 cruises undertaken. In addition to the cruise ships, three mega yachts and four large private yachts visited different communities. In 2015, five cruise ships also travelled through the northwest passage.

Two Swedish icebreakers also used the passage to re-deploy from west to east.

5.14.1.4 Arctic Shipping Regulations

In Canada, Arctic shipping is governed by several pieces of federal legislation. These include the *Arctic Waters Pollution Prevention Act* and regulations, the *Canada Shipping Act 2001*, the *Marine Liability Act,* the *Marine Transportation Security Act*, the *Coasting Trade Act* and the Canada Labour Code. The purpose of these acts is to enhance safety and to protect life, health, property and the marine environment. Canadian construction standards for ice class ships are found in the Arctic Shipping Safety and Pollution Prevention Regulations, under the *Arctic Waters Pollution Prevention Act.* These standards outline the level of construction needed for ships to operate in the Arctic, and what times of the year they are allowed to operate based on the vessel class.

6 CLIMATE CHANGE

As described in *Strategic Environmental Assessment in Baffin Bay and Davis Strait: Oil and Gas Life Cycle Activities and Hypothetical Scenarios* (Nunami Stantec Ltd. 2018), the full life cycle of a hypothetical oil and gas project in Davis Strait or Baffin Bay could be in the range of 45–80 years from the start of seismic exploration, through exploration drilling to production and eventually decommissioning. Given that climate is expected to affect conditions within the Area of Focus, to address potential environmental effects of such development over that period into the future, effects of climate change on the biophysical and human environment will need to be considered. This chapter describes potential changes in climate that might occur in the Area of Focus. Predictions described in this section will be used to generally discuss how climate change may affect specific VECs and VSECs (Section 7) and interact with predicted project and cumulative effects.

In this section, the change in climate is presented from the standpoint of climate projections described in the literature, taken mainly from the recent report by the IPCC in its Fifth Assessment Report, referred to as AR5 (IPCC 2014a). More specific to the region, climate change projections have been run as part of this assessment, using more recent climate data (1999 to 2013) for Clyde River, Nunavut. The results of both the general IPCC projections and the projections made specifically for the Baffin Bay and Davis Strait region as part of this assessment are used to generate a set of conclusions regarding future climate change that are directly applicable to the Area of Focus for the SEA. The existing climate and meteorology of Baffin Bay and Davis Strait is described in Section 3.1.

IQ may or may not support the projections, but Nunavummiut explained that to adapt to climate change, Inuit will need to rely on IQ; Nunavummiut added that not only should people in the North adapt, but also the rest of the world (Nunavut Tunngavik Inc. 2005).

Climate change is characterized by the change in meteorological elements or variables such as surface temperature, precipitation, or frost days averaged over a period that is on the order of decades. Weather is characterized by changes in many of the same elements, but over a much shorter period including hours, days and weeks. Many studies have assessed potential change in climate over 30-year periods. For example, the time periods from 1971–2000 and 1981–2010 are often referenced for comparison with climate projections. Other time periods are used too, in a slightly different way; for example, the IPCC projections described in this section for the Arctic and Baffin Bay and Davis Strait are often compared to the period 1986–2005.

IQ observations that were repeatedly shared by multiple communities and integrated in the Nunavut Climate Change Centre report include the following:

- "Sea ice conditions have changed; the ice is thinner, freezes up later and melts earlier. Similar observations have been made for lake ice.
- *Aniuvat* (permanent snow patches) are decreasing in size. There is more rain, and the snow and ice form later in the year and melt earlier.

- The weather is unpredictable. It changes faster than it used to with storms blowing up unexpectedly.
- Water levels have gone down, making it hard or impossible to travel by boat in certain areas.
- Temperatures are warmer throughout the year.
- New species have been observed.
- The land has been observed to be drier and the stability of the permafrost is changing.
- The length and timing of the traditional Inuit seasons have changed." (Nunavut Climate Change Centre n.d.)

Additional IQ observations shared during the 2001 *Elder's Conference on Climate Change* include the following:

- "Winters are getting shorter, summers are getting longer.
- We are losing the ice in our glaciers and fiords. Permafrost is melting. We see vegetation growing where ice used to be.
- The sun's rays are increasing. Inuit need stronger suntan lotion.
- We now see birds and wildlife that we have never seen here before. Ravens are everywhere and snow geese are too numerous.
- Heavier winds can be dangerous, be cautious. Because of global warming, we could become subject to catastrophes like hurricanes.
- Caribou meat tastes different now and there are concerns about contaminants and diseases. We send samples out to labs, but never get results back. Caribou hides are thinner.
- More Inuit are dying from cancers, including skin cancers. We have to find out if this is from mining or contaminants or from climate change.
- Fall ice forms later and may not be safe to travel on until Christmas.
- If trends continue, Hudson Bay (and other areas) may never freeze over. The impact on wildlife will be tremendous.
- Inuit have to be prepared for the impacts of global warming.
- Water levels are getting lower.
- The floe-edge is receding faster.
- More ships are traveling through the Northwest Passage due to the lower ice coverage in recent years." (Nunavut Tunngavik Inc. 2001)

Boas (2002, as cited in Nunavut Department of Environment 2005) stated: "The weather seems to be a little less sure, but all I can say is that the weather always changes and is unpredictable year to year, because some days, some seasons and years do not behave exactly as the years before them."

General observations from a review of the most recent report by the Intergovernmental Panel on Climate Change (Church et al. 2013; Collins et al. 2013; IPCC 2014b; Kirtman et al. 2013), with a focus on the Northern Hemisphere and the Arctic, are presented here.

- The principal driver of long term warming of the planet is related to the total emissions of CO_2; and the relationship between the change in mean global temperature and the concentration of CO_2 in the atmosphere is approximately linear.
- The Arctic region is referred to as the area between 67.5ºN and 90ºN. The change in the mean Arctic air temperature is projected to be 2.2 to 2.4 times that of the change in the global mean, relative to 1986–2005. The warming is projected to be greatest in winter, and smallest in the summer.
- The mean atmospheric pressure at sea level is projected to decrease in high latitudes, as global temperature rises. This can affect the path that storms take as they develop, hit, and dissipate.
- There is considerable uncertainty in projecting changes in storms and storm tracks, in the Northern Hemisphere, and especially in the North Atlantic. Nevertheless, the projected trend is for storms that are more intense, with higher winds, and more precipitation than at present.
- There is a poleward migration of the sub-tropical dry zones.
- The long term global precipitation will increase as the global temperature increases, but this is expected to vary substantially with geography. At high latitudes, it is likely that precipitation will increase in proportion with the increase in humidity in the atmosphere.
- There is likely to be an increase in annual run off in high northern latitudes by 2100, corresponding to increases in winter and spring precipitation during that timeframe.
- It is very likely that Arctic Ice Cover will decrease, with year-round thinning, as the global mean surface temperature increases (up to 94% decrease in September). Under one IPCC AR5 modeling scenario, a nearly ice-free Arctic Ocean is projected to occur in the month of September, and this could happen as soon as 2050. Rapid ice loss events are expected in the future.
- Snow cover in the Northern Hemisphere is projected to decrease as the global surface temperature rises, with one scenario projecting a decrease of up to 25% from 1986–2005 levels.

6.1 Representative Concentration Pathways

The concept of Representative Concentration Pathways (RCPs) is used in most climate projection literature and data summaries. The RCPs are trajectories of atmospheric greenhouse gas concentrations (not emissions) adopted by IPCC in its most recent report, the Fifth Assessment Report, referred to as AR5 (IPCC 2014b). The RCPs represent different sets of input data for use in climate models and were developed by considering a wide range of possible futures that relate to expected emissions and concentrations of GHGs, sulphur dioxide, future economic conditions, land use changes, de-forestation, re-forestation, air pollution control and government policy. Thus, they are not predictions, but rather provide a basis for a consistent set of potential conditions, that in turn help to provide reasonable comparisons in the output of the various climate models. The various RCPs reflect uncertainty about future conditions that could lead to different concentrations of greenhouse gases in the atmosphere and are used as a basis for modelling potential changes in global air temperature, precipitation, ice conditions, and other climate variables.

There are four different scenarios of varying combinations of GHG emissions, atmospheric concentrations, air pollutant emissions and changes in land use, that are commonly used in climate projections. Those four RCP scenarios are as follows:

- RCP2.6—stringent mitigation, global warming less than 2°C, CO_2 concentration 430 to 480 ppm
- RCP4.5—intermediate mitigation, global warming less than 2.6°C, CO_2 concentration 480 to 580 ppm
- RCP6.0—intermediate mitigation, high GHG emissions, global warming less than 3.1°C, CO_2 concentration 580 to 750 ppm
- RCP8.5—mitigation not specified, very high GHG emissions, warming less than 5°C, CO_2 concentration 750 to greater than 1,000 ppm

In this assessment, two scenarios are considered: the RCP4.5 pathway and the RCP8.5 pathway. For the purpose of this report, the RCP4.5 pathway is referred to as the Intermediate Concentration Pathway and the RCP8.5 pathway as the Maximum Concentration Pathway.

In the Intermediate Concentration Pathway, the global GHG emissions are projected to peak around 2040 and then decrease. In the Maximum Concentration Pathway, global GHG emissions continue to rise beyond 2100 (see Figure 6.1).

The two scenarios were selected for use in this assessment as they provide a reasonable intermediate scenario, and a reasonable maximum scenario. Many researchers have reviewed recent data, and concluded that as a global entity, we are tracking closer to the Maximum Concentration Pathway because global GHG emissions continue to track close to the RCP8.5 emission rate shown in Figure 6.1. Depending on the success of initiatives to curb GHG emissions, future global emissions could track more closely to the other scenarios, also shown in Figure 6.1.

The Intermediate Concentration Pathway (RCP4.5) represents an intermediate scenario for comparison purposes, and the Maximum Concentration Pathway (RCP8.5) provides a scenario where less is achieved in terms of GHG reductions, and is the scenario with the highest GHG concentrations in the atmosphere.

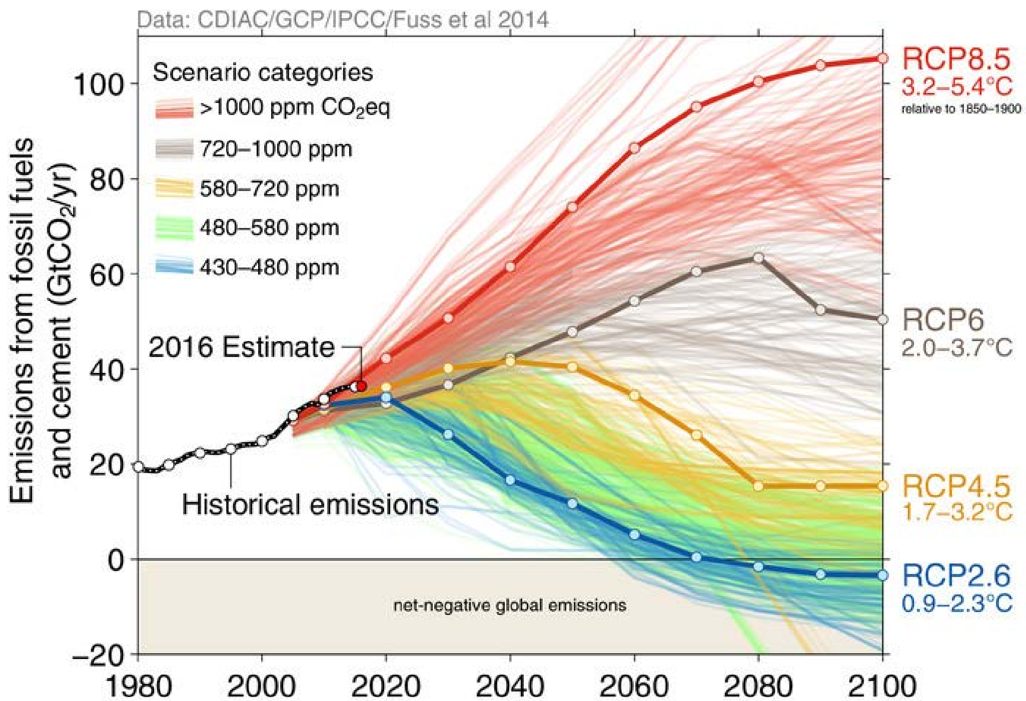


Figure 6.1 The Four Main Representative Concentration Pathways

6.2 Climate Change for the Arctic and Baffin Bay and Davis Strait

A review of the latest IPCC assessment (Collins et al. 2013; IPCC 2014b) was conducted to ascertain the potential changes in climate for the Arctic Region and, where available, specifically for the Baffin Bay and Davis Strait region. Highlights of the findings, taken largely from the IPCC reports, and IQ are provided here.

6.2.1 Surface Temperature

Polar amplification is the disproportionate change in temperature that occurs near the Arctic and Antarctic poles (as opposed to the global average), caused by greenhouse gas emissions of human origin, and changes in surface reflectivity. Arctic amplification is warming of the Arctic at high latitudes generally between 67.5ºN and 90ºN. The timeframes for looking at the future and comparing projections to the present are 2081–2100 for future, with comparisons to 1986–2005.

There is a strong seasonal character to the warming in the Arctic. Warming is projected to peak in early winter (November–December) and the rate of warming during this season is projected to exceed the global average by a factor of about four. Warming would be lowest in summer, when more heat is taken up in the melting of ice and snow, and in warming the ice water and sea water.

There is a fairly well-defined feedback between ice and cover and atmospheric temperature due to the reflecting ability (also known as albedo) of both the snow and ice. The ice extent and snow cover changes with the seasons and, as it changes from a lighter to a darker shade, the solar radiation is not reflected as strongly, and more energy is absorbed at the surface.

There is a vertical structure to the warming of the atmosphere, where warming is projected to be greatest near the surface, and less so aloft.

The researchers acknowledge several factors which complicate the climate projections. These include:

- Initial ice state and timing
- Inversion strength, in a stable Arctic atmosphere
- Ocean heat transport, between south and north
- Albedo feedback, where the rate of warming goes up as the surface darkens
- Short wave and long wave radiative forcing, and associated feedback (see below)
- Clouds and associated feedback

These complications lead to a medium confidence (as described in IPCC 2014) in the specific climate projections.

"Radiative forcings" refers to the changes in radiation that cause, or force, climate change to happen. For example, solar radiation warms the surface of the Earth, and some heat is released back to the atmosphere, but at different wavelengths than when it was absorbed. Heat is absorbed (or reflected) differently at different wavelengths—some of this re-radiated energy is absorbed by clouds and not fully lost back to space. This is the nature of the greenhouse effect that warms the planet.

The projected changes in surface air temperature and ocean temperature for regions of high latitude (North of 60°N), are shown in Table 6.1 (Collins et al. 2013; Figure 12.12).

The projections for near surface ocean temperature are about +1°C to +2.5°C (see Table 6.1)

Table 6.1 Annual Mean Temperature Change—Atmosphere and Ocean

Annual Mean Temperature Change (2081–2100) North of 60ºN		
	Intermediate Concentration Pathway	**Maximum Concentration Pathway**
Atmosphere—near surface	+ 4°C to +5°C	+ 7°C to +9°C
Ocean—near surface	+ 1°C to +1.5°C	+ 1.5°C to +2.5°C
SOURCE: Collins et al. 2013; Figure 12.12 in that report)		

More specifically, for the Baffin Bay and Davis Strait region, using the Intermediate Concentration Pathway, the change in surface air temperature is projected to be +3°C to +4°C and for the Maximum Concentration Pathway the change is projected to be +5°C to +9°C (Collins et al. 2013; Figure 12.11).

Nunavummiut Elders and hunters report that temperatures are now warmer throughout the year, altering the timing and duration of traditional Inuit seasons (Nunavut Climate Change Centre n.d.); participants have observed that the permafrost is melting (Nunavut Tunngavik Inc. 2005).

> We used to be able to cache meat in late spring and it would be perfect for the winter. Now, if we try that, it will be infested with bugs. Today, the springs are very short and summer comes earlier every year. We usually go to Committee Bay to go fishing. We used to be able to travel overland during the spring. But, this is now impossible as the snow melts earlier in the year. It used to start getting cold in early October and ice would form. Freeze-up is later and later every year. Also, we noticed that in the spring, the snow does not freeze at night anymore. This was the practice to travel only at night, when the frozen layer can support the weight of a dog team and sled…Even the summer snows have disappeared. Where there used to be snow in the shady areas, even small permanent ice patches, which remained throughout the summer have melted. I have noticed as well, that during the spring we no longer experience the cold nights. We used to wait until it had got cold enough for the surface layer to freeze, at which time we would travel throughout the night to our destination. It no longer gets cold enough for the surface layer to freeze over enough to support the weight of a qamutik and most nights, it doesn't get cold enough to freeze even the surface layer. As well, during the summer, we no longer experience the swarms of mosquitoes, due to the puddles drying out faster and not allowing the larvae to hatch into adults. However, we have noticed a huge increase in the numbers of houseflies. So many of them are around that sometimes you think the side of the house is black, and it is completely covered with these houseflies. They are now too numerous compared to the old days. (Qaunaq 2001, as cited in Nunavut Tunngavik 2001).

Inuit from Qikiqtarjuaq, Pangnirtung, and Iqaluit have reported that winter temperatures are now warmer (Nunavut Department of Environment 2010; Novaqilik 2002, as cited in Nunavut Department of Environment 2005; Boaz. H, 2002, as cited in Nunavut Department of Environment 2005) and Inuit from Pangnirtung indicated that the winter season is becoming shorter and the sun is becoming hotter (Nunavut Department of Environment 2005).

Regarding extremes, while there is some uncertainty in the specific projections, it is virtually certain that, as global temperatures rise, the Arctic will experience disproportionately hotter temperatures and fewer cold extremes or the Maximum Concentration Pathway, the minimum temperature during the coldest day of the year is expected to rise by 7–9°C in 2081–2100.

Similarly, using the Maximum Concentration Pathway, the number of frost days in Baffin Bay and Davis Strait is projected to drop by 20–40 days in 2081–2100 (Collins et al. 2013; Figure 12.13 in that report).

6.2.2 Precipitation

Changes in the quantities of precipitation tend to scale with changes in mean surface temperature, for both Intermediate and Maximum Concentration Pathways. The precipitation in northern latitudes is seasonal and is expected to increase. The largest changes at high latitudes are expected to occur in winter and spring, including an increase in snowfall in colder regions and a decrease in snowfall in warmer regions, corresponding to fewer frost days. As may be expected, the change is not expected to be uniform across the geography.

Nunavummiut Elders and hunters noted changes in the amount of precipitation relative to historical averages, indicating that there is now more rain, and the snow and ice forms later in the year and melts earlier (Nunavut Climate Change Centre n.d.). Inuit from Iqaluit noted that it is becoming warmer and there are not as many long stretches of cold as there were in the past; ice fog used to be common from January through February, but it is occurring less often as well (Nowdlak, J. 2002, as cited in Nunavut Department of Environment 2005).

The changes in seasonal precipitation projected for Baffin Bay and Davis Strait, for 2081–2100, relative to 1986–2005 are provided in Table 6.2.

Table 6.2 Seasonal Precipitation Change—Baffin Bay and Davis Strait

Seasonal Mean Precipitation Change (2081-2100)	
Season	**Maximum Concentration Pathway**
December -January-February	+40% to +50%
March-April-May	+20% to +30%
June-July-August	+30% to +40%
September-October-November	+40% to +50%
SOURCE: Collins et al, 2013 (Figure 12.22 in that report)	

The long-term changes in precipitation are driven largely by change in surface temperature, and associated change in humidity. The presence of black carbon and stratospheric ozone also influence precipitation and, in turn, are related to changes in heating and atmospheric circulation.

6.2.3 Runoff

Under the Maximum Concentration Pathway, runoff (of water) increases are likely; this is consistent with projections of increased precipitation in these regions.

During the Nunavut Coastal resource Inventory in Grise Fiord, interviewees reported that there is less run-off from glaciers in the summer and glaciers are breaking off; this is resulting in effects on trail conditions (Nunavut Department of Environment n.d.)

6.2.4 Extreme Precipitation

The distribution of events associated with large amounts of precipitation is projected to change considerably as the climate warms; a shift to more intense, individual storms is projected. However, changes in extreme precipitation do not seem to be related to the total precipitation.

These events are influenced by changes in maximum water vapour concentration; as a result, this may increase the intensity, but not necessarily the frequency of heavy snow or rain events. Little information is provided on the change in frequency of the heavy precipitation events.

Episodes of more intense precipitation are projected to occur in the wet seasons, especially at high latitudes. The daily extreme precipitation is projected to increase with temperature, but only at higher latitudes. However, the natural variability in extreme events is large, and this affects the quality of the projections.

One metric used to assess extreme weather events related to precipitation is a measurement of the precipitation that occurs over a period of 5 consecutive days, and the maximum value of this metric over a given period of 10 or more years. The projected change in the maximum five-day precipitation for Baffin Bay and Davis Strait for 2081–2100, relative to 1980–2000, is 10% for the Intermediate Concentration Pathway and 20% for the Maximum Concentration Pathway (Collins et al. 2013).

Thunderstorms, large hail, high winds, and tornadoes are part of the Earth's water cycle. As reported by IPCC, there are two main competing factors in the formation of these events: i) the overall general increase of energy in the system and ii) the decrease in wind shear in the atmosphere. There is a large variability in these factors—and this makes it difficult to produce projections that are accurate. There is still not enough research done to draw firm solid conclusions on projected changes to these extreme weather events (Collins et al. 2013).

Overall, projections suggest a trend toward more thunderstorms, but few details on variables such as frequency are provided.

6.2.5 Storms

Storms in the regions of the planet that are located outside the tropics are referred to as extratropical storms, and these are a focus of this assessment.

Nunavummiut Elders and hunters stated that the weather is unpredictable, changing faster than it used to, with storms blowing up unexpectedly (Nunavut Climate Change Centre n.d.). Inuit from Iqaluit have indicated that storms are becoming stronger, stating:

> We now get these really rainy days that are just like the southern showers that we experience down south. These rains stem from heavy, deep, dark clouds that hold a lot of rain and it is just as strong as down south. We never used to get those kinds of storms, where there was so much rain that everything is covered with water. These storms also produce the occasional thunder and lightning storm. (Nowdlak, J. 2002, as cited in Nunavut Department of Environment 2005)

Inuit from Pangnirtung have observed occasional landslides, which have been attributed to climate change (Novaqilik, 2002, as cited in Nunavut Department of Environment 2005).

Extratropical storm tracks are expected to shift poleward. The shift depends on the change in atmosphere and changes in the degree of shift in the jet streams. For the northern hemisphere, in winter, the projections show an overall reduced frequency of storms and less of a poleward shift, than in the Southern Hemisphere.

Factors that affect changes in storm tracks and storm strength include the horizontal resolution in atmospheric flows (i.e., the jet streams in the atmosphere) and the Atlantic Meridional Overturning Circulation (i.e., the change in ocean currents in the North Atlantic).

As reported by IPCC, there is substantial uncertainty in predicting storm tracks in the Northern Hemisphere (Collins et al. 2013). It is suggested that this is likely because the links among surface warming, storms in the North Atlantic, and influence on and by climate are more complex than simply predicting changes in patterns and trends of atmospheric pressure, especially in the long term out to the year 2100.

One metric used to assess storms and storm tracking is the number of storms per unit time, per unit area, referred to as the storm track density. This metric has been established for different seasons of the year. For example, it is known that the strongest storms in the higher latitudes often occur in fall or winter, rather than in the summer.

The changes in storm track density projected for Baffin Bay and Davis Strait, for 2081–2100, using both concentration pathways are provided in Table 6.3.

Table 6.3 Storm Track Density—Baffin Bay and Davis Strait

	Projected for 2081–2100	
	Intermediate Concentration Pathway	**Maximum Concentration Pathway**
Change in Storm Track Density (number per month per unit area)	- 0.3 to + 0.3	- 0.9 to + 0.3
SOURCE: Collins et al, 2013 (Figure 12.20 in that report)		

The storm track density projections in Table 6.3 suggest that there would be little change under the Intermediate Concentration Pathway. In contrast, under the Maximum Concentration Pathway; the storm track density is projected to be lower in 2081–2100, meaning that less storms are projected for that region for that period.

There have not been many studies on storms in Baffin Bay and Davis Strait region. Residents state that storms in this region in the fall can be quite variable. The storms often have heavy snowfall, and strong winds, creating blizzard conditions, and these can be extreme. Inuit involved in travel, hunting and fishing have reported sudden and surprising changes in the weather, for example change in the winds, bringing with them an abrupt change from cold to warm temperatures (Roberts et al. 2008). Inuit from Iqaluit have observed that there have been fewer blizzards recently (Joamie, M. 2002, as cited in Nunavut Environment 2005).

Villarini and Vecchi (2012), Zhang et al. (2004), and others report that cyclone activity and intensity have increased in the Arctic, and suggest that storm tracks have shifted northward, with stronger winds associated with global warming. There is some support for both increases and decreases in the frequency of the storms.

One study reported measurements from weather balloons (rawinsondes) released during 6 different storms that passed over the southern part of Baffin Island in the autumn of 2005 (Roberts et al. 2008). The rawinsonde is released into the atmosphere to study weather conditions aloft and is outfitted with instruments to measure the upper-air conditions, including wind direction and speed, temperature, pressure, and relative humidity, and how these might change with height above the ground. Once released, the balloon travels upward, and sends signals from a radiosonde transmitter that is being tracked with radar or a radio-direction finder. Highlights of that study are provided below (Roberts et al. 2008).

In the eastern Arctic area, on average, the stormiest months are October and November. The storms can consist of heavy snowfall, strong winds, rain, fog, temperatures below freezing, and reduced visibility due to blowing snow or fog. These seem to be associated with periods of higher relative humidity.

The weather is often controlled by large scale pressure distributions that form to produce flows from the southeast to the north. These events are often associated with a shift in a zone of low pressure and very cold air known as the Polar Vortex. The shift occurs as the large stable cold air mass moves from the high Arctic to another region such as the northern part of Hudson Bay. On occasion a shift in the Polar Vortex further south may result in cool temperatures in the southern USA.

Frontal passages occur with associated and well-developed changes in wind speed and direction. The changes in wind direction during the passing of these fronts is often from southeast to northwest.

The types of precipitation during these events include snow, ice crystals (many different types), freezing drizzle, rain and fog. Sometimes, as the front passes through a given region, all of these may be experienced. Some additional notes on these storms include (Roberts et al. 2008):

- Storms originated in the USA Midwest, the Canadian Prairies, or Eastern Canada
- Maximum air temperatures were warmer than normal
- Wind speeds in the studies ranged from 35 km/h to just over 100 km/h
- The strongest winds were reported from the southerly and southeasterly directions
- Snow accumulation ranged from 2–10 cm during the storms
- Visibility was reduced in blowing snow to less than 2 km

There was a concern that hazardous conditions associated with these storms could increase in the future. This could be in the form of events with more rain, as surface air temperature warms, causes more snow and ice melt, and associated runoff. The consequences are likely to be related to excess water and flooding on land, and less sea ice to travel or hunt on.

6.2.6 Sea Ice Cover

The Arctic Sea Ice cover is projected to shrink considerably in the period 2000 to 2100 (Collins et al. 2013). The variability in the model results is considerable. Some projections predict that the Arctic Ocean will be almost entirely ice free in late summer, by about 2050.

During the NCRI in Grise Fiord, interviewees reported that the open water season is currently lasting longer and sea ice is melting sooner and breaking up faster than it had previously; interviewees noted that there is less summer ice and the ice is less stable, which results in dangerous traveling conditions (Nunavut Tunngavik 2005; Nunavut Department of Environment n.d.). Similar conditions are observed in Qikqtarjuaq, with interviewees noting that these changes alter hunting practices, and earlier ice break-up results in more bears in town (Nunavut Environment 2010). Inuit in Iqaluit and Pangnirtung have also observed sea ice forming later and breaking up or melting earlier than it has in the past (Nunavut Department of Environment 2005; Novaqilik 2002, as cited in Nunavut Department of Environment 2005; Keenaiak, A. 2002 as cited in Nunavut Department of Environment 2005; Boaz, H. 2002, as cited in Nunavut Department of Environment 2005; Kownirq 2002, as cited in Nunavut Department of Environment 2005; Tiglik 2002, as cited in Nunavut Department of Environment 2005). Sea ice also appears to be thinner although whether it is thinner everywhere or only in specific locations was not known (Nunavut Department of Environment 2005).

Pijamini (2001, as cited in Nunavut Tunngavik Inc. 2001) has observed changes to glaciers and sea ice since arriving in the region in 1962:

> …my first impression was one of ice and more ice. There were huge glaciers and the summers were very short. It would start freezing up around September and as I recall, it would snow in August. A few times, I remember we were still seal hunting on the ice into August and sometimes the sea-ice never completely melted and it didn't leave the Sound. Then it would freeze-up over the previous ice cover. Nowadays, the ice cover completely melts and we now have progressively longer ice-free seasons. The open water season is pronouncedly longer than even 30 years ago. The sun is hotter and the median high temperature now reaches over 7°C, which was unheard of even 10 years ago. The glaciers in our mountains have steadily digressed to the point where they are no longer perceptible to our eyes. We have to wander up unto the mountain reaches in order to see the glaciers at this point in time. The melting of the glaciers has affected us and we cannot use our usual shortcut via the gooseneck valley because it has melted to the point where there are house-sized boulders blocking the skidoo path. We are no longer able to travel to the other side of our island where there are char. The river…is getting shallower and shallower, to the point where it is hard for the fish to reach the lake.

The projected decrease in sea ice areal coverage is greatest at the end of the summer (i.e., in September). Using the Maximum Concentration Pathway, the reduction in Arctic sea ice in 2081-2100 is projected to be up to 34% in February and up to 94% in September, relative to 1986–2005 (Collins et al. 2013). Based on the observed changes in sea ice extent to date, as presented in Section 3.1, the basis for this projection seems to be valid.

Members of the Hunters and Trappers Organization from Qikiqtarjuaq expressed concerns that less ice has recently been forming on the Greenland side of Baffin Bay (Government of Nunavut 2017g). During the SEA community engagement session in Grise Fiord, a community member stated: "Because of climate change the ice is beginning to recede," (Nunavut Impact Review Board 2017).

In the context of the northern latitudes, "nearly ice free conditions" is defined as a coverage of sea ice that is less than 1 by 10^6 km^2 (1 M km^2) for a period extending for five consecutive years. As reported in the IPCC results, most models predict that the Arctic will be nearly ice-free in September, and this may well occur before the end of the 21st century. Several model projections indicate that this will occur at about 2050–2070.

Satellite observations of Arctic sea ice have been made and recorded since the late 1970s, and these continue today. The changes in sea ice extent, projected for 2081–2100, relative to satellite observations of 1986–2005, are shown in Table 6.4.

Table 6.4 Projected Change in Sea Ice Extent, Arctic Ocean by 2081-2100

	Satellite Observations—1986–2005	Projected Change—Intermediate Concentration Pathway	Projected Change—Maximum Concentration Pathway
February—Sea Ice Extent (10^6 km^2)	15.5	- 2	- 5
September—Sea Ice Extent (10^6 km^2)	7.1	- 4	- 6
SOURCE: Collins et al. 2013 (Figure 12.28 in that report)			

As noted above, observations of sea ice are continually being recorded. Projections have been compared to more recent observations up to 2012. The results suggest that the sea ice extent is changing faster than projected (Collins et al. 2013). It is emphasized that the impact of natural variability is important in the comparison, because the observed record is relatively short. Nevertheless, a review of the model projections and recent observations suggests a decline in sea ice extent that is faster than the mean projected value.

In summary, as reported by the IPCC, it is very likely that Arctic sea ice cover will continue to shrink and thin year-round, as surface air temperatures rise.

6.2.7 Waves

There is low confidence in the projections of future storm tracks in the Northern Hemisphere. Therefore, there is low confidence in projections on waves or significant wave heights (SWH). The projected largest change in SWH is for the Southern Ocean, and a negligible change is projected for all other ocean basins. There is considerable debate in the literature on these findings. Nevertheless, the projection of less sea ice in Baffin Bay and Davis Strait suggests that enhanced wave generation is likely to occur in accordance with the longer open water season (Church et al. 2013).

During the NCRI in Grise Fiord, interviewees stated that larger waves are resulting in greater coastline erosion, adding that there is currently also less snow and more wind (Nunavut Department of Environment n.d.)

6.2.8 Snow Cover and Frozen Ground

Analyses of snow cover in the IPCC reports have focused on the Northern Hemisphere. The areal coverage of snow is referred to as the snow cover extent. The projected change in snow cover extent is for a decrease of 9–17% under the Intermediate Concentration Pathway, and from 17–33% under the Maximum Concentration Pathway. It is very likely that the snow cover extent in spring will be substantially lower by 2100, for both pathways.

The projections for change in permafrost vary widely. The physical processes that result in changes to permafrost are relatively complex, especially with variation in underlying geology and depth. The models are now beginning to handle those physical processes that drive the permafrost change much better.

The projected change in the area of near surface permafrost in high latitudes, is for a reduction of 38–64% for the Intermediate Concentration Pathway, and 69–93% for the Maximum Concentration Pathway, relative to 1986–2005 values.

Despite variability in model projections, it is virtually certain that near-surface permafrost extent will shrink as the climate warms. Inuit from Pangnirtung indicated that permafrost is melting to a deeper level (Nunavut Department of Environment 2005).

Inuit from Iqaluit have observed changes in permanent snow cover (*aniuvat*), stating: “It’s a lot warmer now and these aniuvat are long gone prior to summer. They used to remain all summer, but they melt now and you can see where the old aniuvat used to be, because those sites are bare of vegetation and they are lighter than the surrounding area,” (Nowdlak, 2002, as cited in Nunavut Department of Environment 2005). Nowdlak (2002, as cited in Nunavut Climate Change Centre n.d.) also stated: “Permanent snow patches that remain in the hills around Iqaluit all year are one of the indicators that Inuit use to monitor environmental changes. In recent years, these permanent snow patches have reduced in size”. Inuit from Iqaluit indicated that the snow that is present is becoming very hard and does not have as many *pukajaaq* (ice crystals) as would be expected, potentially due to the wind (Nunavut Department of Environment 2005). Tiglik (2002, as cited in Nunavut Department of Environment 2005) noted that the lack of snow is resulting in effects on travel routes and hunting. Inuit from Pangnirtung have observed that there has been less snow recently and the snow that falls has been melting faster; this has had an effect on sledding (Nauyk, S. 2002, as cited in Nunavut Department of Environment 2005).

6.2.9 Weather Forecasting and Climate Change

The changing climate makes weather forecasting more difficult in many areas, but particularly in those geographical regions where the data observation network is sparse, and where there is a critical dependence on the transitions from liquid to frozen water. In the early days, the basis of weather forecasts was based on the concept of persistence—the continuing trend in weather elements from one day to the next (Neiburger et al. 1973). The basis of modern forecasts is a computer-intensive, gridded estimation of pressure changes in the atmosphere that determine the trajectory of weather disturbances ranging from weak depressions (in pressure) to large storms including hurricanes.

In areas where the surface weather monitoring network is sparse, forecasts are often tailored by using statistical relationships between the computer forecast and the actual conditions, for example by the perfect prognosis method, or model output statistics (MOS) techniques (Walker 1984). These relationships are based on development datasets. For example, the computer forecast and observed conditions are compared by techniques such as regression analysis and those equation sets are used to improve the computer-based forecast.

The use of any technique relying on past data to produce future estimates is very sensitive to the changes in the data, as the techniques are inherently based on an assumption of a stable, unchanging dataset. Clearly all datasets have intrinsic variability due to fluctuations in weather, but changes in the climate represent a change in the averages of the fluctuations, so that the net effect will become a further inaccuracy in the forecasts. Exacerbating this problem is the fact that many of the models for weather elements and climate change are based on concepts of linear change (Walker 1984). This approach does not do well in consideration of abrupt changes, such as ocean circulation patterns, or, at a local time and spatial scale, the transitions from liquid water to ice and back. The distinct differences in the albedo of snow-covered surfaces, or ice, and liquid water and tundra are responsible for very different energy balances of the surface. A change in climate that crosses the freezing threshold (for water) is a very large change. Less obviously, small changes in ocean circulation that cause a shift in the surface temperature of the ocean—such as el Nino and la Nina of the Pacific—may cause large changes in weather on a broad scale.

It is the freezing transition that may be of greatest concern to Canada's indigenous peoples, as the frozen surface is a transition from limited mobility to a freer mobility among islands and across the mouths of rivers and bays. Forecasting these transitions is difficult in a stable climate, and more so in a changing one.

The occurrence of extreme events is another area of analytical difficulty. Extreme events, such as maximum possible rainfall, temperature and wind speed extremes, and other element maxima are significant events. The incidence of and trajectories of icebergs are also controlled by the temperature, wind and ocean currents, that is, by weather elements that are changing. Where weather disasters are involved, and where relief may be hampered by great spatial separation, the possibility of weather extremes must be considered carefully.

The financial impact of weather disasters is also relevant. Most extreme value statistics are based on an analysis of past extreme events. The probabilities of 1:100 year, for example, are typically based on consideration of an extended record of maximum yearly values of an element, such as wind speed or river flow. The change in climate will eventually render the past data set unreliable. It may be that different analysis methods are essential to cope with changes in the climate. This part of climate change may be the most difficult aspect to address, as there is a strong dependence on a long record to produce reliable results, and the pace of change may introduce more variance into the estimates than can be tolerated in assessments of financial risk or project feasibility.

6.3 Climate Projections—for Baffin Bay and Davis Strait

The climate projections for the Baffin Bay and Davis Strait region presented here are based on data from a weather station located at Clyde River, Nunavut. (see Figure 6.2). The station details are provided in Table 6.5.

Table 6.5 Station Details for Clyde River, Nunavut

Station ID	Clyde River Climate (2400802)
Location	Clyde River, NU
Coordinates	-68.5167, 70.4833

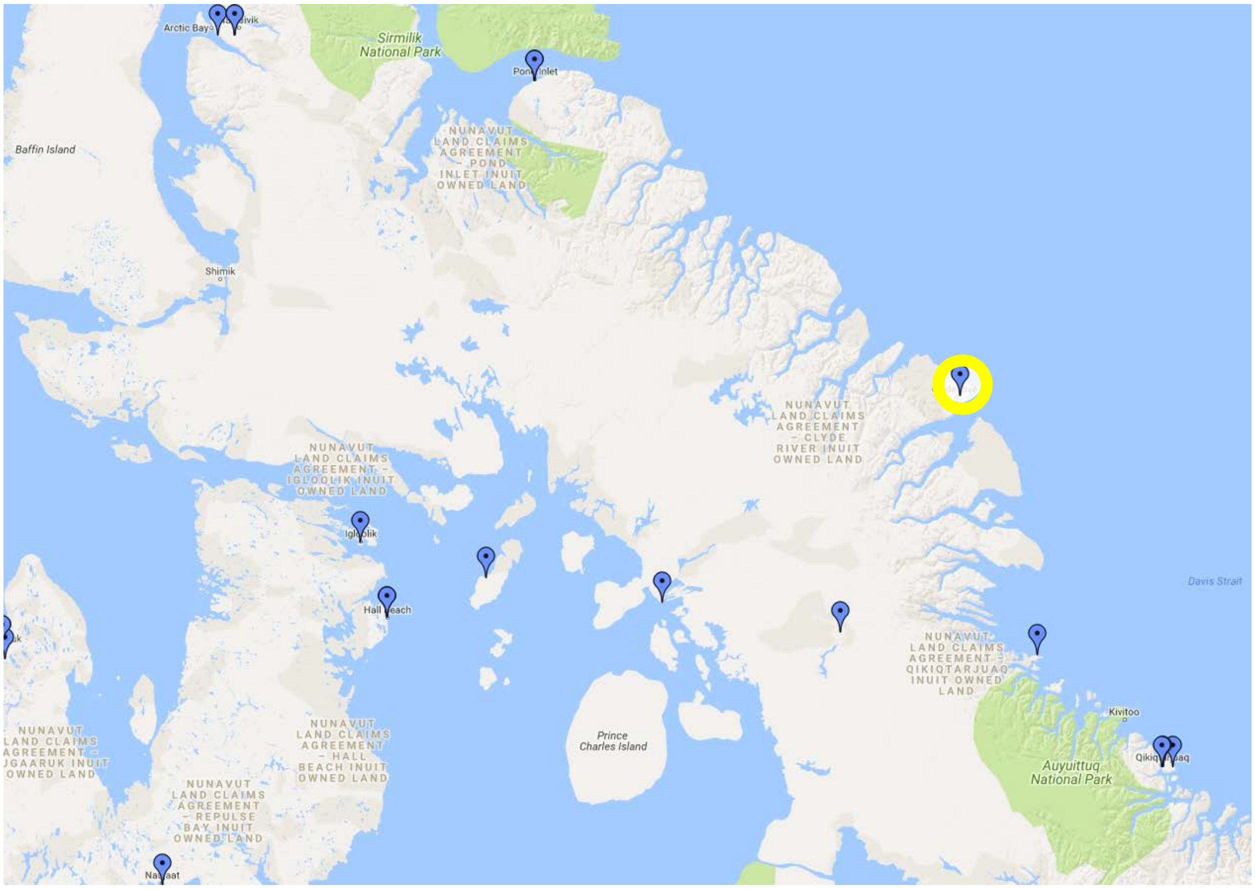


Figure 6.2 Weather Stations in the Canadian Arctic—Highlighted location is Clyde River

In the review of available data and the period of record, there was insufficient data available from the Clyde River Climate station on all elements. Therefore, temperature, precipitation, and daily frost statistics were taken from the Canadian Gridded Temperature and Precipitation Anomalies (CANGRD) database on data for Clyde River, prepared and maintained by Environment and Climate Change Canada (ECCC) (ECCC 2018c). As stated on the website, CANGRD is a set of Canadian gridded annual, seasonal, and monthly temperature and precipitation anomalies, which were interpolated from stations in the Adjusted and Homogenized Canadian Climate Data database.

The climate projections for Clyde River were extracted from the Climate Change Hazards Information Portal database, via the Risk Sciences International data portal (Risk Sciences International 2018).

The projections of future climate described herein were made as part of this assessment. The model was started with this 1999–2013 data from CANGRD and were produced from runs of 37 different Global Climate Models (this study and Risk Sciences International, 2018). This 1999–2013 dataset is a shorter and more recent period of data and was selected to initiate the climate models because the observed changes in the North are happening faster there than at other non-polar locations. These more recent data are more reflective of the current conditions than data from 1981–2010, and the accuracy of the model runs is likely to benefit from the more recent data, as a starting point.

The climate projections for Baffin Bay and Davis Strait are compared with the average values for the period 1981–2010. In this climate analysis, Winter is defined as December, January and February; Spring is defined as March, April and May; Summer is defined as June, July and August, and Autumn is defined as September, October and November. These categorizations are similar to those used by the IPCC in their seasonal projections.

Future projections are based on the two scenarios described above: the Intermediate Concentration Pathway (RCP4.5) and the Maximum Concentration Pathway (RCP8.5). The projections were made for the following time horizons: 2020s, 2050s and 2080s. The 2020s:time horizon uses trend data and projections for the period 2005 to 2035. This period could be considered as “current climate”. The 2050s time horizon refers to the period of 2035 to 2065. The 2080s refers to the period of 2065 to 2095.

6.3.1 Projected Changes in Mean Temperature

The largest change is projected using the Maximum Concentration Pathway for 2080s, to occur in winter and is +12.1°C (Table 6.6). This is similar to, and a bit higher than the projection by IPCC.

Table 6.6 Average Change in Mean Temperature Relative to 1981–2010

Season	Average Change in Mean Temperature (°C)					
	Intermediate Concentration Pathway			Maximum Concentration Pathway		
	2020s	2050s	2080s	2020s	2050s	2080s
Annual	1.6	3.0	3.7	1.8	4.5	7.5
Winter	2.1	4.3	5.5	2.5	6.7	12.1
Spring	1.2	2.4	3.1	1.5	3.7	6.4
Summer	0.7	1.3	1.6	0.7	2.0	3.4
Autumn	2.2	4.0	4.7	2.5	5.5	8.2

Additional details in the climate projections are shown in Figure 6.3 to Figure 6.6; the changes in mean daily temperature for the 1999–2013 period are shown by the blue bars. The trend in those data are plotted as the red line. The average value for the reference period of 1981–2010 is shown as the green bar. The climate projections for the 2020s, 2050s, and 2080s, are represented by the brown bars.

In all cases, the trends in projected change in temperature are upward. The projected values are higher than the reference period.

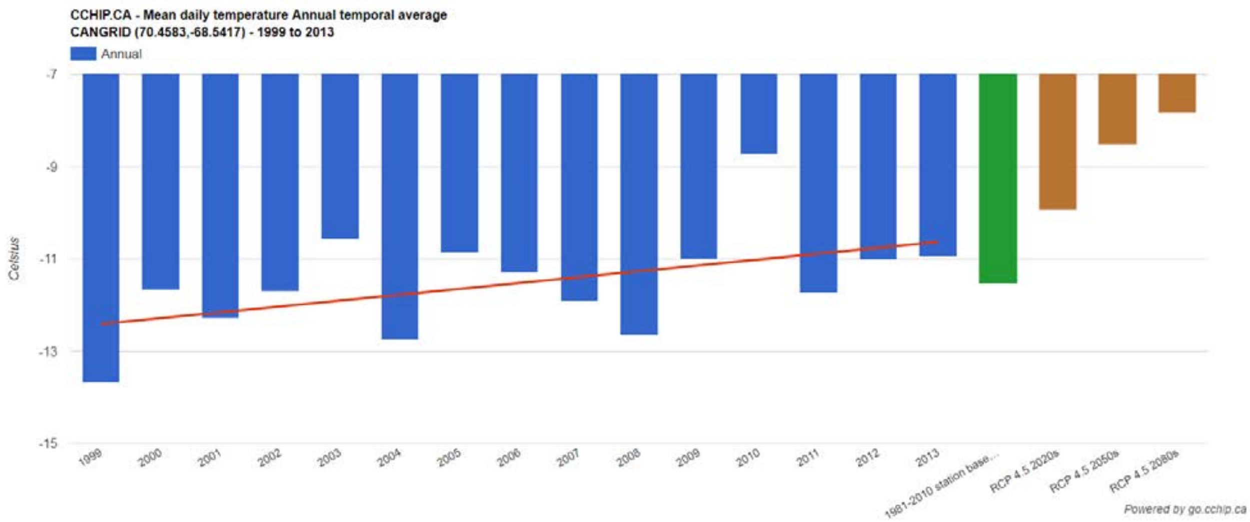


Figure 6.3 Annual Temporal Average—Mean Daily Temperature—Intermediate Concentration Pathway

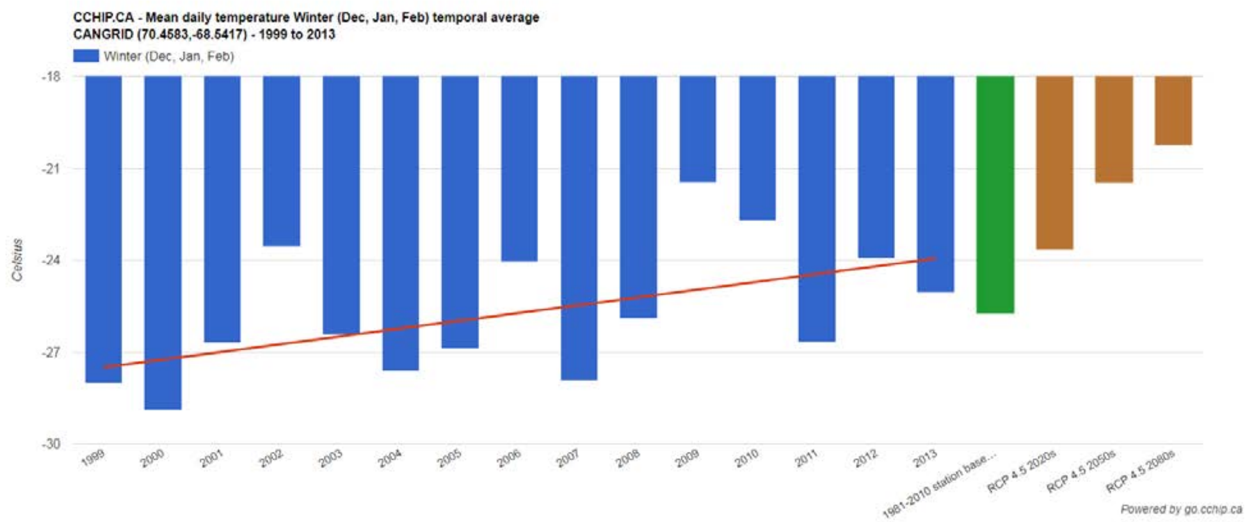


Figure 6.4 Winter Temporal Average—Mean Daily Temperature—Intermediate Concentration Pathway

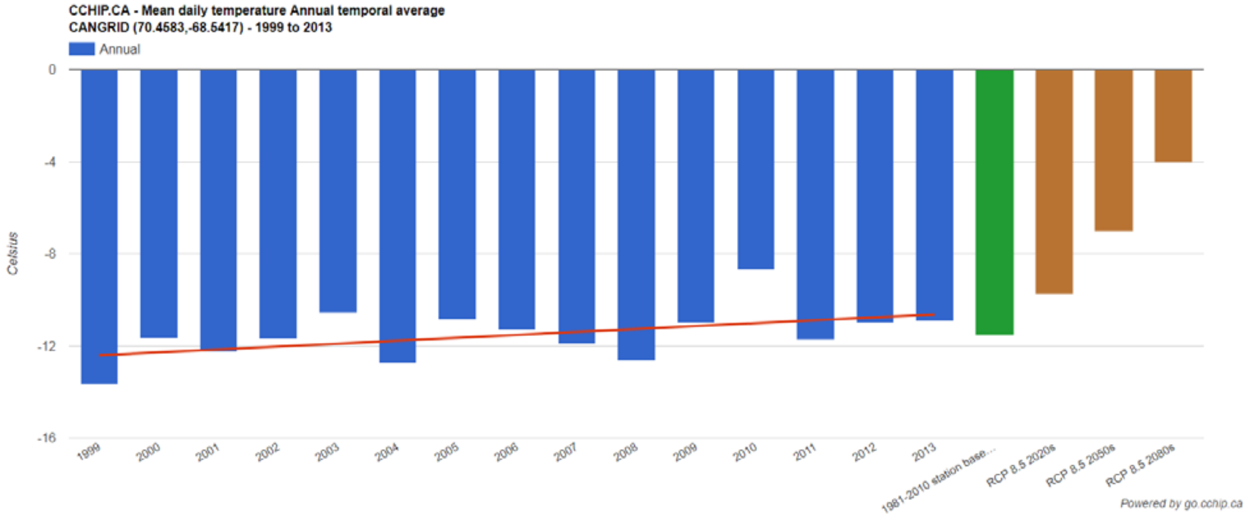


Figure 6.5 Annual Temporal Average—Mean Daily Temperature—Maximum Concentration Pathway

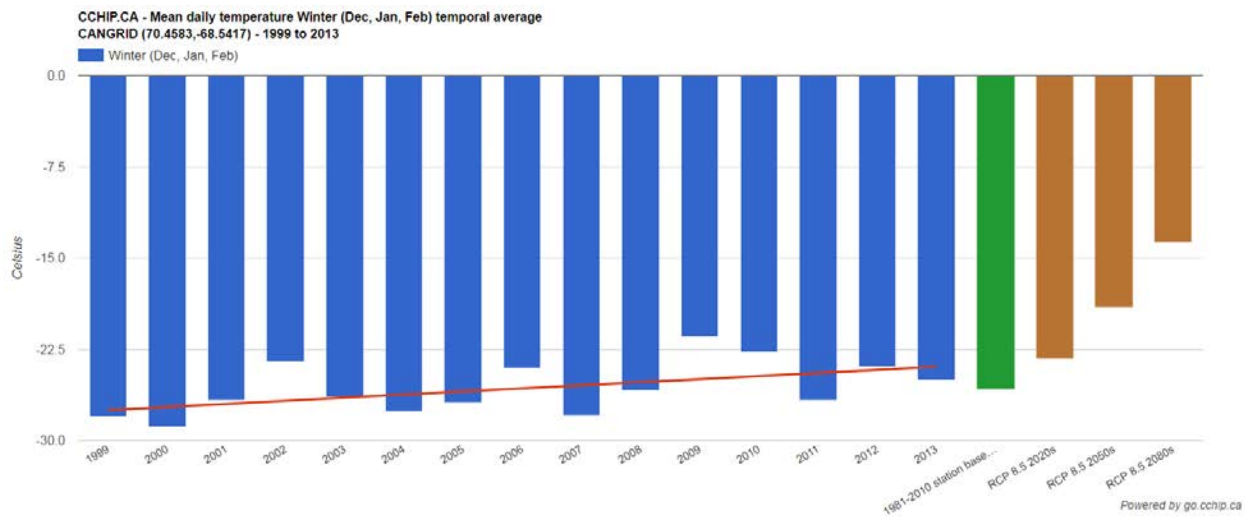


Figure 6.6 Winter Temporal Average—Mean Daily Temperature—Maximum Concentration Pathway

6.3.2 Projected Changes in Maximum Temperature

The average change in the maximum surface air temperatures projected for Clyde River are provided in Table 6.7. The largest change is projected using the Maximum Concentration Pathway for 2080s, to occur in winter and is +11.2°C.

Table 6.7 Average Change in Maximum Temperature from 1981-2010

Season	Average Change in Maximum Temperature (°C)					
	Intermediate Concentration Pathway			Maximum Concentration Pathway		
	2020s	2050s	2080s	2020s	2050s	2080s
Annual	1.4	2.8	3.5	1.6	4.0	6.9
Winter	2.0	4.1	5.3	2.3	6.2	11.2
Spring	1.1	2.1	2.8	1.3	3.2	5.6
Summer	0.7	1.3	1.6	0.7	1.9	3.3
Autumn	1.9	3.5	4.2	2.2	4.9	7.3

6.3.3 Projected Changes in Minimum Temperature

The average changes in the minimum surface air temperature projected for Clyde River are provided in Table 6.8. The largest changes are projected using the Maximum Concentration Pathway for 2080s, to occur in winter and autumn at +11.6°C and +10.3°C, respectively.

Table 6.8 Average Change in Minimum Temperature from 1981-2010

Season	Average Change in Minimum Surface Air Temperature (°C)					
	Intermediate Concentration Pathway			Maximum Concentration Pathway		
	2020s	2050s	2080s	2020s	2050s	2080s
Annual	1.7	3.4	4.2	1.9	4.9	8.3
Winter	2.1	4.3	5.5	2.4	6.4	11.6
Spring	1.4	2.8	3.7	1.7	4.2	7.3
Summer	1.0	1.7	2.1	0.9	2.4	4.2
Autumn	2.5	4.7	5.8	2.7	6.6	10.3

6.3.4 Projected Changes in Precipitation

The average changes in precipitation projected for Clyde River are provided in Table 6.9. The largest changes are projected using the Maximum Concentration Pathway for 2080s. The largest annual average is 35.1%, relative to 1981–2010. The largest seasonal value is projected to occur in winter and is 60%. The precipitation change values for spring, summer and autumn are lower, on the order of 30–36%. Similar to temperature, these projected values are similar, if a bit higher, to those presented by IPCC.

Table 6.9 Average Percent Change in Total Precipitation relative to 1981-2010

Season	Average Change in Total Precipitation (%)					
	Intermediate Concentration Pathway			Maximum Concentration Pathway		
	2020s	2050s	2080s	2020s	2050s	2080s
Annual	6.1	13.9	16.9	7.5	19.2	35.1
Winter	7.8	20.1	27.0	11.1	29.8	60.0
Spring	5.6	9.9	12.7	5.0	14.3	29.8
Summer	5.8	12.0	14.4	7.2	16.6	28.7
Autumn	6.7	16.5	18.4	8.6	21.1	35.8

Additional details in the climate projections for precipitation are shown in Figure 6.7 and Figure 6.8. In the figures, the measured changes in mean annual precipitation for the 1999–2013 period are shown by the blue bars. The trend in those data is plotted as the red line. The average value for the reference period of 1981–2010 is shown as the green bar. The climate projections for the 2020s, 2050s, and 2080s, are represented by the brown bars.

The trends in the observed (i.e., measured) data are both downward. For the projections, the trends in projected change in precipitation are upward. The projected values are higher than the reference period. The highest values are projected for the 2080s using the Maximum Concentration Pathway. The change in trend direction may be associated with the warming of the atmosphere, and higher carrying capacity of the air masses in the region, which are thought to lead to higher precipitation.

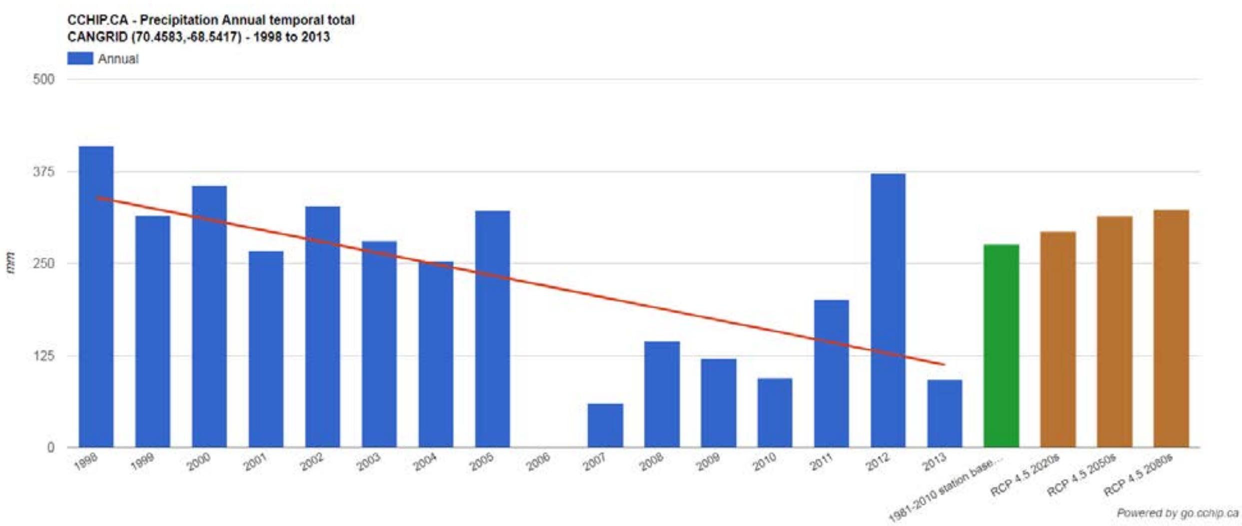


Figure 6.7 Annual Precipitation Temporal Total—Intermediate Concentration Pathway

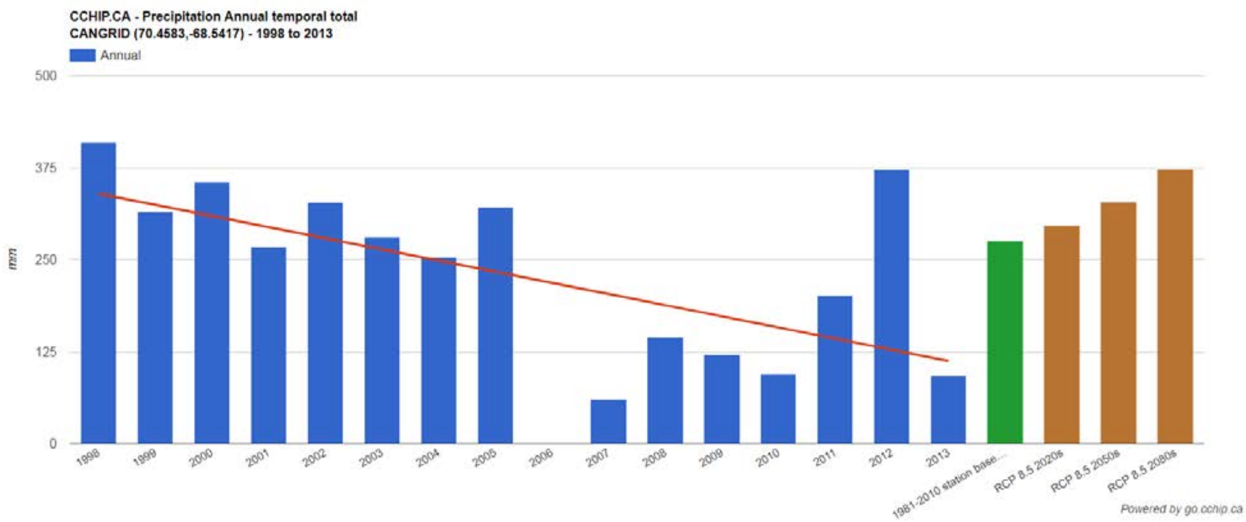


Figure 6.8 Annual Precipitation Temporal Total—Maximum Concentration Pathway

6.3.5 Projected Changes for Daily Frost

The average values for the number of frost free days per year projected for Clyde River are provided in Table 6.10. The largest changes are projected using the Maximum Concentration Pathway for 2080s. The largest change is from 68 to 131 frost free days in the 2080s. These projected values are similar, and a bit higher, to those presented by IPCC.

Table 6.10 Average Frost-Free Days

	Average Frost-Free Days	
Period	**Intermediate Concentration Pathway**	**Maximum Concentration Pathway**
Baseline	68	68
2020s	81	83
2050s	95	108
2080s	102	131

Additional details on the climate projections for frost days are shown in the daily frost profiles in Table 6.7 and Table 6.8. In the figures, the probability of a frost day to occur is charted for each day of the year, with a range of 0 to 100%. The 100% value indicates that on that day of the year, frost is 100% likely. At 0%, this value indicates with certainty that frost is going to occur on that day. The average values are observed at the 50% probability.

The historical frost day probability over the period 1999-2013 is indicated by the blue line. The projected values of frost probability of the 2020s, 2050s and 2080s are indicated by the green, orange and red lines respectively.

As shown in both Figure 6.9 and Figure 6.10, the projected values of frost probability are high in winter, spring and fall days, and decrease in the summer days. The projected values also drop off sooner and begin to increase later in the year with the 2080s projections. As shown in the table above, the number of days projected to be below 50% probability, using the Maximum Concentration Pathway and for the 2080s period, is 131 days. This is compared to the historical value of 68 days.

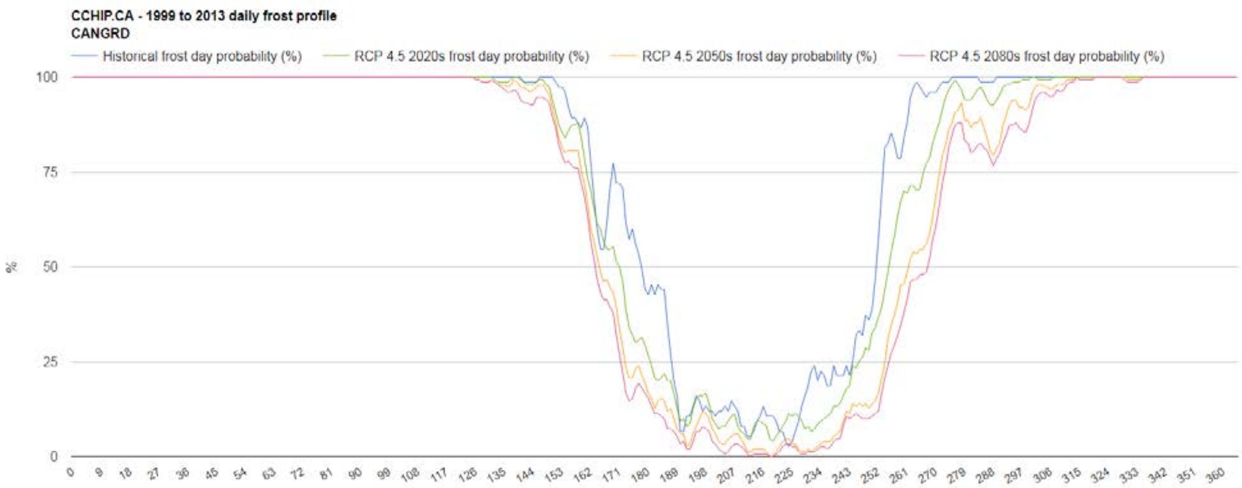


Figure 6.9 Daily Frost Profile—Intermediate Concentration Pathway

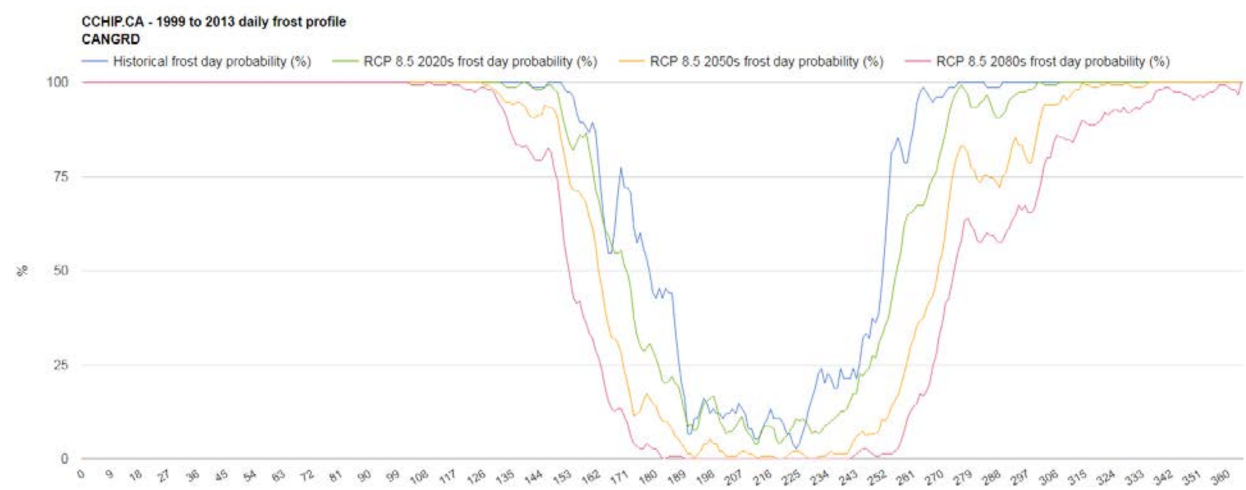


Figure 6.10 Daily Frost Profile—Maximum Concentration Pathway

6.4 Summary

The surface air temperature in and around Baffin Bay and Davis Strait is projected to rise by approximately 9–12°C by 2100 (Maximum Pathway), and the change is projected to be highest in the winter season. The number of frost free days are projected to increase from 68 to over 100 days, with the maximum projected value at 131 days.

The SST in Baffin Bay and Davis Strait is a function of the exposure to sunlight, warm and cold water inflows and discharges, salt content, winds, and surface albedo. The SSTs, as measured in August, provide the best representation of Arctic Ocean summer SSTs—as these are not affected so much by the cooling and subsequent ice growth in late September. The observed trends in Baffin Bay are not uniform. The trend in the northwest Baffin Bay is 0 to -0.5°C per decade, while in the central part of the Bay, the trend is approximately +0.8°C per decade. The SST trends on the west side of Greenland are higher, about 1°C per decade. Sea water temperatures near the surface in Baffin Bay and Davis Strait are projected to increase by 1.5 to 2.5°C by 2100.

Precipitation changes are projected to increase in Baffin Bay and Davis Strait by 40–60%. The changes are strongly seasonal, with the maximum values projected to occur in winter. The form of precipitation depends on a number of factors including the humidity and the air temperatures compared to the freezing point. The projected air maximum temperatures remain below freezing, in winter and spring, and crossover to above freezing in the autumn. The temperatures both current and projected are above freezing for the summer. The form of precipitation would therefore be more rain and less snow, at those projected temperatures, and this is more likely to occur in the autumn.

Sea level pressures are likely to change with variation in the frequency of storms over the region.

Snow cover is projected to decrease by 9–33%, and this seems to be consistent with the projection for frost free days. It is likely that snow cover in the Spring will be substantially lower by the year 2100.

The sea ice extent is reaching a lower value earlier in the year than in the past. Freeze up starts between late September–early October and reaches a maximum between February–March. Ice melt begins between May–June, and sea ice extent reaches a minimum in September. The minimum sea ice extent has decreased substantively from values in 1981–2010. The sea ice extent is projected to decrease in the Arctic by 34% in February and 94% in September. This is likely to be similar for Baffin Bay and Davis Strait, except that the frozen Baffin Bay and Davis Strait already opens up and is nearly ice free in September.

The main sources of icebergs and subsequent drift patterns in Baffin Bay and Davis Strait are in areas near Disko Island on the west side of Greenland. Most icebergs in Baffin Bay are generated from Greenland glaciers north of Disko Bay up to Kap York and two areas to the north of there. The total number of icebergs calved from Greenland glacial ice in these areas and released to Baffin Bay and Davis Strait is estimated to be 25,000 to 30,000 per year. The changes in the mass of the Greenland ice sheet are thought to be related to presence and number of icebergs in Baffin Bay and Davis Strait. Estimates of glacial ice net loss are -264 to -270 gigatonnes (Gt) per year. As surface air temperatures increase, the rate of loss is likely to increase, producing more icebergs in the near term. This may mean more icebergs in Baffin Bay and Davis Strait initially, but it is recognized that with sufficient warming this number may eventually decrease due to more rapid melting.

The frequency of extreme events related to storms in the Baffin Bay and Davis Strait region is projected to stay similar to present values, or to decrease. Although there may be fewer storms, the trend in storm intensity is still upward, although few details are provided. There is considerable uncertainty in the projections associated with the projections of extreme events in this region.

7 POTENTIAL EFFECTS, MITIGATION AND PLANNING CONSIDERATIONS

7.1 Physical Environment

Potential impacts associated with routine activities described in the hypothetical scenarios of offshore oil and gas development and exploration are identified in Table 2.1.

The impacts of routine activities for the oil and gas scenarios that could result in effects on the physical environment are:

- **Air emissions** associated with exploration, drilling, production and transport
- **Noise** associated with seismic surveys, marine transportation, and drilling
- **Routine discharge** associated with marine transportation and drilling operations
- **Drill and mud cuttings** associated with exploration and production drilling operations
- **Ice Disturbance** associated with icebreaking vessels and ice management around drilling structures

Potential impacts on Physical Environment VECs resulting from activities associated with oil and gas scenarios are identified in Table 7.1. Potential effects of accidents and malfunctions on the physical environment are addressed in Section 7.1.4.

Table 7.1 Summary of Potential Impacts on Physical Environment

	Potential Environmental Impacts				
Valued Ecosystem Component	**Air Emissions**	**Noise**	**Routine Discharge**	**Drill and Mud Cuttings**	**Ice Disturbance**
Climate and Meteorology					
Air Quality and Greenhouse Gas Emissions	✓				
Oceanography			✓		
Sea Ice and Iceberg Conditions					✓
Acoustic Environment		✓			
Geology					
Coastal Landforms					
Marine Sediment				✓	
NOTES: "✓" = Indicates potential effect from oil and gas activity					

Potential effects on VECs from routine activities associated with each of the impacts identified above are discussed in Section 7.1.1. Effects are discussed in the context of the activities associated with each of the hypothetical scenarios (Section 2.3.3.1).

Scenario D (no offshore oil and gas activity) will not result in impacts from oil and gas activities on the physical environment. However, if oil and gas development does not proceed in the Area of Focus, it is important to note that effects on the physical environment may still occur as a result of interaction with other anthropogenic activities (e.g., increases in shipping and tourism, port and infrastructure development) or impacts associated with climate change (see Section 2.3.4).

The potential for cumulative effects and transboundary effects are discussed in Sections 7.1.2 and 7.1.3. Potential effects of accidents and malfunctions are discussed in Section 7.1.4. Mitigation measures and planning considerations that could be used to reduce or eliminate potential effects are discussed in Section 7.1.5.

Only VECs that have been indicated in Table 7.1 as having an interaction with an impact associated with the oil and gas activities are discussed below. If a VEC is not expected to interact with oil and gas activities, or if potential effects from interaction can be mitigated under existing regulations or using standard practices or planning considerations, then it is assumed that residual effects on the VEC would not occur and it is not considered further in the discussion of potential effects.

7.1.1 Potential Effects from Routine Activities

Potential effects considered in the discussion of effects on the physical environment are defined as follows.

CHANGE IN AIR QUALITY

A change in quality refers to the alteration of ambient air resulting from the release of air contaminants to the atmosphere. Change in air quality is measured as ground level concentrations of air contaminants in micrograms per cubic metre (µg/m^3), including sulphur dioxide (SO_2), nitrogen oxides (NO_X), carbon monoxide (CO), total particulate matter (PM), and particulate matter less than 2.5 microns ($PM_{2.5}$).

CHANGE IN GREENHOUSE GAS EMISSIONS

A change in greenhouse gas emissions refers to the release of GHGs to the atmosphere. GHG emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are considered. Total GHG emissions in CO_2e per year are determined using the mass of individual species and global warming potentials (GWPs) from IPCC Report 5 (IPCC 2013).

CHANGE IN NOISE LEVELS

A change in noise levels refers to a change in the nature of the receiving environment as compared to ambient noise levels.

CHANGE IN SEA ICE QUALITY AND EXTENT

A change in sea ice quality and extent refers to the alteration of sea ice structure, thickness, distribution or stability resulting from the movement of an icebreaker through the ice or the placement and operation of in water infrastructure that alters the natural formation and/or dynamics of sea ice.

CHANGE IN WATER QUALITY

Change in water quality refers to any alteration to pH levels, dissolved oxygen, water temperature, total suspended solids (TSS) or contaminants in the water column.

CHANGE IN SEDIMENT QUALITY

A change in sediment quality refers to the alteration of sediment quality including physical changes (e.g., sand and silt size fractions) or changes in the chemical composition of sediments (e.g., from drilling cuttings and muds) or release of contaminants that settle on the seafloor.

Only potential effects that have been indicated in Table 7.1 as having an interaction with a VEC that could result in potential residual effects are discussed below. If a VEC is not expected to interact with oil and gas activities, or if potential effects from interaction can be mitigated under existing regulations or use of standard practices or planning considerations, then it is assumed that effects on the VEC would not occur and it is not considered further in the discussion of potential effects.

7.1.1.1 Air Emissions

AIR QUALITY AND GREENHOUSE GAS EMISSIONS

The potential environmental effects of the hypothetical scenarios on air quality and greenhouse gas emissions include change in air quality and change in greenhouse gases. The atmospheric environment is also a pathway to other biological environment VECs (e.g., fish and fish habitat, waterbirds and marine mammals).

Air quality issues associated with the scenarios include the release of air contaminants from combustion of fossil fuels (diesel fuel, natural gas, fuel gas) for transportation and power, and processes associated with exploration and production drilling (e.g., flaring). The air contaminants of interest are common air contaminants (CACs), and volatile organic compounds (VOCs). The air contaminants considered in an assessment of effects are therefore:

- Total particulate matter
- $PM_{2.5}$
- Particulate matter less than 10 micrometres in diameter—PM_{10}
- NOx
- SO_2

- CO
- VOCs
- Ground level ozone (O_3)

These air contaminants have been selected for the following reasons:

- They contribute to ambient concentrations in air, which are regulated by Nunavut and Canada
- The potential sensitivity of human health to air quality
- Deposition to the marine environment is a pathway to the marine ecosystem

A GHG is any gas that contributes to potential climate change. The GHGs absorb heat radiated by the earth and warm the atmosphere, leading to what is commonly known as the greenhouse effect. The GHGs of interest for an assessment of effects are:

- CO_2
- CH_4
- N_2O

The GHGs are known to contribute to global warming which causes changes in the world's atmosphere, land, and oceans. These changes may have both positive and negative effects on people, plants, and animals. The release of scenario-related GHGs are a contributing factor in anthropogenic alteration of climate. Other GHGs such as sulphur hexafluoride or the perfluorocarbons are not expected to be used or released from scenario activities and, therefore are not considered further in the discussion of effects.

The regulatory requirements for Nunavut include ambient air quality standards, emission limits on incineration of waste, and limits on mercury in waste (Nunavut Department of Environment 2011; Nunavut DOE 2012; Nunavut DOE 2010). Due to the nature of the scenarios, the federal ambient air quality standards are also applicable. Regulatory requirements for air quality and greenhouse gas are summarized in Appendix A.

Exploration and production drilling activities that would result in the release of air contaminants and GHGs to the atmosphere are associated mainly with 1) drilling; subsea installations; wellhead, offshore platform and floating and production storage and offloading (FPSO) 2) vessels; transportation and production; and 3) power generation and related combustion of petroleum hydrocarbons. The emission rates from these activities are quantified below given that the equipment will be operational throughout a period that extends beyond one year (e.g., 2–5 years).

Potential effects of oil and gas scenario activities on air quality and GHG emissions are assessed in the context of air contaminant emissions (SO_2, NO_X, CO, PM_{10}, $PM_{2.5}$ and VOCs) and GHG emissions (CO_2, CH_4, N_2O). Since this is a Strategic Environmental Assessment, the details of the activities and specifications of equipment and marine support vessels is not fully known. The quantities of fuel for each of the activities can therefore not be calculated at the equipment level. As a result, the quantities of air contaminants and GHGs cannot be estimated for the assessment Scenarios at the equipment level. However, the sources of emissions from each Scenario are described for each Scenario. Further, after those sources are described, an order-of-magnitude estimate of the quantities of air contaminants and GHGs that could be released for the Scenarios A, B, and C is provided. The basis for this estimate is the National Pollutant Release Inventory for Offshore Platforms in the ocean region off Newfoundland and Labrador (ECCC NPRI), and the national database on GHGs (ECCC GHGRP 2018).

Air contaminants and greenhouse gases would not be released for the No Development case (Scenario D).

Scenario A—Seismic Surveys

Fuel consumption by marine vessels conducting 2D and 3D seismic surveys in the Area of Focus during the open water season is expected to release quantities of greenhouse gases and air contaminants to the atmosphere. The emissions arise from the fuel combustion needed to drive the marine vessels during the surveys. The 2D surveys can take 1-3 years to complete. The 3D surveys are typically done in an open water season, over a period of about 4-6 months.

The equipment needed are the marine seismic vessel and 1-2 support vessels that are ice capable.

The quantity of greenhouse gases for seismic surveys is directly proportional to the quantities of fuel burned as this is related to the size of the vessels, the time spent doing the surveys, and the engine efficiencies.

During normal operation, any air contaminants that are released during a survey would be dispersed and would not be expected to exceed regulatory standards at any onshore receptors.

Scenario B—Exploration Drilling

If the 3D surveys identify hydrocarbon potential in the region being explored, exploration drilling is done to drill into the reservoir to confirm presence and extent of hydrocarbon, and the vertical extent of the reservoir. The time to drill a well is about 35-65 days. Exploration drilling can be conducted year round, but needs the support from icebreakers and other marine vessels.

As noted in the Scenarios report (Nunami Stantec Ltd. 2018), the main sources of air contaminants and GHGs are related to:

- Burning of diesel or natural gas to produce electric power
- Venting of methane and volatile organic compounds (VOCs) from processes or as fugitive emissions
- Flaring and well testing
- Offshore loading of oil at loading buoys

During platform and topsides tow-out and mating[113], air and GHG emissions would result from the operation of various tugs and supply vessels, the crane heavy-lift vessel and the topsides stand-by generator.

Air emissions will also result while the drill ship or semi-submersible vessel is transiting to the drilling site and from the operation of power generating units such as dual-fueled turbines. During the installation and commissioning of the platform, the turbines would operate on diesel fuel.

Scenario C—Field Development and Production

If the assessment of the 2D and 3D surveys and other supporting information indicate a favourable business case, the development of the oil or gas field may proceed. There are options to do this. As noted in (Nunami Stantec Ltd. 2018), production could take place through a subsea system of oil or gas producing wells, or gas injection wells. The marine vessels would include an FPSO or and FLNG with capacity to match the production from the wells. These vessels would be supported by vessel shuttle tankers to transport the product to market destinations. The number and frequency of tankers would depend on production rates and vessel capacity.

Activities would also include the operation of the wellhead platform, drilling, completions, well interventions and transport of the product to the nearby floating production, storage and offloading (FPSO) vessel as noted above.

The operation and maintenance of subsea drill centres, if needed, would involve drilling, completions and well interventions. The subsea drill centre would produce crude that would be directly transported back to the FPSO vessel for processing.

The major sources of air contaminants and GHGs during development and production would include the following:

- Power generation
- Operation of vessels as described above
- Operation of helicopters
- Flaring
- Maintenance activities (i.e., welding, solvent use)
- Fugitive emissions (i.e., leaking valves, pump seals, compressor seals, flanges / connectors and pressure relief valves)

During normal operations of the wellhead platform, a support vessel would likely be on stand-by for the platform 365 days per year and at least one supply vessel will also be in operation 365 days per year, travelling between the onshore and the offshore site, transferring supplies. Helicopters will also routinely travel between the onshore and the offshore site to transport employees to and from work, approximately

[113] Offshore oil and gas production platforms are typically fabricated onshore and then towed by tugs and barges to its final site where it is secured.

three round trip flights per week. Typical emissions from the operation of vessel and helicopter engines include CO, NO_2, SO_2, TSP, PM_{10}, $PM_{2.5}$ and CO_2.

Power generation could be supplied by turbine generators during normal operation, burning either diesel fuel or fuel gas. The primary emissions from the combustion of diesel or produced gas include NO_2, CO, SO_2, TSP, PM_{10} and $PM_{2.5}$.

The flare system is an essential component of the pressure relief and safety system of the wellhead platform. The flare system would be designed to prevent over-pressurization of equipment during process upset conditions and dispose of associated gas produced during emergency situations (i.e., blow down during a de-pressurization). The air emissions during flaring include CO, NO_2, TSP, PM_{10} and $PM_{2.5}$. A small amount of fuel gas would be continuously used for flare pilots during the operation of the well head platform; however, the associated air emissions would be minimal compared to other operational sources.

Blowdown events are expected to be rare. If they occur, the emissions from the blowdown events are expected to be short in duration, and disperse rapidly with distance from the source, to well below ambient standards at onshore receptor locations. Thus, these events are not expected to cause substantive effects on receptors located outside the immediate area around the drilling platform.

Estimate of Emissions: Air Contaminants and Greenhouse Gases

As noted above, the detailed equipment specification for the oil and gas activities in each Scenario is not known at this time, and this makes it difficult to estimate fuel quantities and related emissions. However, the federal government does publish data on emissions in the offshore oil and gas sector. Emissions of air contaminants are shown in Table 7.2 for three existing oil and gas platforms located off eastern Newfoundland (ECCC NPRI 2017).

These data can be used to estimate the potential emissions from the activities described in the Scenarios (as one activity). This is done by taking the average of the three different operations – Hibernia, Terra Nova, and Sea Rose, and allocating these values to the Scenarios. It is acknowledged that the activities may not be exactly the same; however, this is sufficient to provide an order-of-magnitude estimate of emissions from the oil and gas activities described in the Scenarios. The actual emissions may be more or less than those shown here for a specific project.

Table 7.2 Air Contaminant Emissions—from Offshore Oil and Gas Activities

	Air Contaminant Emissions Reported to ECCC (NPRI)—2016 (tonnes /year)				
Sources	**NOx**	**CO**	**VOCs**	**TSP**	**SO2**
Hibernia	1,064	701	461	168	NR
Terra Nova	2,219	439	116	118	NR
Sea Rose	2,567	602	436	168	NR
Average	1,950	581	338	151	NR
SOURCE: (ECCC NPRI 2017)					

The quantities of predicted air contaminants from the Scenarios and the territory of Nunavut are shown in Table 7.3 for comparison. Note that Nunavut emissions reflect known amount in 2015; future emission volumes are likely to differ.

Table 7.3 Potential Emissions of Air Contaminants—Scenarios vs Nunavut

Air Contaminant	Total Emissions Oil and Gas Scenario (tonnes/year)	Total Emissions Nunavut 2015 (tonnes/year)	Scenarios vs Nunavut Emissions, (%)
PM	151	10,400	1.5%
VOCs	338	700	48.2%
NO_X	1,950	12,600	15.5%
CO	581	2,040	28.5%
SO_2	NR	2,560	-
SOURCE: (ECCC 2018a)			

As shown, the quantities for emissions range from about 2–48% of the Nunavut emissions. As noted previously, the Nunavut emissions for 2015 are low compared to other provinces, partially because of the small number of sources (e.g., small number of communities), and because of the small number of industrial operations located in the Nunavut Territory.

Despite the estimate where the scenario emissions are a large fraction of the Nunavut emissions, the scenario quantities are relatively small compared to other provinces that have higher level of industrial activities. The air contaminants released from the scenario are expected to disperse in a direction downwind from the points of release and, in doing so, decrease in concentration due to air entrainment into the exhaust plume. The dispersion is expected to result in concentrations that reach close to ambient levels about 5–10 km away from the sources. Given that offshore exploration activities are likely to be several km offshore, and the offshore area within the Area of Focus is spatially large, air emissions from a single offshore drilling operation would be dispersed rapidly and would not likely reach onshore locations. Overall, the effects of these emissions on ambient air quality are not expected to exceed regulatory standards at any onshore receptors.

Estimate of GHG Emissions

A similar approach can be used to estimate the potential emissions of GHGs to the atmosphere from the oil and gas activities described for each of the Scenarios. As with air contaminants, the federal government does publish data on GHG emissions in the offshore oil and gas sector. These are provided in Table 7.4 for three existing oil and gas platforms located off eastern Newfoundland (ECCC GHGRP 2018).

These data can be used to estimate the potential emissions from the activities described in the Scenarios (as one activity), by calculating the average and allocating these values to the Scenarios. It is acknowledged that the activities may not be exactly the same; however, this is sufficient to provide an order-of-magnitude estimate of emissions from the oil and gas activities described in the Scenarios. The actual emissions may be more or less than those shown here for a specific project.

Table 7.4 GHG Emissions—from Offshore Oil and Gas Activities

	GHGs Reported to ECCC GHGRP for 2016 (tonnes /year)			
sources	**CO_2**	**CH_4**	**N_2O**	**Total CO_2eq**
Hibernia	517,524	1,613	15.5	562,463
Terra Nova	527,836	902	34.3	560,600
Sea Rose	401,696	1,307	38.6	445,861
Average	482,352	1,274	29	522,975
SOURCE: (ECCC GHGRP 2018)				

Estimates of the total GHG quantities released to the atmosphere from the oil and gas activities in the Scenarios and the reported Nunavut emissions are provided in Table 7.5. It is emphasized that emissions from an actual project may be lower or higher than those presented, depending on the methods and equipment to be used in the exploration, development and production activities.

Table 7.5 Potential Emissions of Greenhouse Gases—Scenarios vs Nunavut

Greenhouse Gas (GHG)	Total Emissions (tonnes/year)	Total Emissions Nunavut 2016 (tonnes/year)	Scenarios vs Nunavut Emissions, (%)
CO_2	482,352	656,000	73.5
CH_4	31,850	10,000	319
N_2O	8,781	34,000	26
CO_2e	522,975	700,000	74.7
SOURCE: (ECCC 2018b)			

As shown, the Scenario GHG emissions are 74.7% of the Nunavut total for 2016, which is a relatively large fraction of the Nunavut emissions. As noted above, the number of sources in Nunavut in 2016 is relatively small, and the GHG emissions from Nunavut also are relatively small compared to other provinces.

The GHG emissions from Canada are 704,000,000 tonnes CO_2e per year (2016). Global emissions for 2014 were estimated to be 47.4 billion tonnes CO_2e (47,350,940,000 tonnes reported in CAIT 2018). The potential GHG emissions from the Scenarios (Seismic Surveys, Exploration, Field Development and Production) therefore are less than 0.08% of the national emissions, and a very small fraction of global emissions. Nonetheless, all GHG contributions add cumulatively to the overall potential for global warming.

Emissions of air contaminants and GHGs associated with the Scenarios are likely to be approximately similar (same order of magnitude) to those from Nunavut in 2016. This is because the quantities from Nunavut are relatively small, and any addition from activities associated with oil and gas exploration or production is likely to be a relatively a large fraction on Nunavut's emissions.

Based on the recent monitoring data, the existing air quality in Nunavut on land is generally good overall, meaning it meets the Nunavut ambient standards (Appendix A) most of the time. It is inferred that air quality above the ocean on Baffin Bay and Davis Strait is similarly good most of the time. However, there are few studies available to substantiate this.

The air contaminants released from the scenario in the Area of Focus are likely to disperse and decrease in concentration to within background values about 5–10 km away from the sources. Since the area is large, the potential effects on Air Quality will affect a small part of a large geographic area for the duration of the activities. Once activities cease, emissions will cease. Effects to Air Quality in the Area of Focus are concluded to be small in geographic extent and, with dispersion over a large area, would result in a small magnitude of change in ambient air quality at receptors onshore. There would be rapid recovery once emissions cease. Overall, the effects of these emissions on ambient air quality are not expected to exceed the Nunavut ambient air quality standards at any onshore receptors (the ambient standards are provided in Appendix A).

The releases of GHGs to the atmosphere from the Scenarios are adding to an existing adverse effect (IPCC 2014a). However, as shown above, the contribution is very small.

7.1.1.2 Noise

ACOUSTIC ENVIRONMENT

The primary source of underwater noise from oil and gas activities is associated with seismic exploration, drilling activities, and vessels used to transport products, personnel, and equipment or undertake ice-breaking activities. A summary of potential noise levels is provided below and the assessment of noise levels associated with oil and gas activities and the associated potential effects on Biological VECs are discussed in Section 7.2.

Shepard et al. (2001) conducted a winter field survey (April 2000) of noise at two near shore locations on the Beaufort Sea near Prudhoe Alaska. The study included measurements of underwater noise, ice vibration and airborne noise at varying distances from the prospect locations, up to 4 km distant. Measurements were made with construction activities (sheet pile driving, snow plowing, general trucking) present and without. Results showed that airborne noise with pile driving using a vibrahammer was mainly a local effect; at a distance of 150 m, vehicle and machinery noise were dominant; measured levels ranged from 0–50 dB above ambient, with highest levels being in the 200 Hz to 8 kHz range. At a distance of 1 km, two tonal ranges were noted at low frequencies, one at 23 Hz and one at 500–2,000 Hz. The airborne noise levels were noted to be 5 dB and 12 dB above ambient, at these frequencies. Airborne noise levels from the Northstar, from trucking but without pile driving, were moderately above background at a distance of 150 m; at greater distances, there seemed to be very little difference between the noise with the activities and without; the activity noise was tonal, mainly in the 30–70 Hz range, with some narrow bands in the 200 Hz to the 4 kHz range. At distances greater than 150 m, only natural noises associated with weather and snow conditions were observed.

Recordings of sounds underwater, and in air, and of ice borne vibrations, were made at Northstar Island, an artificial gravel island in the Beaufort Sea near Prudhoe Bay, Alaska (Blackwell et al. 2004). The objective was to assess the acoustic characteristics and range dependence of sounds and vibrations produced by drilling and oil production during the winter, when shorefast ice surrounds the island. Drilling produced the highest underwater broadband (10–10,000 Hz) levels (maximum = 124 dB re: 1 µPa at 1 km), and mainly affected the 700–1,400 Hz frequencies. In contrast, neither drilling nor production activities increased broadband levels in air or ice relative to levels during other island activities. In the air, background levels were reached 5–10 km from Northstar, with the actual distance depending on the wind. but irrespective of drilling. Northstar sounds were probably audible to seals, at least intermittently, out to about 1.5 km in water and about 5 km in air.

Blackwell and Greene (2006), studied underwater sounds and, to a lesser extent, the airborne sounds from an oil production island in the Beaufort Sea in summer. The objective of this study was to determine the levels, characteristics, and range dependence of underwater and in-air sounds produced during the open-water seasons of 2000–2003 by the Northstar oil development, located in nearshore waters of the Alaskan Beaufort Sea. Sounds from the island (construction, drilling, and oil production activities) were compared with sounds from the vessels being used to support the island. The main finding is that the marine vessels (crew boat, tugs, self-propelled barges) were the main contributors to the underwater sound field and were often detectable underwater, as much as approximately 30 km offshore. The airborne noise measurements were not affected by the presence of vessels and reached background values 1–4 km from Northstar.

The sounds and vibrations in the frozen Beaufort Sea were studied during the construction of a gravel island just offshore (Greene et al. 2008). Underwater and airborne sounds and ice-borne vibrations were recorded from sea-ice near an artificial gravel island during its initial construction in the Beaufort Sea near Prudhoe Bay, Alaska. The measurements were made to characterize the construction sounds to help in assessment of their possible impacts on wildlife. The main activities at the site included ice augering, pumping sea water to flood the ice and build an ice road, a bulldozer plowing snow, a Ditchwitch cutting ice, trucks hauling gravel over an ice road to the island site, a backhoe for trenching the sea bottom, and both vibratory and impact sheet pile driving. For all but one sound source (underwater measurements of pumping), the strongest one-third octave band was under 300 Hz. The sound and vibration levels, as measured in the strongest one-third octave band for different construction activities, reached median background levels less than 7.5 km away for underwater sounds, less than 3 km away for airborne sounds, and less than 10 km away for in-ice vibrations.

Atmospheric noise is anticipated to be associated with vessels used for seismic exploration and survey and drilling support, or from aerial support (i.e., helicopters) used to support crew transfer to and from seismic vessels and drilling platforms. Noise associated with these activities is expected to be localized and to attenuate to background levels within 1–5 km from the noise source. Given the offshore nature of potential activities, effects are anticipated to be minimal.

7.1.1.3 Routine Discharge

OCEANOGRAPHY

Routine discharges from some of the scenario activities may cause a change in water quality. Several guidelines and regulations for the treatment of routine discharge have been developed to reduce the potential for environmental effects from waste management in offshore drilling and production operations (see Section 2.3.3.2).

A recent assessment of effects for an offshore drilling program in Atlantic Canada with similar activities to those included in the scenarios predicted that activities may result in small-scale and localized releases of waste products, and potentially contaminants, during routine operations (Statoil Canada Ltd. 2017). Potential liquid discharges from drilling and production installations include deck drainage water, sewage, and cooling water. Bilge and deck drainage water that comes into contact with drilling installations could become contaminated with oil (Statoil Canada Ltd. 2017). Grey wastewater from the galley, washing and laundry facilities, and black wastewater from accommodations is also produced on drilling and production installations (Statoil Canada Ltd. 2017). Discharges of organic wastes were predicted to lead to localized organic enrichment (Peterson et al. 1996), though no adverse effects were anticipated as volumes would be quite small at each drill site (Statoil Canada Ltd. 2017). Sanitary waste water is usually released into the sea (Boertmann and Mosbech 2011), which may lead to localized organic enrichment (Peterson et al. 1996).

Potential effects from produced water discharged from drilling platforms into the sea are generally considered to be small due to dilution (Boertmann and Mosbech 2011). Produced water from drilling is minimal and is typically aerosolized and flared. Nutrient concentrations in produced water can be very high (e.g., ammonia) (Boertmann and Mosbech 2011). Oil concentrations in produced water are generally low; however, oil sheens may occur on the surface near the discharge point, especially in calm weather (Boertmann and Mosbech 2011). There are concerns regarding the discharge of produced water under the ice, as there is a risk of accumulation just below the ice, where degradation, evaporation, and other processes are slower (Boertmann and Mosbech 2011).

In addition to produced water from production platforms, discharges of oil components and different chemicals may occur in relation to deck drainage (drilling and production), cooling water (production), ballast water (supply vessels, production platform), bilge water (supply vessels), cement slurry (drilling and production), and the testing of blowout preventers (drilling and production) (Boertmann and Mosbech 2011). These discharges must be in accordance with OWTG to minimize impacts[114] (National Energy Board et al. 2010).

114 Offshore waste treatment guidelines were developed specifically for Atlantic Canada and may need to be revised to consider the Arctic Environment if offshore oil and gas drilling operations were to proceed

Results from the ongoing Grand Banks Environmental Effects Monitoring (EEM) programs have shown no environmental effects on the marine environment from contamination due to operational discharges from production platforms (Stantec Consulting Ltd. 2017a, 2017b). In the event of Scenario A (exploration with offshore seismic survey) there would be no change in water quality. In the event of Scenario B (exploration drilling) there could be a change in water quality as a result of routine discharges from drilling activities and the operation of project vessels. In the event of Scenario C (field development and production) there could be a change in water quality as a result routine discharges from drilling activities and the operation of project vessels. In the event of Scenario D, where no offshore oil and gas activity would take place, there would be no change in water quality.

Exploration and production drilling could cause adverse effects on water quality as a result of routine discharges. In the case of exploration drilling, there could be adverse effects on water quality as a result of routine discharges; however, these effects are not expected to change water temperature or water quality (including oil content in water). In the case of production drilling, there could be adverse effects on water quality as a result of routine discharges, as well as from produced water.

In the case of exploration drilling, the magnitude of the effects of routine discharges on water quality are expected to be small and of short to medium-duration (weeks - months beyond the duration of activities). Effects would be confined to the immediate vicinity of the discharge point. Effects are expected to be reversible, and water quality would return to baseline conditions in weeks to months once the release of routine discharges has ceased. During drilling activities, the release of routine discharges is expected to be continuous. Routine discharges from exploration drilling are not expected to have an effect on water quality outside the defined Project Area.

In the case of production drilling, the magnitude of the effects of routine discharges on water quality are expected to be low, of medium duration (weeks to months beyond the duration of activities) and could occur up to 10 km from the discharge point (ExxonMobil 2011). During drilling activities, the release of routine discharges is expected to be continuous. The effects are expected to be reversible, with recovery to baseline conditions in months once the release of routine discharges has ceased. Routine discharges from production drilling are not expected to have a measurable effect on water quality outside a 10 km radius from where discharges are released into the water column.

The effects of Climate Change on the oceanography in the Area of Focus are not expected to alter the prediction of effects of routine discharge on water quality. An extended open water season may be associated with extended operating seasons for some activities (e.g., longer drilling season during exploration drilling), leading to an increase in frequency or duration of the effect. However, residual effects of routine discharge on water quality would still be localized to the immediate vicinity of the discharge to the water column and magnitude would be low. Effects of climate change on water quality could include changes in water temperature, and the amount of freshwater present in the water column.

7.1.1.4 Drill and Mud Cuttings

MARINE SEDIMENT

Drilling creates large quantities of drilling wastes composed of rock cuttings and the remnants of drilling muds (drilling fluids). Cuttings and muds are usually deposited on the seafloor beneath the drill rig, where they can change the sediment quality (physical and chemical compositions) of the substrate (e.g., increased concentrations of certain metals and hydrocarbons) (Breuer et al. 2008).

The liquid base of drilling muds can be either water (WBM-water-based mud) or synthetic fluids (SBM-synthetic-based mud); synthetic fluids include synthetic muds, ethers, esters, olefins, and others (Boertmann and Mosbech 2011). Ester-based cuttings have been shown to cause severe but short-lived effects due their rapid degradation, which may result in localized oxygen depletion in marine sediments (Boertmann and Mosbech 2011). Olefin-based cuttings are also degraded fairly rapidly, but do not cause oxygen depletion (Boertmann and Mosbech 2011). Both WBM and SBM include bentonite and / or barite (detected in sediments as barium), and other chemicals that include potassium chloride, caustic soda, soda ash, visosifiers, filtration-control additives, and shale inhibitors added to control mud properties (Statoil 2017).

Impacts from WBM are limited if environmentally safe drilling chemicals are used; therefore, WBM are usually released into the marine environment when drilling is complete (Boertmann and Mosbech 2011). In general, WBM is considered less harmful to the environment than SBM, as it contains mainly water and does not form surface sheen (Husky Energy 2017). SBM can form sheens on the surface. Particles from SBM do not disperse as widely as with WBM (Husky Energy 2017); therefore, discharges of WBMs are likely to disperse more widely in the water column before reaching the seabed than SBM (Boertmann and Mosbech 2011). Limited field studies on the impacts from WBM have shown that effects are restricted to a distance of less than 100 m from platforms (Schaanning et al. 2008); however, the use of WBM potentially moves effects on the seafloor to the water column, where dilution is a major factor in reducing impacts (Boertmann and Mosbech 2011). Potential effects from the discharge of drill cuttings on sediment quality could include elevated trace metals in sediments in the immediate area of deposition, and a change in the composition of sediments based on the naturally-occurring sediment type in the vicinity of the drilling activities (Bakke et al. 2013). There could be an increase in sediment grain size, organic enrichment in sediments, and an increase in suspended particulate matter and turbidity in the water column (Husky Energy 2017). Primary interactions from discharge of drill cuttings include cuttings deposition and potential seabed disturbance (smothering habitat), chemical toxicity, and bioaccumulation (uptake of contaminants by marine organisms) (Husky Energy 2017).

Based on existing EEM studies in Atlantic Canada (Stantec Consulting Ltd. 2017a, 2017b) (Husky Energy 2017), there may be limited changes to sediment quality as a result of some scenario activities (i.e., production drilling). There was evidence that drilling activity caused elevated concentrations of hydrocarbons and barium near drill centres, and that fines and sulphur concentrations also may have been elevated near drill centres (Stantec Consulting Ltd. 2017a, 2017b)(Husky Energy 2017). It was determined that sediment contamination at drill centres did not extend beyond the zone of influence that was predicted by drill cuttings modelling (e.g., Seaconsult Marine Research Ltd. 2000). Hydrocarbons were detected between 5 and 8 km from the source, and barium levels were elevated beyond background levels to approximately 2 km from the source (Husky Energy 2017). These results are similar to that of the Terra Nova EEM program on the Grand Banks off of the southeast coast of Newfoundland , which determined that the highest levels of hydrocarbons and barium extended from 1 to 2 km from the source (DeBlois et al. 2014). Increases in fines and sulphur concentrations were limited to within 1 km from the source (Husky Energy 2017).

Exploration and production drilling will add rock cuttings and remnants of drilling muds to the environment that will affect sediment quality in small localized areas immediately surrounding the drilling activity (i.e., within less than a 10 km radius) (Seaconsult Marine Research Ltd. 2000). These areas are extremely small relative to the size of the Area of Focus, even if several drilling operations were to occur simultaneously in the region. Use of WBM and SBM will reduce initial effects on sediment quality and are not expected to persist for more than months to years. While the physical presence of cuttings may physically cover existing sediment, the areas covered would be small. Over time, the rock cuttings would become part of the bottom sediment environment and could be used as habitat by benthos and fish.

In the event of Scenario A, exploration with offshore seismic survey, there would be no change in sediment quality. In the event of Scenario B, exploration drilling, there could be a change in sediment quality as a result of the deposition of drill and mud cuttings from drilling activities. In the event of Scenario C. field development and production, there could be a change in sediment quality as a result of deposition of drill and mud cuttings from drilling activities. In the event of Scenario D, where no offshore oil and gas activity would take place, there would be no change in sediment quality. More details on these Scenarios are provided in Section 2.3.3.

While the effects of drill and mud cuttings on sediment quality are expected to be adverse, the magnitude of the effects are expected to be low, and the effects would be localized in the immediate vicinity of where the cuttings are deposited on the seafloor. The duration of the effects is expected to be medium to long term (weeks or months—years beyond the duration of the activity). The effects are expected to be reversible and sediment quality would recover to baseline conditions in weeks to months, and possibly months to years, once the deposition of drill cuttings has ceased. During drilling activities (exploration and production drilling), the deposition of drill cuttings is expected to be frequent. Drill and mud cuttings are not expected to have an effect on sediment quality outside the immediate area of deposition on the seafloor.

The effects of climate change on marine sediment in the Area of Focus are not expected to alter the effects of drill and mud cuttings on sediment quality. An extended open water season may be associated with extended operating seasons for some activities (e.g., a longer drilling season), leading to an increase in frequency of the effects. However, residual effects of drill cuttings on sediment quality would still be localized to the immediate vicinity of deposition on the seafloor, and the magnitude would be low.

7.1.1.5 Ice Disturbance

Sea Ice and Iceberg Conditions

In the event that sea ice or icebergs pose a risk to oil and gas structures or equipment associated with Scenarios A, B, or C, elements of the ice management plan would be invoked. This could involve ice breaking by marine ice-breaking vessels or iceberg deflecting or towing to avoid contact with large icebergs. Disturbance of sea ice by icebreakers can potentially result in a change in sea ice quality and extent.

The use of icebreakers to support seismic survey programs and exploration and production drilling platforms would result in localized changes to the sea ice along the transit route.

Given that the area of sea ice that might be affected would be small compared to the overall extent of ice in the Area of Focus, and that ice cover would refreeze after disturbance during winter months, there is not likely to be any appreciable change to sea ice quality or cover on average within the Area of Focus. Similarly, as a result of physical disturbances by oil and gas activities, there is not likely to be any appreciable change to the natural course of iceberg development or iceberg drift on average over the Area of Focus. Effects of ice disturbance in the offshore marine environment will be primarily relevant to habitat alteration for biological environment VECs, particularly marine mammals. These effects are discussed in Section 7.2.1.4.

7.1.2 Cumulative Effects

Table 7.6 below outlines the past, present, and future activities in the Area of Focus that have the potential to interact with oil and gas activities and affect the Physical Environment.

Table 7.6 Potential Cumulative Effects—Physical Environment

Other Projects and Physical Activities with Potential for Cumulative Environmental Effects	Potential Cumulative Environmental Effects: Change in Air Quality	Change in Greenhouse Gas Emissions	Change in Sea Ice Quality and Extent	Change in Noise Levels	Change in Water Quality	Change in Sediment Quality
Past and Present Physical Activities and Resource Use						
Mining—Baffinland Mary River Mine (marine transportation)	✓	✓	✓	✓		
Commercial Shipping	✓	✓	✓	✓		
Commercial Fishing	✓	✓		✓		
Tourism (cruise ships)	✓	✓		✓		
Research (Military, Academic)	✓	✓	✓	✓		
Traditional Use and Practices, Traditional Harvest, Traditional Foods				✓		
Oil and Gas—Greenland	✓	✓	✓	✓	✓	✓
Oil and Gas—Atlantic Canada	✓	✓	✓	✓	✓	✓
Future Physical Activities						
Mining (marine transportation)	✓	✓	✓	✓		
Deepwater Port (Iqaluit)	✓	✓		✓		
Commercial Shipping	✓	✓	✓	✓		
Commercial Fishing	✓	✓		✓		
Tourism (cruise ships)	✓	✓	✓	✓		
Research (Military, Academic)	✓	✓	✓	✓		
Traditional Use and Practices, Traditional Harvest, Traditional Foods				✓		
Oil and Gas—Greenland	✓	✓	✓	✓	✓	✓
Oil and Gas—Atlantic Canada	✓	✓	✓	✓	✓	✓
Oil and Gas – Baffin Bay and Davis Strait (Scenario A, B, and C)	✓	✓	✓	✓	✓	✓

NOTE:
✓ = those “other projects and physical activities” whose residual effects are likely to interact cumulatively with residual environmental effects associated with oil and gas activities in the Area of Focus.

As discussed above, environmental effects on the physical environment are expected to be generally localized around the source of the impact or dissipate to background levels within a small radius of the source. Given the offshore location of oil and gas activities associated with the scenarios and the small scale of potential effects, it is not anticipated that residual effects from oil and gas activities would interact with other activities to result in cumulative effects. Exceptions include Scenario activities that would contribute to global GHG emissions and those contributing to underwater noise.

While representing a small contribution when compared to global emissions, Scenario activities that contribute to GHG emissions would require mitigation to be applied. This includes meeting best available technologies to maintain efficiency for the activities that burn fuels such as diesel fuel, aviation fuel or fuel gas (see Section 7.1.5 and Appendix B)

Underwater noise can affect a large area and has been identified as an impact of concern for the sustainability of marine organisms. Cumulative effects of underwater noise on Biological Environment VECs are discussed in Section 7.2.1.1

7.1.3 Transboundary Effects

The long-range transport of air pollutants can occur from one country to another or from one jurisdiction to another (i.e. from Canadian federal waters into the NSA), and environmental effects on air quality and human health could result. The extent of the effect depends on the source strength (quantities of emissions) and the weather conditions at the time, including the prevailing winds. For example, it is well known that air contaminants travel from Europe to Asia (rapid travel) and from North America to the Arctic (slower travel). Canada and the USA have the Canada-United States Air Quality Agreement that was started in 1991 and has been revised and updated on a regular basis.

Regarding the Area of Focus—the prevailing winds are from the North and Northwest and so, for most of the time, the probability of air contaminants from the scenario to leave the Area of Focus in any appreciable quantities is quite low. In cases where the location of the scenario is close to the border on federal waters, the probability is a bit higher. In those cases, it is recommended that a more detailed study be done to assess the potential effects.

7.1.4 Accidents and Malfunctions

Potential accidents and malfunctions were described in Nunami Stantec Ltd. (2018) and include: fire and explosions; loss of life (falling off the vessel); downed aircraft (helicopter); vessel collisions; major weather and sea ice conditions; vessel strike with marine mammals; and hydrocarbon spills. Hydrocarbon spills have the greatest potential to affect VECs for the Physical Environment and are the focus for the remaining discussion. This could include small accidental spills from ships or platforms, spills during equipment failure or vessel malfunctions, or large events such as a subsea blowout. Hydrocarbon spills could affect oceanography, marine sediment, sea ice and icebergs. Aspects of coastal landforms, specifically the coastlines, would also be affected but this is discussed in Section 7.2.4.1 (Coast and Shorelines).

7.1.4.1 Oceanography

The accidental release of hydrocarbons and other associated contaminants (e.g., aerosols and volatiles) have the potential to cause a change in water quality. The extent of the potential effects on water quality depends largely on the level of exposure, the spill trajectory, and the amount of the oil and associated toxic components released into the marine environment (Statoil Canada Ltd. 2017). The effects of the release of hydrocarbons in the marine environment are largely dependent on oceanographic conditions, exposure duration, oil type, and oil containment and treatment methods (Statoil Canada Ltd. 2017).

Batch spills resulting from scenario activities would affect water quality (and thus habitat quality) in the vicinity of the spill site. This would be short-term in nature, lasting until the slick disperses through surface wave action in the offshore environment (Statoil Canada Ltd. 2017). A subsurface or surface blowout has a larger potential to have long-term effects on water quality than a batch spill.

In terms of dispersants used in oil spill response, the component with the greatest toxicological effect does not come from the dispersant alone, but rather from the effects of the water column's exposure to chemically dispersed oil (DeLeo et al. 2016). Burning of a contained surface slick could also cause a change in water quality.

7.1.4.2 Marine Sediment

The accidental release of hydrocarbons and other associated contaminants have the potential to cause a change in marine sediment quality. The extent of the potential effects on sediment quality depends on the level of exposure, the spill trajectory, and the amount of oil and association toxic components released into the marine environment (Statoil Canada Ltd. 2017). Spilled oil itself is not predicted to interact with or accumulate in sediments based on modelled scenarios in the eastern Newfoundland offshore region; however, interactions with sediments are likely with flocculation and sinking events associated with plankton and microbial pathways (Statoil Canada Ltd. 2017). Flocculation is the process by which fine particulates are clump together and may settle to the bottom of the water column and add to localized sedimentation.

In the case of natural gas, colder water has a tendency to form hydrates. Natural gas hydrates are ice-like solids that form when free water and natural gas combine at high pressure and low temperature. This can occur in gas and gas/condensate well, as well as in oil wells. These hydrates can settle to the seafloor and could potentially affect sediment quality.

Dispersants used in the event of a spill can cause coagulation that settles on the seafloor, often at a distance from the source of the spill, which could potentially affect water quality.

A subsurface blowout has a larger potential to have long-term effects and a greater increase of sedimentation than a batch spill (Statoil Canada Ltd. 2017). In the case of a subsurface blowout, oil may accumulate in sediments, changing the natural chemical composition of the sediment (Statoil Canada Ltd. 2017).

7.1.4.3 Sea Ice and Icebergs

A potential release of hydrocarbons may change the nearby sea ice in terms of albedo (reflecting capacity) and this could increase the rate of ice melting in the area of the spill. The ice may help contain the hydrocarbons to some extent initially, but as the ice melts or weathers, the contaminants would be released to the water, where interactions would be the same as described above for changes in water quality.

A subsurface blowout of light oil would affect the sea ice in a similar way to that described above, except that the effect on reflectivity would not be as pronounced, as the ice would be darkened but from the underside. Over time, the contaminants would be released to the water, with potential effects as described above. A subsurface blowout of heavy oil is not likely to affect the sea ice.

A subsurface blowout of gas may be strong enough to break sea ice at the surface and result in some small area of open water for a period of time. This area would re-freeze once the gas flow was brought under control.

7.1.5 Mitigation Measures and Planning Considerations

Mitigation measures to avoid or reduce effects from scenario-related releases of air contaminants and GHGs to the atmosphere are centered on use of best available technologies, and efficient use of high quality fuels. The mitigation measures apply to both Exploration and Appraisal (Scenarios A and B), and Development and Production phases (Scenario C), and include:

- Use of best available technologies regarding fuel combustion and emission controls
- Use of high quality fuels, e.g., low sulphur fuel oil, or natural gas as primary fuel
- Reduce vessel and aircraft traffic through planning
- Maintenance, inspections and efficient operation of equipment
- Monitor the number of flaring events, reduce where possible
- Use of efficient/reduced emission technology and incorporate into design where technically and economically feasible
- Adhere to Nunavut and Canada air quality objectives and standards
- Adhere to MARPOL requirements

Mitigation measures to avoid or reduce effects on water and sediment quality from the release of routine discharges and deposition of drill and mud cuttings include:

- Operational discharges would need to be treated prior to release in accordance with the OWTG and other applicable regulations and standards (e.g., MARPOL, IMO Ballast Water Management Regulations and Transport Canada’s Ballast Water Control and Management Regulations).
- Exploration drilling platforms would carry out ballast tank flushing prior to arriving in Canadian waters.

- The selection and screening of chemicals to be discharged, including drilling fluids, would need to be in accordance with the Offshore Chemical Selection Guidelines for Drilling and Production Activities on Frontier Lands.
- If formation flow testing with flaring is conducted during exploration drilling, produced hydrocarbons and produced water would need to be flared. If a large amount of produced water is encountered, it would need to be treated in accordance with the relevant regulatory requirements prior to ocean discharge or shipped to shore for disposal.
- Appropriate handling, storage, transportation, and on-shore disposal of solid and hazardous waste (including biomedical waste) at an approved facility.
- SBM-related drill cuttings would need to be returned to the drilling installation and treated in accordance with the OWTG before being discharged to the marine environment. WBM-related drill cuttings can be discharged without treatment.
- Whole SBM is typically reconditioned and reused a number of times. No excess or spent SBM will be discharged to the sea. Spent or excess SBM that cannot be re-used during drilling operations would need to brought back to shore for disposal at an approved facility.
- During the initial phases of the well, which are typically drilled without a riser, excess cement may be discharged to the seabed. Once the riser has been installed, all cement waste would need to returned to the drilling platform, and be transported to shore for disposal in an approved facility.

7.2 Biological Environment

Potential impacts associated with routine activities of offshore oil and gas development and exploration, as described in the hypothetical scenarios, are identified in Table 2.1.

The impacts of routine activities for the oil and gas scenarios that could result in effects on the biological environment:

- **Noise** associated with seismic surveys, marine transportation, and drilling
- **Routine discharge** of waste water associated with marine transportation and drilling operations
- **Drill and mud cuttings** associated with exploration and production drilling operations
- **Habitat alteration** associated with icebreakers, offshore infrastructure, offshore drilling equipment, and onshore infrastructure

Potential impacts on Biological Environment VECs resulting from activities associated with oil and gas scenarios are summarized in Table 7.7.

Table 7.7 Summary of Potential Impacts on Biological Environment

Valued Ecosystem Component	Potential Impacts			
	Noise	Routine Discharge	Drill and Mud Cuttings	Habitat Alteration
Species at Risk[1]	✓	✓	✓	✓
Coast and Shoreline				
Plankton	✓			
Benthic Flora and Fauna	✓	✓	✓	✓
Fish and Fish Habitat	✓	✓	✓	✓
Waterbirds	✓	✓	✓	✓
Marine Mammals	✓	✓	✓	✓
Special and Sensitive Areas				✓
Areas of Concern or Importance				✓

NOTES:
✓ = Indicates potential effect from impacts associated with oil and gas activities
[1] Potential environmental effects on species at risk (see Section 4.1) are not addressed separately (or individually), but are discussed under marine fish and fish habitat, waterbird, and marine mammal VECs.

These impacts could result in potential effects on Biological Environment VECs. Potential effects on VECs from routine activities associated with each of the impacts identified above are discussed in Section 7.2.1.

Effects are discussed in the context of the activities associated with each of the hypothetical scenarios (2.3.3.1).

If no offshore oil and gas activities were to occur (Scenario D), no associated effects to the biological environment would occur. However, effects on the biological environment will still occur as a result of interaction with other anthropogenic activities (e.g., increases in shipping and tourism, port and infrastructure development) or impacts associated with climate change (see Section 2.3.4).

The potential for cumulative effects and transboundary effects are discussed in Sections 7.2.2 and 7.2.3. Potential effects of accidents and malfunctions are discussed in Section 7.2.4. Mitigation measures and planning considerations that could be used to reduce or eliminate potential effects identified in Section 7.2.1 are discussed in Section 7.2.5.

Only VECs that have been indicated in Table 7.7 as having an interaction with an impact associated with oil and gas activities are discussed below. If a VEC is not expected to interact with oil and gas activities, or if potential effects from an interaction can be mitigated under existing regulations or using standard practices or planning considerations, then it is assumed that residual effects on the VEC would not occur or be minimal, and the specific effect is not considered further for the VEC.

7.2.1 Potential Effects from Routine Activities

Potential effects considered in the discussion of effects on the biological environment are defined as follows.

CHANGE IN BEHAVIOUR

A change in behavior is a detectable reaction resulting from sensory disturbance, shading, masking, or stress response that could ultimately affect the ability of an animal to survive. Change in behavior resulting from sensory disturbance is generally linked with activities that produce underwater sounds that could induce habitat avoidance. Other pathways that may be linked with change in behavior include physical disturbance resulting in displacement, artificial lighting and increased TSS.

CHANGE IN HEALTH

Consideration of change in health includes effects on biological VECs due to increased exposure to contaminants in the sediment or water column. The pathway for this effect can be direct (e.g., resuspension of contaminated sediments, exposure to contaminated runoff) or indirect (e.g., through consumption of contaminated prey or choice of less-preferred prey) and result in decreased reproductive success or decreased survival.

CHANGE IN HABITAT

A change in habitat is a physical alteration of the habitat and could include contamination, removal, alteration, or disturbance of habitat. A change in habitat may result from either direct pathways (e.g., icebreaking, artificial lighting, contamination of sediment, increased TSS in the water column, modified sediment dispersal and deposition patterns) or indirect pathways resulting in physical changes to habitat outside of the footprint of the activity (e.g., air emissions, modified drainage patterns and currents). Note that for the purposes of this assessment, *change in habitat* does not include effects resulting from underwater noise. Effects associate with underwater noise are discussed in the context of a *change in behavior* or a *change in mortality risk* (see below).

CHANGE IN MORTALITY RISK

Change in mortality risk refers to injury or death resulting from the physical impact of a project activity such as vessel strike, crushing, smothering or resulting from intense underwater sound (i.e., air guns). Change in mortality risk would also include increased mortality resulting from direct project related human actions, such as predator control (e.g., removal of polar bears from project site).

7.2.1.1 Noise

PLANKTON

Marine plankton could be affected by noise during seismic exploration (Scenario A) but no effects are expected from noise associated with Scenarios B and C as noise levels are not expected to be intense enough to harm plankton. Research indicates that exposure to underwater noise associated with seismic sound source arrays may result in a change in mortality risk for marine plankton in the immediate vicinity of the seismic activity. Zooplankton and ichtyoplankton (fish and invertebrate eggs and larvae) cannot avoid the pressure wave created by air guns and can be killed within a distance of less than 2 m, and incur sub-lethal injuries within 5 m of the sound source (Østby et al. 2003 cited in Boertmann and Mosbech 2011).

de Soto et al. (2013) provided evidence that noise exposure during larval development could increase mortality risk by producing body malformation in marine invertebrates. Scallop larvae exposed to playbacks of seismic pulses showed developmental delays and 46% showed body abnormalities (de Soto et al. 2013). McCauley et al. (2017) suggested that seismic surveys can cause mortality of a magnitude that affects zooplankton populations. Exposure to experimental airgun signals decreased zooplankton abundance and caused a two to threefold increase in dead adult and larva zooplankton. Impacts were observed up to 1.2 km (maximum range sampled) from the sound source, which was more than two orders of magnitude greater than the previously assumed impact range of 10 m.

While effects of seismic operations on plankton can be adverse, the effects would be restricted to a portion of the ensonified area[115] (up to approximately 1.2 km from the source) of the seismic activities. It is expected that plankton populations would recover rapidly once seismic operations have ceased (months through to the next reproductive cycle). As seismic operations are not expected to be frequent in space or time within the Area of Focus, seismic operations are expected to have a low to moderate magnitude effect on the regional abundance or sustainability of plankton.

Climate change will increase the duration and spatial extent of the open water season and therefore creates the potential for seismic operations to cover larger areas for longer periods of time. This could increase the frequency and geographic extent of the effect. However, effects of seismic operations on plankton are not expected to change magnitude or duration.

[115] The extent of the area surrounding the sound source where sound levels are elevated above baseline levels.

Uncertainty surrounding effects characterization results from the relative lack of research on seismic effects on plankton, and on Arctic plankton in particular. Potential non-linear feedback loops between climate change and plankton also are not well understood, such as changes in bloom phenology due to sea ice changes (e.g., Wassmann and Reigstad 2011), and changes in abundance and species composition due to changes in ocean circulation, surface conditions, and temperatures (e.g., Barton et al. 2016; Blais et al. 2017).

BENTHIC FLORA AND FAUNA

Benthic flora and fauna could be affected by noise during seismic exploration (Scenario A), but no effects are expected from noise associated with Scenarios B and C as noise levels are not expected to be intense enough to harm plankton. It has been suspected that seismic noise can cause changes in behaviour, dominated by startle responses, and physiological damage to arthropods or shellfish and thus increase their mortality risk (Carroll et al. 2017). There continues to be large gaps in our understanding of potential impacts of marine seismic surveys on marine invertebrates and the disparity between results from the laboratory and the field continues the controversy on this issue (Andriguetto-Filho et al. 2005; Carroll et al. 2017; Hawkins et al. 2015; Przeslawski et al. 2017).

In general, invertebrates do not have the ability to hear sound, although they can detect pressure waves (Christian et al. 2003). Many invertebrates, such as snow crab (*Chionoecetes opilio*), do not contain gas filled organs, and this decreases their vulnerability to loud noises (Keevin and Hempen 1997). The results from a recent study on the effect of 2D seismic surveys on snow crab on the continental slope of the Grand Banks did not support the contention of harvesters in Atlantic Canada who concluded seismic noise from hydrocarbon exploration was having strong negative effects on catch rates (Morris et al. 2018). Their results suggest that if seismic effects on snow crab exist, they are smaller than changes related to natural spatial and temporal variation (Morris et al. 2018). However, scallop beds that suffered an extensive mortality event in Australia coincided almost exactly with dates of seismic operations in the area (Przeslawski et al. 2017).

In conclusion, benthic flora and fauna appear relatively resilient to noise disturbances and effects on behaviour and mortality are expected to be low or negligible, local, restricted to the seismic activity and of medium-term duration (i.e., months to a year or more).

Climate change will increase the duration and spatial extent of the open water season and therefore creates the potential for seismic operations to cover larger areas for longer periods of time. This could increase the frequency and geographic extent of the effect. However, effects of seismic operations on benthic flora and fauna are not expected to change.

Uncertainty surrounding effects characterization results from the lack of a comprehensive field study conducted during seismic operations with sufficient statistical power to conclusively discern between potential project effects and natural variability in behaviour, distribution, abundance and mortality of benthic invertebrates. Some uncertainty of future effect characterization also results from interactions with climate change impacts on benthic invertebrates (e.g., changes in benthic pelagic coupling in the Arctic [e.g., Wassmann and Reigstad 2011], ocean acidification [e.g., Goethel et al. 2017]) which may alter species composition, abundance and distribution (Renaud et al. 2015), and thus could potentially alter effects from noise on the local benthic fauna.

FISH AND FISH HABITAT

Marine fish could be affected by underwater noise generated by seismic exploration (Scenario A), exploration drilling (Scenario B) or production drilling (Scenario C). The potential effects associated with exposure of marine fishes to underwater noise may include a change in behaviour or change in mortality risk.

Underwater noise generated by oil and gas activities, such as 2D and 3D seismic surveys, exploration or production drilling, and increased marine shipping traffic, may result in localized and temporary changes in behaviour of marine fishes. Responses of marine fishes to underwater noise are known to vary by species, life stage, history of exposure to similar sound sources, and the duration, intensity, frequency, and geographic extent of the underwater sound exposure (Popper et al. 2014). As such there are currently no established underwater noise thresholds for behavioural disruption of fish (Popper et al. 2014). Intense pulse-type underwater sounds (e.g., sounds generated by coastal impact-pile driving or airgun arrays during seismic surveys), and intermittent sounds from passing vessels have resulted in localized and temporary avoidance by various fish species (e.g., salmonids, herring, flatfish), by changing the direction of swimming to areas away from the sound source (Feist et al. 1996). Other observed behavioural responses to intermittent sound sources have included “startle” response (flexion of body followed by a burst of faster swimming in the original swimming direction), “alarm response” (intense variable movements) or no response (Feist et al. 1996; Schwarz and Greer 1984).

Some fish (e.g., cod) have been reported to respond with a weakened swimming response after repeated exposure to underwater sound sources (Mueller-Blenkle et al. 2010); however, other changes in behaviour may still occur (Bejder et al. 2009). For example, exposure to continuous sound (e.g., generated by exploration or production drilling) may result in the “masking” of (i.e., interference with the detection of) biologically important sounds (e.g., signals used by fish for prey detection, predator avoidance or communication) (Hawkins et al. 2015; Mueller-Blenkle et al. 2010; Schwarz and Greer 1984). Potential masking of biologically important sounds by repetitive sounds, such as those generated during seismic surveys, has yet to be studied (Hawkins et al. 2015).

Underwater noise can also cause barotrauma[116] in fish as a result of sudden changes in pressure leading to the damage of major organs and tissues and thus increasing mortality risk (Halvorsen et al. 2012a; Halvorsen et al. 2012b; Popper et al. 2014). At-source sound pressure levels (SPLs) generated by airgun arrays used for seismic surveys may be up to 262 dB re 1µPa (OSPAR Commission 2009). Such levels of underwater noise have the potential to result in barotrauma of fish, and with exposures above 207 dB re 1µPa (SPL_{peak}) may result in immediate or delayed mortality of fish (Popper et al. 2014). The severity of barotrauma injuries varies with the intensity of the underwater noise exposure, the life stage, and the physiology of fish (i.e., whether a swim bladder is present and functions in hearing). During exposure to

116 Barotrauma refers to injuries caused by increased air or water pressure

intense sounds pressures, negatively-buoyant fish without a swim bladder (e.g., most adult flatfish) are the least sensitive to barotrauma, whereas fishes with swim bladders that are used for hearing (e.g., herring), and fish eggs, are the most sensitive to barotrauma ((Halvorsen et al. 2012a; Halvorsen et al. 2012b; Popper et al. 2014).

The effects of underwater noise associated with seismic exploration, exploration drilling and production drilling on marine fish are adverse and expected to be of low to high magnitude depending on the species, life stage and type of noise. Effects would be local, restricted to the immediate area of those activities, and be continuous. Changes in behaviour of marine fish exposed to underwater noise are expected to be reversible in the short term (hours to days) following removal of the sound source. Potential mortalities from underwater noise generated by seismic activity would be low in number, and numbers affected are not expected to be at a level that would substantially affect the regional abundance or sustainability of marine fish populations.

Changes in sea ice associated with climate change may increase the spatial and temporal range of seismic explorations, drilling activities and associated ship traffic. Although this may create noise for longer and over a potentially wider area. These changes are not expected to substantially alter the characterization of potential effects of underwater noise on marine fish in the Area of Focus.

Some uncertainty in the effects characterization exists stemming from a lack of detailed knowledge of fish species composition, distribution and abundance in the Area of Focus. In addition, expected changes in physical and chemical ocean conditions (mainly sea ice, temperature, and nutrients) may alter the species composition, productivity, prey availability, and distribution and abundance of marine fishes in the Arctic (e.g., Frainer et al. 2017; Kortsch et al. 2015), potentially altering the percentage of species vulnerable to noise effects.

WATERBIRDS

Waterbirds could be affected by in-air or underwater noise during seismic exploration (Scenario A), exploration drilling (Scenario B), field development and production drilling (Scenario C), and by ship and air traffic associated with Scenarios A, B, or C.

In-air and underwater noise have the potential to create a change in behaviour and mortality risk to waterbirds.

Depending on the activity and associated level of noise production, waterbirds may adjust patterns in habitat use or behaviour due to noise-based sensory disturbance. At certain sound level thresholds (e.g., Science Applications International Corporation (SAIC) 2011) (see Appendix C), noise production may result in temporary or permanent injury or mortality for exposed birds. There are few studies that characterize effects to waterbirds from acute or chronic in-air or underwater noise, and species-specific differences remain poorly described in the literature. Generally, waterbirds may adjust patterns in habitat use or behaviour in response to in-air or underwater noise produced during seismic exploration surveys (i.e., avoidance of disturbed areas), or in response to marine infrastructure or activities (Agness et al. 2013; Ronconi and Clair 2002; Schwemmer et al. 2011).

The propagation and attenuation of in-air or underwater noise is influenced by factors such as the sound type (e.g., continuous or impulsive), sound pressure level, and frequency spectrum of the sound source in combination with localized oceanic conditions (e.g., bathymetry, topography, base sediments, temperature-salinity, and surface conditions) (Ronconi and Clair 2002). For in-air noise transmission, (Gladwin et al. 1988) found that waterbirds, including waterfowl and shorebirds, can be disturbed by noise levels up to 105 dB from 500 m to 1,200 m away. Sustained aircraft noise in the vicinity of bird aggregations, particularly active breeding colonies, can cause birds to flush from breeding or foraging habitats for extended periods (Harris 2005), although Dunnet (1977) found that aircraft transiting greater than 100 m above active breeding colonies did not elicit a behavioural response in several cliff-nesting species (e.g., fulmars, guillemots, gulls). If food provisioning during migration, fledging, or nesting is interrupted based on behavioural responses to noise, this can have consequences for the health and survivorship of waterbird species.

Underwater acoustic modelling indicates that waterbirds may be exposed to source levels of up to 262 dB re 1 µPa-m during seismic exploration; drilling and transiting are estimated to produce broadband source levels of 190 dB re 1 µPa-m (OSPAR Commission 2009). There are different views among bioacousticians about the best method for estimating injury and disturbance effects on marine animals, and there is little consensus on how to perform those assessments across different taxa. Canada has not developed prescribed sound level criteria for assessing injury or behavioural responses of waterbirds to underwater noise. In the absence of defined criteria or thresholds, potential noise-based effects on waterbirds are best characterized based on the available information in peer-reviewed scientific literature. For example, the diving frequency of long-tailed duck did not change as a result of underwater seismic exploration in the Beaufort Sea, Alaska (Lacroix et al. 2003), and rhinoceros auklet bycatch did not decrease significantly when gillnets were equipped with acoustic devices emitting a 1.5 kilohertz (kHz) signal at 120 dB at a reference pressure of 1 µPa (dB re 1 µPa) (Melvin et al. 1999). However, for common murre, Melvin et al. (1999) did find that bycatch was reduced by 50%, suggesting that common murre actively avoided the area influenced by underwater noise. More recently, Anderson Hansen et al. (2016) found that great cormorants could detect underwater noise up to 2 kHz at 71 dB re 1 µPa. Other studies have found that, depending on the frequency, intensity, and duration of underwater noise, waterbirds may be displaced from suitable breeding, foraging, staging, or roosting habitats (Bellefleur et al. 2009; Ronconi and Clair 2002; Science Applications International Corporation (SAIC) 2011), but that the extent of displacement varied by species, age, or seasonal sensitivities (Agness et al. 2013; Bellefleur et al. 2009; Schwemmer et al. 2011; Velando and Munilla 2011).

In general, waterbird species that feed in groups are considered especially sensitive to potential noise-based disturbances as they are thought to rely on underwater acoustic cues from their conspecifics[117], other predators, and prey, for foraging (Anderson Hansen et al. 2016). At high enough received sound levels, waterbirds can also experience direct physiological effects. Sudden, high-amplitude noise sources that produce pressure pulses near the source can result in lethal or sub-lethal injury (e.g., barotrauma) from shock waves (Science Applications International Corporation (SAIC) 2011). Interim

[117] Members of the same species

recommendations have been developed by the Science Applications International Corporation (SAIC) on behalf of the US Navy for evaluating the onset of injury to marbled murrelet from pile driving. The Science Applications International Corporation (SAIC) (2011) determined that an underwater cumulative sound exposure level (SEL) of 202 dB re 1 µPa^2-s can cause auditory injury (e.g., loss of cochlear hair cells) to marbled murrelet, and that cumulative SELs exceeding 208 dB re 1 µPa^2-s SEL could result in non-auditory injury (e.g., barotrauma). Given available scientific evidence, the Science Applications International Corporation (SAIC) (2011) concluded that terrestrial and marine mammals represent reasonable surrogates for characterizing auditory injuries to marbled murrelets, while thresholds for fish are useful for estimating non-auditory injuries in birds.

Changes in behaviour and mortality risk for waterbirds may occur as a result of in-air and underwater noise generated by activities under Scenarios A, B, or C. The magnitude of effects of in-air or underwater noise is considered to be moderate since these changes are not anticipated to adversely impact the viability of waterbirds present within the Area of Focus. Changes in waterbird behaviour as a result of seismic exploration and ice-breaking activities, including associated vessel and air traffic, are anticipated to be medium-term in duration (i.e., occurring over several breeding seasons), local in extent (restricted to the immediate area of those activities), and be continuous while the activity is occurring. Effects would be reversible once conditions return to baseline after activities cease. Seismic surveys and ice-breaking activities will occur as multiple irregular events.

Changes in waterbird behaviour as a result of noise produced during drilling, and associated vessel and air traffic may be long-term in duration, depending on the Scenario and the intensity of the activity, but are likely to be localized and reversible. Drilling activities, and associated vessel and air traffic will occur as multiple regular events.

Effects of in-air and underwater noise on change in mortality risk for waterbirds are anticipated to be localized, occur as multiple irregular events, and may be short- or medium-term in duration (depending on the scenario).

Changes in timing and duration of ice formation and melt due to climate change may extend the duration of oil and gas activities within the Area of Focus as the open water season extends. As a result, waterbirds have the potential to be exposed to longer periods of in-air and underwater noise associated activities in Scenarios A–C. However, this is not expected to modify the effects characterizations.

Some uncertainty in the effects characterization exists due to a lack of prescription of threshold criteria for assessing injury or behavioural responses of waterbirds to underwater noise, and there are few studies that characterize species-specific differences in response to noise. In addition, expected changes in physical and chemical ocean conditions (mainly sea ice, temperature, and nutrients) may alter the species composition, productivity, prey availability, habitats, and distribution and abundance of waterbirds in the Arctic (e.g., Gall et al. 2017; LeBlanc et al. 2017; Ramírez et al. 2017; Wong et al. 2016)), potentially altering the time, place, and percentage of species vulnerable to noise effects.

MARINE MAMMALS

Marine mammals could be affected by noise during seismic exploration (Scenario A), exploration drilling (Scenario B) or production drilling (Scenario C), and by icebreaker activity and other vessel activity associated with Scenarios A, B, or C. At lower levels, underwater noise has the potential to change marine mammal behaviour, and at higher levels can increase mortality risk.

Change in marine mammal behaviour can result from underwater noise created during 2D and 3D seismic surveys, exploration and production drilling, including drilling support vessels such as ice breakers, shipping during production, and decommissioning. The level of response to noise generated during oil and gas activities depends on the time of year, intensity and duration of the noise, distance from the sound source, the ability for the animals to hear the noise (i.e., the animals hearing frequency range), the species in question, its activity during noise exposure, and the novelty of the sound (Ellison et al. 2016; Richardson et al. 1995b; Southall et al. 2007). Such effects to narwhals have been witnessed by Barnabas (as cited in The Association of Fishers and Hunters in Greenland 2013).

> "Living in High Arctic, I have experienced behaviour of narwhales and other marine mammals. We learned that there was seismic testing in the area of Greenland. Although the seismic testing have to happen yet in the waters in Nunavut, we know that narwhales were acting in different ways than normal behaviour in the past two years. We also learned the past two years the migration of narwhales has changed as well. They are moving more to the west. Some communities that never had narwhales are getting narwhales like Igloolik and Cambridge Bay. Because of migration, our quota system is affected in Nunavut. When we learn that oil companies want to do seismic testing in the waters in our area the people were against it and cause court injunction in Qikiqtani Inuit Association. But, this court injunction is only temporary. North Greenland and in Nunavut high arctic share some of the pods of narwhales and this is a great concern to the people in our area because any exploration whether oil exploration or other development will affect our diet on country food. Some of the experience we know happened before Nunavut was created back in late 1980, when Pan Arctic was exploring in high arctic. We have seen and are able to approach narwhales in spring, because the whales were, I guess, hard of hearing. When Pan Arctic finished, the normal behaviour came back until 2008, we learned and know that narwhales are behaving differently again."

Typically, the levels of underwater noise during 2D and 3D seismic surveys, exploration and production drilling, and decommissioning exceed the National Oceanic and Atmospheric Administration (NOAA) (2016) threshold for behavioural change (i.e., 160 dB root mean square SPL (SPL_{rms}) for impulsive sources and 120 dB SPL_{rms} for continuous sources) at varying distances from the source noise (see Appendix B for a description of the threshold) (e.g., Richardson et al. 1995b), and may result in changes in behaviour such as masking of marine mammal communications, changes in surface activity and diving, and displacement (e.g., Gomez et al. 2016). Such changes in behaviour have been documented for several species found in the Area of Focus. During the NIRB SEA community engagement sessions (Nunavut Impact Review Board 2017), Inuit of Resolute Bay reported that "after seismic surveying, people have witnessed dead animals. There are always positives and negatives. With seismic surveys, sound travels and can affect and impact wildlife equilibrium, and their behaviour could change as a result. Whales can't function without their navigation".

Bowhead whale response has included change in calling rates or avoidance of the area (e.g., Blackwell et al. 2013; Blackwell et al. 2015; Harwood et al. 2010), and change in surfacing and diving behaviour, although responses vary depending on the activity state of the whales (Robertson et al. 2013). Beluga have also been noted to temporarily avoid areas where seismic activity is occurring (Harwood et al. 2010). Unknown sources of explosive sounds heard in open waters near Kimmirut appeared to decrease the number of beluga whales entering the inlet (Nunavut Wildlife Management Board (NWMB) 1998). Fin whales have shown avoidance and change in calling in response to airgun noise (Castellote et al. 2012). Proposed links between narwhal ice entrapment and seismic surveys have been made. On three occasions, narwhals stayed in their coastal summering habitat longer than usual and their delayed migration to offshore wintering habitat left them entrapped in ice (Heide-Jørgensen et al. 2013). Further studies are required as direct causality could not be determined in this retroactive study (Heide-Jørgensen et al. 2013). Northern bottlenose whales near the Scotian Gully did not appear to avoid the region, based on vocalizations, during 3D seismic surveys (Simard et al. 2005).

Bearded seals and ringed seals have shown avoidance during seismic surveys (Harris et al. 2001). When exposed to seismic surveys, ringed seals have been shown to abandon breathing holes and subnivian lairs (Kelly et al. 1988). Walrus response to seismic surveys has been varied (e.g. avoidance, change in behavior), and it is anticipated that a temporary change in behaviour is likely (Garlich-Miller et al. 2011). Communication masking as a result of seismic surveys has been noted as possible, depending on distance from the source, for ringed seals (Sills and Reichmuth 2016), bowhead whale, and potentially beluga (Guan 2016).

Drilling and associated activities such as vessel noise, and icebreaker activities may also result in changes in marine mammal behaviour and communication masking. Bowhead whales have changed calling rates as a result of drilling and associated vessel noise (Blackwell et al. 2017), and exhibited changes in feeding and surfacing in response to playbacks of drilling (Richardson et al. 1990). Conversely, they have also been observed exhibiting normal behaviour 4 km from drill ships (Richardson et al. 1990). Beluga whales have shown avoidance response to drilling noise (Awbrey and Stewart 1983). Ringed seals have shown varied responses, with records of displacement from breathing holes or abandonment of lairs during exploratory drilling activities (Harwood et al. 2010), and no significant change in abandonment of subnivian lairs when exposed to noise from drilling activity (Harwood et al. 2007; Williams et al. 2006). During the NCRI, Inuit of Qikiqtarjuaq noted that seals are increasingly observed in low traffic areas as a result of vessel noise (Nunavut Department of Environment 2010).

Behavioural responses to icebreaker activity has been noted for cetaceans and pinnipeds. Beluga have been noted to exhibit avoidance behaviour (Erbe and Farmer 2000; Finley and Greene 1993), and narwhal similarly have exhibited avoidance behaviour and change in vocalizations (Finley and Greene 1993). Seals and walrus have also exhibited temporary displacement as a result of icebreaking activity, although dependent on distance from the source. For example, Brueggeman (1993) noted that walrus behavioural responses to icebreaking activity decreased beyond 0.46 km from the activity.

Communication masking has also been noted for beluga as a result of icebreaking activity (e.g., Erbe and Farmer 1998; Erbe and Farmer 2000). Inuit of Iqaluit, Kimmirut, Pangnirtung and Pond Inlet have noted behavioural changes in beluga and bowhead whales as a result of anthropogenic noise, with noise deterring whales from reaching certain camps that were previously visited and overall lower whale populations since the 1960s, particularly in Clearwater Fiord, Cumberland Sound, Frobisher Bay, Kimmirut Inlet, Nualla and Pond Inlet (Nunavut Wildlife Management Board (NWMB) 1998; Arnakallak 2000, Jaco Evic 2000, Lucassie Nutaraaluk 2000, Simon Akpaliapik 2000, as cited in NWMB 2000). Near Kimmmirut, beluga whales that used to feed along the floe edge, are now making dive-ins from further away and/or are making less dive-ins overall, with the majority of dive-ins conducted at night. Behavioural changes, resulting from boating related noise have also been noted in killer whale populations (NWMB 2000).

Potential change in mortality risk, which includes injury from underwater noise, may result from underwater noise from seismic surveys (e.g. Southall et al. 2007), although the potential for an effect can be reduced through standardized mitigations for seismic surveys (see Section 7.2.5 and Appendix B).

Change in mortality risk may also occur for ringed seals pups due to abandonment of lairs from seismic surveys resulting in increased stress and inability to deal with change in heat loss from being forced into the water (Kelly et al. 1988).

While changes in marine mammal behaviour as a result of oil and gas activities under Scenarios A, B, and C may occur, these changes in behaviour are not anticipated to affect the sustainability of the marine mammals present in the Area of Focus.

Seismic surveys and icebreaking activity are anticipated to result in temporary and short-term change in marine mammal behaviour and communication masking, lasting for the duration of the activity or continuing over the short term after the activity has ceased. Impacts would be local in so far that it is restricted to the acoustic footprint of the activity. The magnitude of the effect is considered to be moderate, as underwater noise levels will be above current baseline conditions but are not anticipated to affect the viability of the marine mammal populations present and are reversible with conditions returning to baseline once activity ceases. Seismic surveys and icebreaking will occur as multiple irregular events but are not expected to be frequent.

Change in marine mammal behaviour from drilling and associated vessel activities may be long term in duration, depending on the Scenario, but are likely localized, resulting in specific areas with levels of underwater noise above thresholds. The effects are anticipated to be moderate in magnitude, as underwater noise levels will be above current baseline conditions but are not anticipated to affect the viability of the marine mammal populations present and are reversible.

Changes in mortality risk are only anticipated for seismic surveys. The predicted effect would be short term, occurring only during the activity. Changes in mortality risk to ringed seal pups from seismic surveys are anticipated to be localized, and long-term as it may take several years to replace dead pups. Although changes in mortality risk are adverse, they are not anticipated to affect the viability of the marine mammal populations present and may occur as multiple irregular events.

Changes in timing and duration of ice formation and melt due to climate change may extend the duration of oil and gas activities within the Area of Focus as the open water season extends. As a result, marine mammals may be exposed to longer periods of underwater noise associated activities in Scenarios A-C (Reeves et al. 2014). However, this is not expected to modify the effects characterizations.

Uncertainty in the assessment of changes in behaviour of marine mammals as a result of underwater noise is considered to be moderate. There is uncertainty associated with the types of changes in behaviour that may occur (e.g., change in vocalizations vs avoidance), the unknown relationship between individual changes in behaviour and population-level effects, and the amount of time required for recovery from the disturbance. In addition, expected changes in physical and chemical ocean conditions (mainly sea ice, temperature, and nutrients) may alter the species composition, productivity, prey availability, habitats, and distribution and abundance of marine mammals in the Arctic (e.g., Bluhm and Gradinger 2008; Hamilton et al. 2017; Kovacs et al. 2011; Moore and Huntington 2008), potentially altering the time, place, and percentage of species vulnerable to noise effects.

7.2.1.2 Routine Discharge

Routine discharges can be released in Scenarios A, B, and C; and include produced water, bilge water, ballast water, sewage, and other wastes legally permitted to be released. These may contain organic acids, polycyclic aromatic hydrocarbons, phenols, volatiles, metals, or various nutrients. Depending on properties of the substance, discharged materials may disperse into the water column in the vicinity of vessels, drill rigs or platforms. Routine discharge from vessels and oil and gas activities are subject to international and federal regulations (i.e., *Fisheries Act, Clean Water Act, Canada Shipping Act*). Within Canada and especially in the Arctic, waste water and produced water must also be treated before discharge. As further legislated by the *Arctic Waters Pollution Prevention Act* and regulations, no oil base fluid or whole mud containing oil base fluid can be discharged to the sea.

BENTHIC FLORA AND FAUNA

Benthic flora and fauna may be affected by routine discharges under Scenarios A, B and C. Effects under these scenarios may include changes in habitat through chronic contamination, particularly by metals and hydrocarbons, and associated changes in health, as well as through the introduction of invasive species from ballast water.

Liquid and solid discharges may be ingested or absorbed by benthic flora and fauna, and accumulate harmful constituents over time (Boesch and Rabalais 2003; Olsgard and Gray 1995). Bioaccumulation of some contaminants (e.g., heavy metals) may lead to cascading effects through the Arctic food web, which is primarily dependent on benthic biomass (e.g., Bluhm and Gradinger 2008; Piepenburg 2005b). However, routine discharges from oil and gas activities do not contain high levels of these types of contaminants.

Strict guidelines exist in Canada for the monitoring of environmental effects from routine discharges from exploration drilling and offshore platforms (e.g., Government of Canada 1985). Although there are often near field effects, there seems to be little evidence of severe, far reaching, or lasting effects on the benthic flora or fauna (e.g., DeBlois et al. 2014; Jerez Vegueria et al. 2002; Whiteway et al. 2014).

Regular discharges of ballast water can introduce biological invasive species into new ecosystems, particularly invertebrates (Niimi 2004). Although this continues to be an issue with the global nature of shipping lines and the movement of exploratory drilling rigs across the world, new ballast water regulations have helped to reduce such impacts (International Maritime Organization (IMO) 2017).

Overall, the effects of routine discharges related to activities in Scenarios A, B and C on marine benthic flora and fauna are expected to be negligible or low, local, continuous and if present, long-term. Discharges, particularly nitrogen from waste discharges, can act as a nutrient input into systems. Currently, Arctic marine food webs are generally not nitrogen-limited and so, this effect pathway is limited (Kędra et al. 2015; Kortsch et al. 2012). However, changes in ocean chemistry in the future are expected and, if these affect the availability of nitrogen, the potential for uptake of harmful discharges through this mechanism could be altered. However, this and other climate change effects on benthos are not expected to modify the effects characterizations.

There is a low level of uncertainty in the effects characterization as the effects of routine discharges on the benthic environment are well studied. Expected changes in physical and chemical ocean conditions (mainly sea ice, temperature, and nutrients); however, may alter benthic species composition, biomass and productivity in the Arctic (e.g., Bluhm and Gradinger 2008). Given that different species are more sensitive to discharges than others (Paine et al. 2014), climate change effects adds some uncertainty to whether impacts of routine discharges on arctic benthic ecosystems would remain low in the future.

FISH AND FISH HABITAT

Fish and fish habitat may be affected by routine discharges under Scenarios A, B and C. Effects under these scenarios may include changes in health through chronic contamination, particularly by metals and hydrocarbons, and associated changes in health.

Effects might occur on fishes from direct ingestion/absorption of the constituents in the water column or indirectly through feeding on contaminated benthic prey

Groundfish are potentially at particular risk as their main prey is benthic, and they often disturb the top surface layer of the benthos, agitating and redistributing potential contaminates into the substrate. Environmental effects monitoring of routine discharges at the TerraNova oil field in eastern Canada; however, revealed little to no detectable biological effects on Iceland scallop and American plaice (DeBlois et al. 2014).

As discussed previously, guidelines and regulations in Canada are designed to limit the release of contaminants to the water column and reduce the potential for effects on marine organisms. Overall, routine discharges from activities related to Scenarios A, B and C are expected to have negligible or low effects on fish and fish habitat. If present, effects are expected to be local, sporadic (for exploration drilling) and continuous and long-term for production. Climate change is not expected to change this characterization.

The level of uncertainty is relatively low. Fish and fish habitat have been exposed to similar routine discharges in similar previous activities in the Arctic and confirm this effects characterization. However, climate change, may increase uncertainty in the future, as it may cause changes in future fish and fish prey species assemblages, some of which may be more sensitive to these types of discharges (see benthic flora and fauna above).

WATERBIRDS

Waterbirds may be affected by routine discharges under Scenarios A, B and C. Effects under these scenarios may include changes in behavior, health, and mortality risk, mediated through changes in the availability and quality of prey and potential direct exposure to contaminants. Substances that can be ingested or absorbed by marine benthos or fish (see sections above) have potential to exert sublethal toxicological effects on internal tissues and organs if regularly consumed and bioaccumulated by waterbirds (Eisler 1987; Leighton 1993). The extent to which sublethal effects may be expressed among waterbirds is influenced by their dependency on habitats that are exposed to routine discharges, the duration and seasonality of exposure to such habitats, as well as the composition of their diet (Neff et al. 2006; Trust et al. 2000).

Depending on the volume, constituents, and ocean conditions, discharged produced water can, and often does, create surface sheens of oil within several hundred metres of the discharge site (Fraser et al. 2006). Although these sheens are generally thin and may disperse quickly, birds that come into direct contact with these oil sheens or slicks will readily adsorb particles onto their feathers. Adsorbed oil reduces the waterproofing, insulating, and buoyancy properties that feathers provide; loss of these functions can result in death due to starvation, hypothermia, asphyxiation, or drowning (Fraser et al. 2006; Leighton 1993; Wiese 2002). Effects of exposure are magnified in cold-water environments where insulating properties are essential for thermoregulation. Among waterbirds, species that interface with the surface of the water have a higher likelihood of interacting with oil sheens (Fraser et al. 2006; Morandin and O’Hara. 2016; Piatt et al. 1990). Hence, diving, pursuit, or surface foragers (e.g., eiders, loons, ducks, alcids, and phalaropes) are most at risk from and sensitive to exposure from routine discharges.

Overall, effects of routine discharges released during activities associated with Scenarios A, B, and C on waterbirds are expected to be low in magnitude since changes are expected to be below environmental thresholds and are not anticipated to adversely affect the viability of waterbirds present within the Area of Focus. Impacts would be local, continuous and short (oiling) to long-term (contaminated prey).

Routine discharges are relatively limited in quantity and geographic scope, and climate change is unlikely to alter these effect characterizations.

Confidence in the assessment of change in behaviour, health, or mortality risk due to routine discharge is moderate to high. The extent to which sublethal effects of regular consumption of contaminated prey may be expressed among waterbirds is influenced by their dependency on habitats that are exposed to routine discharges, the duration and seasonality of exposure to such habitats, as well as the composition of their diet (Neff et al. 2006; Trust et al. 2000). Expected changes in physical and chemical ocean conditions (mainly sea ice, temperature, and nutrients) may likely alter the species composition, productivity, prey availability, habitats, and distribution and abundance of waterbirds in the Arctic (e.g., Gall et al. 2017; LeBlanc et al. 2017; Ramírez et al. 2017; Wong et al. 2016), potentially altering the time, place, and percentage of species vulnerable to routine discharges.

MARINE MAMMALS

Marine mammals may be affected by routine discharges under Scenarios A, B and C. Effects under these scenarios may include changes in behavior, health, and mortality risk, mediated through changes in the availability and quality of prey and potential direct exposure to contaminants. Similar to the effects on waterbirds, marine mammals may bioaccumulate substances from acting as a top-level predator. Changes to the distribution, abundance and quality of the benthic environment and marine mammal prey may potentially result in increasing energy requirements to seek out alternative feeding locations. Produced oil (Fraser et al. 2006) may also interfere with fur, and cause damage from inhalation, and a variety of other effects detailed in Section 7.2.4.4. However, given the restrictions imposed on routine discharges through the *Arctic Waters Pollution Prevention Act* and associated regulations, the potential of such an effect is unlikely.

Routine discharges associated with activities during Scenarios A, B, and C are not anticipated to have a direct effect on marine mammals. Indirect effects, related to marine mammal prey are predicted to be localized, short term in duration, and of low magnitude, affecting limited amounts of marine mammal prey and habitat. Climate change is not expected to change the assessment of these effects.

Overall, effects of routine discharges released during activities associated with Scenarios A, B, and C on marine mammals are expected to be low in magnitude since changes are expected to be below environmental thresholds and are not anticipated to adversely impact the viability of marine mammals present within the Area of Focus. Impacts would be local, continuous and short (exposure to sheens) to long-term (contaminated prey).

Routine discharges are relatively limited in quantity and geographic scope; as a result, climate change is unlikely to alter these effect characterizations.

Uncertainty in the assessment of change in behaviour, health, or mortality risk due to routine discharge is moderate to low. The extent to which sublethal effects of regular consumption of contaminated prey may be expressed among marine mammals is influenced by their dependency on habitats that are exposed to routine discharges, the duration and seasonality of exposure to such habitats, as well as the composition of their diet (Neff et al. 2006; Trust et al. 2000). Expected changes in physical and chemical ocean conditions (mainly sea ice, temperature, and nutrients) may likely alter the species composition, productivity, prey availability, habitats, and distribution and abundance of marine mammals in the Arctic (e.g., Bluhm and Gradinger 2008; Hamilton et al. 2017; Kovacs et al. 2011; Moore and Huntington 2008), potentially altering the time, place, and percentage of species vulnerable to routine discharges.

7.2.1.3 Drill and Mud Cuttings

BENTHIC FLORA AND FAUNA

Drill and mud cuttings can directly affect the habitat, health, and mortality risk of benthic flora and fauna in the vicinity of the drill site during either exploration drilling (Scenario B) or production drilling (Scenario C).

At the drill site, drilling waste cones generally form (e.g., 1–2 m deep in the immediate surrounding about one tenth of a hectare and up to 1 cm deep for the surrounding 1 ha) (BOEM 2015). Such disturbances may remove benthic habitat and bury the associated flora and fauna in the direct area of influence. This can locally fragment habitat on the sea floor, creating a zone of cuttings along benthic habitat, even though the zone is expected to be relatively small in comparison to the size of the study area.

Drill and mud cuttings also contain a variety of constituents that benthic flora and fauna can become exposed to. These may include metals, hydrocarbons, drilling additives, and other chemicals. Many constituents are not readily taken up in biological systems, but polycyclic aromatic hydrocarbons, and chemicals such as barite or cadmium may be (Melton et al. 2000; Neff 2007; Nuneku and Ayobahan 2014). Most of these constituents have lower bioavailability as sediment, than when dispersed in the water (Neff Jerry 2009). As sediments, these can remain for decades or longer in the surrounding ecosystem (Dunton et al. 2012; Trefry et al. 2014).

Local increases in turbidity and suspended sediments can take place both directly from the initial discharge of cuttings, and subsequently from resuspension of cuttings during strong currents and storms. These can decrease the available sunlight for benthic flora or inhibit/clog membranes used for metabolic functions (Järnegren et al. 2017).

Overall, drill and mud cuttings are expected to create a low to moderate level of change to existing conditions. The effects are local, generally near-field, but continuous and potentially long-term. Climate change could alter the magnitude of the effect of specific constituents if increased water temperature or chemistry change the bioavailability of constituents in the areas of deposition. Uncertainty surrounding effects of drill and mud cuttings currently used is low, as their effects have been monitored for many years in multiple locations around the world. Increased uncertainty in these effects characterizations may result from the introduction of any new methods or constituents related to drill cuttings. Expected changes in physical and chemical ocean conditions (mainly sea ice, temperature, and nutrients), may also alter benthic species composition, biomass and productivity in the Arctic (e.g., Bluhm and Gradinger 2008). Given that different species are more sensitive to discharges than others (Paine et al. 2014), climate change effects adds some uncertainty to whether impacts of drill and mud cuttings on Arctic benthic ecosystems would remain low in the future.

FISH AND FISH HABITAT

Drill and mud cuttings can directly affect the habitat, health, and mortality risk of fish and fish habitat in the vicinity of the drill site during either exploration drilling (Scenario B) or production drilling (Scenario C). Discharges can locally elevate constituents above background levels and provide a variety of pathways for exposure. Groundfish face direct exposure from using cuttings as habitat (e.g., Greenland halibut burying in substrate). Exposure can also come from fish feeding on benthic flora and fauna and other prey which have accumulated harmful constituents (e.g., copepods or other invertebrates). Not all chemicals are prone to bioaccumulation (Payne et al. 2011), and concern typically focuses on mercury (which is not usually in drill cuttings and mud) and heavy metals (Neff Jerry 2009). Even if constituent levels are less than lethal to prey, they can be transported to fish and up the food chain to waterbirds, marine mammals, and humans.

Discharge of drill cuttings can cover the local benthic environment (discussed above) close to the drilling activity. This can cause direct mortality of shellfish, and reduce the available of healthy fish habitat, causing individuals to move to other locations. Local reefs, topographic variation, substrate diversity, or other important habitat may be lost under the cone of cuttings. Impacts would vary by species and the importance of the habitat to the local ecosystem.

Cuttings can also locally increase turbidity by increasing the amount of TSS, both during initial discharge and potential resuspension (Kendall et al. 1983; Neff 2003). Discharges can decrease visibility in the water column, reducing the efficacy of sight-based activities such as mating or predation. Turbidity can also clog gills or fish egg membranes, inhibiting respiration, or result in temporary avoidance behavior until TSS returns to baseline levels.

Overall, drill and mud cuttings are expected to have a low to moderate impact on fish and fish habitats. The effects are local, but continuous and potentially long-term.

Climate change could alter the magnitude of the effect of specific constituents if increased water temperature or chemistry change the bioavailability of constituents in the areas of deposition, as well as altering the quality of available prey. Some of these effects are expected to be reduced given the ability of fish to move to other habitats.

Certainty in the prediction of potential effects of drill and mud cuttings is high, as their effects have been monitored for many years in multiple locations around the world, including Atlantic Canada, which has comparable benthic habitat and species composition. Increased uncertainty in these effects characterizations may result from the introduction of any new methods or constituents related to drill cuttings. Climate change may also create additional uncertainty for the future, as it may cause changes in future fish and fish prey species assemblages, some of which may be more sensitive to constituents contained in drill and mud cuttings.

WATERBIRDS

Waterbirds could directly or indirectly be affected by discharges of drill and mud cuttings during exploration drilling (Scenario B), and field development and production drilling (Scenario C).Direct impacts, depending on the species, may include a localized increase in turbidity affecting foraging efficiency, and contaminated prey affecting their health (see the above sections on effects on marine benthos and fish communities). Canadian regulations limit the volume of polycyclic aromatic hydrocarbons that may be present in drilling muds to limit potential toxic effects; in turn, this would limit sublethal effects of exposure by birds (Morandin and O'Hara. 2016). In addition, the National Energy Board provides guidelines on approaches for identification of less toxic drilling mud additives and production chemicals to reduce potential environmental impacts of drilling mud or cuttings and produced water discharges (National Energy Board et al. 2009).

Indirectly, alteration to the distribution, abundance, and health of benthos and fish communities due to discharges (see the above sections) may locally affect the availability and quality of prey for waterbird species. In addition, depending on the distribution of individual waterbird species relative to the location of drilling and mud cutting activities and prey distribution, some birds may alter their behavior and expend additional energy to seek out alternative feeding locations for feeding, or expand forage effort more broadly within existing feeding areas.

Effects from discharges of drill and mud cuttings from activities associated with Scenarios B and C on waterbird behaviour and health are expected to be low in magnitude, localized, and long-term. Discharges of drill wastes is expected to occur as multiple irregular events. With implementation of established mitigation, Canadian regulations, and National Energy Board guidelines, changes are expected to be below environmental thresholds and are not anticipated to adversely affect the viability of waterbirds present within the Area of Focus.

Climate change is not expected to change the characterization of these potential effects.

Uncertainty surrounding effects of drill and mud cuttings currently used is low, although the extent of effects of discharges of drill wastes on waterbirds is influenced by the distribution of individual waterbird species relative to the location of drilling and mud cutting activities, and indirect effects on availability and quality of prey. As noted earlier, increased uncertainty in these effects characterizations may result from the introduction of any new methods or constituents related to drill cuttings. Climate change may also create additional uncertainty for the future, as it may cause changes in waterbird species distribution, abundance and phenology (e.g., Gall et al. 2017; LeBlanc et al. 2017; Ramírez et al. 2017; Wong et al. 2016).

MARINE MAMMALS

Changes in health and changes in behaviour in marine mammals may occur because of discharges of drill and mud cuttings during either exploration drilling (Scenario B) or production drilling (Scenario C). Such effects will likely be indirect, mediated through changes in the distribution, abundance and quality of prey species (see the above sections on benthic fauna and fish and fish habitat for potential effects). If prey is affected, marine mammals may be exposed to contaminated prey, and/or have to expend additional energy to seek out alternative feeding locations, or expand forage effort more broadly within existing feeding areas.

Direct impacts are not anticipated as the potential increase in turbidity, as a result of drill and mud cutting, is unlikely to affect marine mammals (Todd et al. 2014). Ringed seals are visual hunters, and although increases in turbidity may temporarily modify visibility, pinnipeds (including ringed seals, walrus, and bearded seals) have highly developed sensory organs (i.e., vibrissae) which likely assist with foraging in dark or turbid conditions (Hyvärinen 1989; Marshall et al. 2006).

Effects from discharges of drill and mud cuttings from activities associated with Scenarios B and C on marine mammal behaviour and health are expected to be low in magnitude, localized, and long-term. Discharges of drill wastes is expected to occur as multiple irregular events. With implementation of established mitigation, Canadian regulations, and National Energy Board guidelines, changes are expected to be below environmental thresholds and are not anticipated to adversely affect the viability of marine mammals present within the Area of Focus.

Climate change is not expected to change the characterization of these potential effects.

Uncertainty in the assessment of the effects of drill and mud cuttings on marine mammals is considered low. Effects of contaminated prey and increased energy expenditures are well documented, marine mammals are known to habituate to turbid areas, and research indicates effects of increased turbidity is minimal. However, the extent of effects of discharges of drill wastes on marine mammals is influenced by the distribution of individual species relative to the location of drilling and mud cutting activities, and indirect effects on availability and quality of prey. As above, increased uncertainty in these effects characterizations may result from the introduction of any new methods or constituents related to drill cuttings and its effects on marine mammal prey. Climate change may also create additional uncertainty for the future, as it may cause changes in physical and chemical ocean conditions (mainly sea ice, temperature, and nutrients) which may alter the species composition, productivity, prey, habitats, and distribution and abundance of marine mammals in the Arctic (e.g., Bluhm and Gradinger 2008; Hamilton et al. 2017; Kovacs et al. 2011; Moore and Huntington 2008), potentially altering the time, place, and percentage of species vulnerable to the indirect effects of drill and mud cuttings.

7.2.1.4 Habitat Alteration

PLANKTON

Change in health and change in mortality risk on plankton may occur due to habitat alteration caused by icebreaking activities associated with Scenarios A, B and C. No effects on plankton are expected due to habitat alterations caused by the physical presence of drilling platforms and other marine infrastructure. Icebreaking activities during exploration drilling and production can increase the amount of edge effects in pack ice. Edges of the ice pack are correlated with enhanced primary (e.g., algal) production in the spring where light can penetrate into the nutrient rich waters which have been dormant over the winter (Falk-Petersen et al. 2000). This leads to secondary (e.g., plankton) production in the water column, providing a significant portion of the biomass at the base of the Arctic marine food chain (Hop and Gjøsæter 2013). Conversely, the disruption and overturning of ice by the icebreakers during the winter may disrupt ice algal production below the ice. Ice algae are a key component of Arctic food webs, and their disruption can have important consequences for food web functioning and carbon dynamics of the pelagic system (Kohlbach et al. 2016).

Overall, habitat alteration caused by Scenarios A, B, and C are likely to have negligible effects on plankton as the effect would be localized to the path of the icebreaker (affecting a very small proportion of the plankton community), short-term (i.e. limited to hours/days after the icebreaker has transited), and be limited to multiple-irregular events.

Reduced future ice cover and duration as a result of climate change may alter this characterization as it would likely result in a change in ice-algae abundance and distribution.

There is little uncertainty in this effects assessment as it is restricted to ice breaking activities only, which are well understood. The decrease in ice cover as a result of climate change is also well documented. Some degree of uncertainty exists about the impacts of climate change to plankton and associated carbon cycles in the Arctic. Specifically, potential non-linear feedback loops between climate change and plankton are still not well understood, such as changes in bloom phenology due to sea ice changes (e.g., Wassmann and Reigstad 2011), and changes in abundance and species composition due to changes in ocean circulation, surface conditions, and temperatures (e.g., Barton et al. 2016; Blais et al. 2017).

BENTHIC FLORA AND FAUNA

Benthic flora and fauna may be affected by habitat alterations caused by activities associated with Scenarios A, B and C. Specifically, icebreaking activities during all three Scenarios could affect the production and location of sea-ice algae and thus affect benthic-pelagic coupling, resulting in changes in habitat. The physical presence of drilling platforms and other marine infrastructure associated with Scenarios B and C could result in physical removal of habitat and increased mortality risk, but also have the potential to create new habitat. Exploration wells, flowlines and associated sea-floor equipment would alter benthic habitat. Anchors can drag, leaving disturbed paths across bottom habitat. These types of disturbances may change the availability of habitat for local species and cover important substrate.

Overall, changes in habitat for benthic flora and fauna due to habitat alterations is expected to be low to moderate, local, and long term. Changes may occur immediately around the development footprint, but these are likely to be small areas when compared to the large study area.

In association with climate change, small changes in pH balances may take place from the ocean absorbing carbon dioxide. This is likely to decrease the Arctic coral reefs' ability to incorporate carbonate into their habitats, threatening their continued existence. This also could change the availability of carbonate to be incorporated into shells (Gazeau et al. 2007). As coral structures serve as important habitats for benthic flora, fauna, and associated predators, loss of reefs from climate change would reduce the availability of benthic habitat.

Uncertainty about the alterations to habitat for benthic flora and fauna is relatively low. Similar activities to Scenarios A, B, and C have taken place throughout the Arctic, and there have been baseline and impact studies completed examining the impacts to the benthic community. Expected changes in physical and chemical ocean conditions (mainly sea ice, temperature, and nutrients), may alter benthic species composition, biomass and productivity in the future Arctic (e.g., Bluhm and Gradinger 2008). Given that different species haven different habitat requirements, climate change effects adds some uncertainty to whether impacts of habitat alteration activities on Arctic benthic ecosystems would remain low in the future.

FISH AND FISH HABITAT

Fish and fish habitat may be affected by habitat alterations caused by activities associated with Scenarios A, B and C. Specifically, icebreaking activities during all three Scenarios could affect the production and location of sea-ice algae and thus affect benthic-pelagic coupling, resulting in changes in fish habitat and behaviour. The physical presence of drilling platforms and other marine infrastructure associated with Scenarios B and C could result in physical removal of fish habitat and increased mortality risk.

Icebreaking and warming Arctic temperatures decrease under ice habitat important to keystone species such as Arctic cod (Gradinger and Bluhm 2004). Intact ice edges in the spring are further key jumpstart primary and secondary algal and plankton production (described above) (Falk-Petersen et al. 2000), which in turn provide an important food source for many Arctic fish species, including cod and capelin (Bradstreet 1982; Hop and Gjøsæter 2013).

The placement of marine infrastructure on the ocean floor (such as mooring anchors, well heads, etc.) may remove important coral, shoals, or essential fish habitat and cause fish to move to alternate locations. Conversely, infrastructure can also serve as a stable substrate and act as an anchor for invertebrates or plants, creating new fish habitat in an otherwise often monotypic mud or sand environment (Dauterive 2000).

Overall effects on fish habitat and behaviour due to habitat alterations in Scenarios A, B and C are expected to be negligible or low. Positive and negative effects on habitat may occur at a local scale and depending on the alteration be a single event (e.g., laying buried pipeline), be multiple irregular events (e.g., ice breaking) or continuous (e.g., covering of previous habitat with infrastructure). Likewise, the associated duration of the effects may range from short-term to permanent. Climate change is not likely to change this effect characterization. The level of uncertainty in the effects assessment of changes in habitat and behaviour of fish from habitat altering activities is relatively low. The types and scale of activities under the Scenarios are common in the marine environment, have been extensively monitored, and many have well established mitigation measures inside the regulatory framework. Some uncertainty comes from our lack of knowledge about the ecology and specific habitat needs of the marine fish species present in the area, and climate change may create additional uncertainty for the future, as it may cause changes in future fish and fish prey species assemblages, some of which may have different habitat needs and associations. Climate change would be expected to have little direct impact on fish habitat alteration. Indirect impacts could include changes in water temperature or chemistry, and associated changes in the marine ecosystem including changes in species composition and community structure if fish species migrate into the region from adjacent habitats.

WATERBIRDS

Waterbirds may be affected by habitat alterations caused by activities associated with Scenarios A, B and C. Specifically, ice-breaking and other project related vessel traffic during all three scenarios could result in direct and indirect changes in habitat, with effects on behaviour and mortality risk of waterbirds. Construction and development of subsea wells, pipelines, and rigs can result in loss or alteration of benthic substrates, marine benthos, and fish (as described above) in the vicinity of the facilities, as well changes in sensory fields.

Vessel traffic has potential to cause sensory disturbance to waterbirds. Several studies investigating patterns of bird displacement from transiting vessels suggest marine traffic can elicit a diving or flushing (i.e., avoidance) response in waterbirds (Bellefleur et al. 2009; Hentze 2006; Schwemmer et al. 2011). Larger aggregations of birds are more sensitive (i.e., flush at increased distances) to vessel traffic (Schwemmer et al. 2011). In turn, this can reduce the time and efficiency of foraging and nesting, or reduce energy reserves for migrating individuals (Bellefleur et al. 2009; ECCC 2016b; Madsen 1995; Schwemmer et al. 2011), and consequently have adverse effects on the fitness of displaced individuals (Kaiser et al. 2006; Ronconi and Clair 2002; Velando and Munilla. 2011).

Changes in the presence, abundance, and distribution of marine vegetation, invertebrates, and fish communities can alter the availability or distribution of foraging opportunities for coastal waterfowl, seabirds, and shorebirds. Waterbirds may adjust to changes in prey availability by finding alternative foraging sites, using a larger area to sustain feeding requirements, or spending more time in the marine environment (e.g., away from nesting sites) to locate prey. Physical disturbance can also result from marine infrastructure that may impose physical or perceived barriers for access to important habitats if situated in a way that excludes waterbirds from portions of the Area of Focus providing important resources (e.g., breeding habitat, migratory staging areas, open water foraging sites). Generally, behavioural responses will likely vary between species and groups (Rodgers and Schwikert 2002; Schwemmer et al. 2011); however, some species, including eiders and long-tailed ducks exposed to marine traffic demonstrated higher tolerance over time (Bellefleur et al. 2009; Schwemmer et al. 2011).

Artificial lighting sourced from marine infrastructure or seismic and drilling vessels may affect waterbird behaviour and increase mortality risk. Waterbirds (and songbirds) have been documented to adjust migration and foraging patterns in response to artificial lighting. Many bird species are active during the night to avoid daytime predators or to improve foraging on vertically migrating or bioluminescent prey or on nocturnally migrating invertebrates (Rich and Longcore 2006). Birds that migrate nocturnally often orientate on star patterns; in coastal and offshore environments, and interference from artificial light can disrupt seasonal migration patterns by impairing visibility of the stars and, hence, ability to navigate using them (Rich and Longcore 2006). When birds are attracted to artificial light, they may be injured or killed as a result of colliding with lights or adjacent infrastructure; birds can also deplete energy reserves by trying to reach, or continuously circling, lit structures (Merkel and Johansen 2011; Montevecchi 2006; Wiese et al. 2001). Birds that become grounded from exhaustion or injury (from non-lethal collisions) can be susceptible to predation (BirdLife International 2012; Longcore et al. 2013). Inclement weather such as fog or rain can increase collision risk for birds that adjust flight patterns under poor conditions and because suspended moisture increases light refraction (Black 2005; Longcore et al. 2013; Merkel and Johansen 2011). In general, more bird collisions occur in coastal environments than in offshore waters due to the higher concentration of lights in coastal regions (Merkel and Johansen 2011). Among waterbirds, species within the family Alcidae (murres, guillemots, auklets, puffins) and the order Procellariiformes (albatrosses, petrels and shearwaters) are more susceptible to light-induced attraction and mortality compared to other guilds (BirdLife International 2012; Black 2005; Rich and Longcore 2006; Wiese et al. 2001).

While change in habitat use, behaviour, and risk of injury or mortality for waterbirds may occur under Scenarios A, B, or C, the magnitude of habitat alteration are expected to be low to moderate. Changes are not anticipated to adversely affect the viability of waterbirds present within the Area of Focus. Changes in waterbird habitat from construction and development of marine infrastructure resulting in loss or alteration of benthic substrates, marine benthos, and fish are expected to be short- to long-term in duration (depending on the Scenario and type of alteration), localized, and occur as single, multi-irregular, or continuous events and effects. Changes in waterbird habitat from artificial lighting sourced from marine infrastructure or seismic and drilling vessels resulting in increased risk of injury or mortality from collisions would have similar effects. Changes in waterbird habitat from vessel traffic and marine infrastructure resulting in physical disturbance (i.e., avoidance) are anticipated to be short- (seismic exploration and exploration drilling) to long-term (production and decommissioning) in duration, localized, and reversible following completion of activities (Scenarios A and B) or decommissioning (Scenario C). Changes in waterbird migration and foraging patterns in response to artificial lighting sourced from marine infrastructure or seismic and drilling vessels are expected to be short- to long-term in duration (depending on the Scenario), with effects extending from the local to regional scale.

Changes in sea ice cover and timing due to climate change are expected to extend the open water season (Laidre et al. 2015b), and may result in an increase in the duration of oil and gas activities and associated effects. Waterbird populations adversely affected by climate change influences on the availability and quality of foraging and nesting habitat are likely to be more susceptible to effects of increased oil and gas activity, including increased risk of injury or mortality. These factors may alter the prediction of effects on waterbirds.

Uncertainty in the assessment of direct and indirect changes in habitat, behaviour and mortality risk is low to medium. Disturbance of seabirds from vessels and habitat alterations is well documented but the degree of effect depends on the species composition, location and time of year, the specific of which is not always well known and all of which may change with changing climatic conditions (e.g., Wong et al. 2016; Gall et al. 2017; LeBlanc et al. 2017; Ramirez et al. 2017). There is also specific uncertainty related to the distribution of king eider along the east side of Baffin Island and in specifics of the migratory patterns of eastern king eiders (Abraham and FInney 1986b; Sea Duck Joint Venture 2015a) and Eastern Canadian Arctic puffins (Lowther et al. 2002a).

MARINE MAMMALS

Marine mammals may be affected by habitat alterations caused by activities associated with Scenarios A, B and C. Specifically, ice-breaking during all three scenarios could result in direct and indirect changes in habitat, with effects on behaviour, as well as mortality risk. Construction and development of subsea wells, pipelines, and rigs can result in changes to marine mammal habitat (specifically ice habitat), as well as changes in prey species, and thus affect marine mammal habitat and behaviour.

Habitat alterations may lead to changes in marine mammal behaviour and mortality risk, primarily for ice-associated seals (i.e., bearded seal, ringed seal) and walrus, and secondarily for polar bear and cetaceans.

Ringed seals create and maintain birthing lairs in the sea ice through the winter (Burns 1970; Finley et al. 1983) that may be damaged during icebreaking and, as a result, may be abandoned. Similarly, breathing holes maintained by ringed and bearded seals (Cameron et al. 2010; Kelly et al. 2010a) may also be damaged resulting in abandonment and use of alternative breathing holes. Similar to ringed and bearded seals, walrus may abandon areas affected by ice breaking activity.

Damage or abandonment of lairs may result in increased predation by polar bear and arctic fox on ringed seal pups if they are whelped on the sea ice instead of in protective lairs (Kelly et al. 2010b). If birthing lairs are abandoned and newborn pups and mothers are required to move to alternative lairs, increased stress on pups and potential mortality may result from heat loss during the swim to the alternative lair (Kelly et al. 1988). An increase of mortality risk during icebreaking activity may also occur for ringed seals, bearded seals, and walrus pups if they are separated from their mother during the pup's dependent period, as has been documented for other species (Wilson et al. 2017).

Icebreaking may also result in changes in cetacean behaviour and mortality risk. Cetaceans have been observed following icebreakers which may result in the cetaceans being inadvertently caught in isolated areas of open water (Stirling 1980a). However, channels opened by the ship typically close quickly enough that this threat is minimal (Stirling and Calvert 1983). In addition, species such as bowhead whales have the ability to break through ice, reducing the risk of being trapped (Finley 2001).

Changes in polar bear behaviour as a result of habitat alterations from ice breakers are likely to be minimal due to their wide range and access to other suitable habitat. Previous studies have indicated that polar bears do not appear to be disturbed by the presence of icebreakers or the resulting open water, although habitat partitioning may increase energy expenditures (Mauritzen et al. 2003). Change in mortality risk may occur from the presence of offshore platforms for polar bear if they are utilizing habitat near platforms and need to be shot for crew safety (Stirling 1988).

Ice-breaking and benthic habitat alterations from marine infrastructure may result in changes in prey distribution and productivity of under-ice and ice edge habitats, that may indirectly affect marine mammal behaviour and change in mortality risk. For example, the productivity of under ice and ice edge habitats is important for Arctic cod (Coad and Reist 2004a), which are a key part of the diet of beluga (Richard et al. 1994), and ice-dependent pinnipeds (e.g., ringed seal (Yurkowski et al. 2016)). The distributions of ice-dependent pinniped species (e.g., bearded seal) and polar bear, which predate on them, are often strongly associated with the distribution of productive ice edge habitats (COSEWIC 2008b; Kovacs 2016; Moore and Huntington 2008). Changes in benthic or pelagic prey distribution may lead to more energy expenditure in searching for prey, increased stress, and poor body condition (Moore and Huntington 2008), potentially resulting in changes in behaviour due to changes in foraging activity and potential change in mortality risk. Ringed seals, bearded seals, and walrus have been observed hauled out near drill rigs and artificial islands (Harwood et al. 2007; Moulton et al. 2005). The potential for leads to be formed in the lee of an offshore platform may result in increased open water habitat that may be utilized by ringed seals, bearded seals and walrus (Stirling 1988), resulting in change in behaviour and distribution in the region.

Overall, changes in behaviour as a result of habitat alterations from icebreaking and the presence of platforms are predicted to be localized and range from short to long term. Effects are anticipated to be multiple and irregular. The magnitude of the effect is considered to be moderate, as habitat alterations will change baseline conditions but are not anticipated to affect the viability of the marine mammal populations present. Changes in mortality risk from habitat alterations are anticipated to be localized and long-term. Effects are anticipated to be multiple and irregular. Although the effect is adverse it is not anticipated to affect the viability of the populations in the Area of Focus.

Climate change may alter some of these effects characterizations. With increasing extent and duration of the length of the open water season (Laidre et al. 2015b) and thinner ice, there may be less need for ice-breaking and perhaps ice-management associated with oil and gas activities in the future. Although the likely decrease in icebreaking reduces direct ice habitat alteration from oil and gas activities, ice-dependent or ice-associated animals are likely to already be more stressed as a result of habit loss (Ferguson et al. 2017; Mauritzen et al. 2003). If stressed, these animals may have an increased mortality risk and be more susceptible to the same, or lesser degree of, habitat alterations and disruptions from ice-breaking and ice-management activities.

Uncertainty in the effects assessment of habitat alterations on changes in behaviour and mortality risk of marine mammal is moderate. There is uncertainty associated with the level of habitat use by ice-associated seals in recent times and the extent and areas used for birthing lairs by ringed seals in the Area of Focus. As above, climate change may create additional uncertainty for the future, as it may cause changes in physical and chemical ocean conditions (mainly sea ice, temperature, and nutrients) which may alter the species composition, productivity, prey, habitats, and distribution and abundance of marine mammals in the Arctic (e.g., Bluhm and Gradinger 2008; Moore and Huntington 2008; Kovaks et al. 2011; Hamilton et al 2017), potentially altering the time, place, and percentage of species vulnerable to habitat alterations in the Area of Focus.

Special and Sensitive Areas and Areas of Concern or Importance

The effects of habitat alterations on Special and Sensitive Areas and Areas of Concern or Importance and pathways of effects are the same and, therefore, are assessed together. Special and Sensitive Areas and Areas of Concern or Importance could be affected by habitat alterations via activities associated with Scenarios A, B, or C. Special and Sensitive Areas and Areas of Concern or Importance within the Area of

Focus, that may experience change in habitat, are specific to those areas utilized by waterbirds and marine mammals.

Exploration and development activities located in proximity to waterbird breeding colonies have potential to disturb nesting waterbirds. Disturbance can cause birds to abandon nests or young or make them vulnerable to predation (Government of Canada 2017b). Under the *Migratory Birds Convention Act*, waterbirds are protected from harassment and disturbance, including disturbance that may interrupt breeding activities. Additional protections may be afforded to Migratory Bird Sanctuaries, National Wildlife Areas, or National Parks, as well as reserves and conservation areas under territorial jurisdiction. ECCC provides specific guidance on sensitive timing windows and land, water, or air-based disturbance setbacks for marine bird colonies (see Appendix C.4 for details). Notice-to-Airmen also are in effect to avoid major breeding colonies.

Special and Sensitive Areas and Areas of Concern or Importance that are utilized by marine mammals also have the potential for changes in habitat due to icebreaking activities. Change in habitat may occur for ringed seals that create and maintain birthing lairs in the sea ice through the winter (Burns 1970; Finley et al. 1983) that may be damaged during icebreaking. Similarly, breathing holes maintained by ringed seals and bearded seals (Cameron et al. 2010; Kelly et al. 2010a) may also be damaged, resulting in abandonment and use of alternative breathing holes. Change in habitat may also occur for other overwintering species such as walrus, narwhal and polar bear from ice breaking activity.

Change in habitat is predicted to be short term, lasting the duration of activity. Change in habitat is expected to be reversible, returning to baseline conditions once activities cease, and is predicted to be local in extent. The magnitude of the effect is anticipated to be moderate, with change from baseline conditions, but no anticipated effect on the viability of the populations within the Area of Focus. Climate change may increase the magnitude of the effects from changes to Special and Sensitive Areas and Areas of Concern or Importance, as birds and mammals will already be experiencing increased stress through other changes in their preferred environment (as detailed under their respective sections above)

There is some uncertainty in the assessment of changes in habitat of Special and Sensitive Areas and Areas of Concern or Importance. The relative importance and contribution of specific habitats to population viability is not well understood and in these instances, the precautionary approach is applied. Climate change may further add uncertainty in this respect and changes in atmospheric and ocean conditions will likely simultaneously alter the conditions and locations of these special areas and the abundance, distribution and species composition that use and depend on them. How these simultaneous effects may interact is currently unknown.

7.2.2 Cumulative Effects

The potential for project effects from the three development scenarios (seismic exploration, exploration drilling, and production) to contribute to cumulative effects from other human activities (e.g., increased shipping, other industrial activity, human activity associated with tourism, increases in aircraft), not including climate change, is considered for each group of VECs. For Scenario D–No Offshore Oil and Gas Activity, there would be no project effects and, as a result, no contribution to cumulative effects.

However, cumulative changes in habitat, behaviour, health, and mortality risk may still occur as a result of other past, present, or future activities.

Table 7.8 below outlines the past, present, and future activities in the Area of Focus that have the potential to interact with oil and gas activities and affect the Biological Environment. Potential cumulative effects for each of the Biological Environment VECs are discussed below. Potential cumulative effects for each of the Biological Environment VECs identified as having potential residual effects from routine operations, as applicable, are discussed below.

Table 7.8 Potential Cumulative Effects—Biological Environment

Other Projects and Physical Activities with Potential for Cumulative Environmental Effects	Potential Cumulative Environmental Effects			
	Change in Habitat	**Change in Behaviour**	**Change in Health**	**Change in Mortality Risk**
Past and Present Physical Activities and Resource Use				
Mining – Baffinland Mary River Mine (Marine Transportation)	✓	✓		
Commercial Shipping	✓	✓		
Commercial Fishing	✓	✓		✓
Tourism (cruise ships)	✓	✓		
Research (Military, Academic)	✓	✓		✓
Traditional Use and Practices, Traditional Harvest, Traditional Foods		✓		✓
Oil and Gas – Greenland	✓	✓	✓	✓
Oil and Gas – Atlantic Canada	✓	✓	✓	✓
Future Physical Activities				
Mining (marine transportation, air traffic) -	✓	✓		
Deepwater Port (Iqaluit)	✓	✓		
Commercial Shipping	✓	✓		
Commercial Fishing	✓	✓		✓
Tourism (cruise ships)	✓	✓		
Research (Military, Academic)	✓	✓		✓
Traditional Use and Practices, Traditional Harvest, Traditional Foods		✓		✓
Oil and Gas – Greenland	✓	✓	✓	✓
Oil and Gas – Atlantic Canada	✓	✓	✓	✓
Oil and Gas – Baffin Bay and Davis Strait (Scenario A, B, and C)	✓	✓	✓	✓

NOTES:
✓ = those "other projects and physical activities" whose residual effects are likely to interact cumulatively with residual environmental effects associated with oil and gas activities in the Area of Focus.

PLANKTON

Potential cumulative effects on plankton from past, present, and future human activities in the Area of Focus are expected on changes in habitat. Routine discharges (bilge and ballast water) from commercial shipping, fishing, research, mining and tourism vessels entering the water column could degrade habitat quality for plankton. These activities could also introduce invasive species that could be harmful to arctic plankton. The creation of a deepwater port would further increase this cumulative effect as it would increase marine shipping in the Area of Focus.

Overall, the cumulative effect associated with more ship traffic on plankton is expected to be negligible or low, and local. If effects do occur, they would likely result from multiple irregular events and be short-term in duration.

BENTHIC FLORA AND FAUNA

Potential cumulative effects from a future deepwater port are expected on changes in habitat, behaviour, and mortality risk of benthic flora and fauna. Cumulative effects in the Area of Focus may also stem from current or future commercial fishing activities if these use gear types that include bottom contact. The development and operation of a deepwater port would likely include some changes to intertidal and subtidal habitats, including dredging, as well as place of in-fill and pile driving during construction. Sessile benthic flora and fauna may be smothered, mobile species may be temporarily or permanently displaced.

Overall, the cumulative effects associated with a deepwater port and fishing are expected to be negligible or low, local, and medium to long-term, allowing for the local benthic community to recover from the disturbance.

FISH AND FISH HABITAT

Potential cumulative effects on fish and fish habitat may occur from current and future commercial fishing, potentially changing fish habitat and increasing mortality risk to fish. Commercial fisheries can control fish populations throughout the Area of Focus. Commercial fishery management relies on well informed and enforced regulations to ensure continued population health. These regulations are subject to demands placed on stocks by economic and political forces. Several neighboring fisheries (e.g., Atlantic salmon, cod) have experienced historic population declines. Management of fish and fish habitat will become increasingly uncertain as commercial fisheries expand further into the Arctic and possible extend their fishing season. Depending on gear types used, commercial fishing can disturb the benthic environment and thus affect important fish habitat.

Overall, the cumulative effect associated with commercial fishing is expected to be low to moderate and local, and medium to long-term, allowing for the fish populations and their benthic prey and habitats to recover from the disturbance.

WATERBIRDS

Potential residual effects of oil and gas exploration, development, and production activities can interact with other past, present, and future regional projects or activities, and may result in cumulative effects to waterbirds within and adjacent to the Area of Focus. Potential cumulative effects to waterbirds are expected to include change in habitat and behaviour associated with increased physical or sensory disturbance, and change in health and mortality risk associated with habitat alteration, increased collision risk, discharges of cuttings and other waste materials, and indirect effects from air emissions.

An increase in regional oil and gas activities is expected to result in an increase in exposure of waterbirds to in-air and underwater noise associated with seismic exploration, marine infrastructure or activities (e.g., in-water drilling), shipping (e.g., vessel engines), and air traffic. Increased vessel traffic from commercial shipping, fishing, tourism, research and mining, as well as aircraft use will add to these disturbances. Depending on the frequency, intensity, and duration of noise, and species-specific sensitivities, waterbirds may be displaced from suitable breeding, foraging, staging, or roosting habitats (Agness et al. 2013; Bellefleur et al. 2009; Ronconi and Clair 2002; Schwemmer et al. 2011; Science Applications International Corporation (SAIC) 2011; Velando and Munilla. 2011), or experience direct physiological effects (i.e., injury or mortality) (Science Applications International Corporation (SAIC) 2011).

An increase in marine infrastructure in the region (e.g., construction and development of subsea walls, pipelines, and rigs, as well as other industry, government or community infrastructure such as ports) may result in additional loss or alteration of benthic substrates, marine benthos, and fish prey, and may alter the regional availability or distribution of foraging opportunities for waterbirds. Increased regional vessel traffic is expected to increase physical or sensory disturbance to waterbirds (Bellefleur et al. 2009; Hentze 2006; Schwemmer et al. 2011), which may result in reduced access to or exclusion from important habitat (e.g., breeding habitat, migratory staging areas, open water foraging sites) (Bellefleur et al. 2009; ECCC 2016a; Madsen 1995; Schwemmer et al. 2011) and can have adverse effects on the fitness of displaced individuals (Kaiser et al. 2006; Ronconi and Clair 2002; Velando and Munilla. 2011). Higher concentrations of lighting sourced from marine infrastructure or seismic and drilling vessels can disrupt seasonal migration patterns of waterbirds by impairing visibility of the stars used for navigation (Rich and Longcore 2006), and may increase the risk of injury or mortality from collisions with lit infrastructures to which they are attracted (Merkel and Johansen 2011; Montevecchi 2006; Wiese et al. 2001).

An increase in oil and gas activities, including vessel traffic, as well as increased shipping for other uses has the potential to increase the probability of exposure of waterbirds to contaminants (e.g., from discharge of waste materials, accumulation of CO_2, SO_2 and NO_x emissions), with indirect effects to the health and survival of regional waterbird populations (e.g., bioaccumulation through consumption of contaminated prey [Eisler 1987; Leighton 1993; Trust et al. 2000; Neff et al. 2006]; alteration to the distribution and abundance of prey; acidification or eutrophication of marine habitats [McNicol et al. 1987; OCS 2018]).

Cumulative effects on waterbirds from change in habitat and behaviour associated with increased physical or sensory disturbance, and change in health and mortality risk associated with cumulative habitat alteration, increased collision risk, discharges of waste materials, and indirect effects from air emissions, have the potential to be long-term in duration, and regional in extent. Cumulative effects may result from be multiple irregular events or multiple regular events. The magnitude of cumulative effects is expected to be moderate since these changes are not anticipated to adversely affect the viability of waterbirds present within the Area of Focus.

Marine Mammals

Oil and gas exploration, development and operations activities that become aggregated in time or by geographic location, along with other past, present and future activities may result in cumulative effects to marine mammals in the Area of Focus. Potential cumulative effects to marine mammals may include changes in behaviour and changes in mortality risk associated with underwater noise and habitat alteration.

Overlap in oil and gas exploration and commercial shipping and tourism activities may raise the probability of exposure to underwater noise events (e.g., generated by seismic surveys, vessel engines, and icebreaking activity), and increase the ensonified area in the Area of Focus. This may affect the feeding, breeding, or migratory behaviours of marine mammal species, resulting in changes in behaviour. Increases in underwater noise may also result in changes in mortality risk due to the potential of increased birthing lair abandonment by ringed seals (Kelly et al. 1988) and/or a lack of alternative birthing lairs that are not disturbed by noise. Furthermore, a greater number of icebreakers in the Area of Focus, which may cause localized habitat alterations, and affect the availability of suitable reproduction, molting, resting, migrating or feeding habitat for ice-dependent (ice-obligate) marine mammals (polar bear, walrus, bearded seal, and ringed seal) (Moore and Huntington 2008) resulting in additional potential changes in behaviour and mortality risk.

Overall, cumulative effects on marine mammals have the potential to extend across the region and be long-term in duration. Effects are predicted to be multiple irregular events and, although they may be adverse, are anticipated to be moderate in magnitude; they are not expected to affect the viability of species in the Area of Focus.

Special and Sensitive Areas and Areas of Concern or Importance

The cumulative effects on Special and Sensitive Areas and Areas of Concern or Importance and pathways of effects are anticipated to be the same and, therefore, are assessed together.

Oil and gas exploration, development and operations activities that become aggregated in time or by geographic location, along with other past, present and future activities may result in cumulative changes in habitat to Special and Sensitive Areas and Areas of Concern or Importance in the Area of Focus. As identified in Section 7.2.1.4, change in habitat is anticipated only for those areas that are utilized by waterbirds and marine mammals. Similarly, this is anticipated to be the case for cumulative changes in habitat for Special and Sensitive Areas and Areas of Concern or Importance in the Area of Focus.

Change in habitat (i.e., disturbance by vessels) near Special and Sensitive Areas and Areas of Concern or Importance may result from oil and gas exploration activities, and other past, present and future activities including mining, commercial shipping, tourism, military and academic research vessels, and marine vessels used for traditional harvesting. Where vessel activity is in proximity to waterbird breeding colonies, there is potential to disturb nesting waterbirds. Special and Sensitive Areas and Areas of Concern or Importance that are utilized by marine mammals also have the potential for changes in habitat due to icebreaking activities associated with oil and gas exploration, and other past, present and future activities.

Cumulative effects on Special and Sensitive Areas and Areas of Concern or Importance may be long term and region wide. The magnitude of the effect is anticipated to be moderate, but not anticipated to affect the viability of the populations within the Area of Focus.

7.2.3 Transboundary Effects

As described in Section 2.3.7, transboundary effects may occur when residual effects extend outside of Federal waters associated with the Area of Focus into neighboring jurisdictions (i.e. Greenland, NSA), or when a VEC is affected by activities in one jurisdiction and then moves to other jurisdictions (i.e., seasonal migration) where the initial effects are compounded (i.e., by additional impacts) or result in effects on other VEC's in the other jurisdiction. Given the localized nature of the anticipated residual effects on plankton and benthic flora and fauna described above, transboundary effects are not expected. Fish, waterbird and marine mammal populations range over larger geographic areas and, in some cases, migrate over provincial and international boundaries. If oil and gas activities in the Area of Focus result in population level effects, those effects could be compounded by effects from other jurisdictions, or aspects of the human environment that value biological VECs (e.g., traditional harvest, commercial fishing) may be affected.

For Scenario D–No Offshore Oil and Gas Activity, there would be no transboundary effects on VECs associated with oil and gas activities.

FISH AND FISH HABITAT

Transboundary effects may be present for fish species in the Area of Focus if the effect is substantial enough to affect their long-term health or population density, their seasonal migration or general distribution extends outside the region (e.g., straddled stocks, [Balton 1996]), and they are an important ecological, subsistence or commercial resource in that jurisdiction. Canada is a signatory the United Nations Agreement on Straddling and Highly Migratory Fish Stocks (1995), which came into force in 2001. As a signatory, Canada committed itself to adopting the precautionary approach in managing commercially exploited fishes whose distribution either straddles, or is encompassed by, Canada's 200 nautical mile Exclusive Economic Zone (Hutchings and Rangeley 2011). Within the Area of Focus, such issue could potentially apply to Atlantic cod, Arctic cod and Atlantic salmon, Atlantic herring, Atlantic halibut, capelin and several skate and grenadier species.

As discussed, most residuals effects from Scenarios A, B, and C on fish and fish habitat are expected to be local and thus transboundary effects are currently considered to be negligible. Future changes in fish species distribution and abundance and associated fisheries may alter such an interpretation.

WATERBIRDS

Based on the distribution of waterbird species which require multiple locally specific habitats for different life stages and processes, as well as the ecology and life history of species migrating across provincial and international boundaries, residual effects of oil and gas activities and environmental effects have the potential to result in transboundary effects to waterbirds. Transboundary effects to waterbirds are expected to include change in migratory patterns associated with alteration of staging habitat; change in health associated with increased contaminant load; and change in risk of injury or mortality associated with hunting pressure across jurisdictional boundaries.

The Area of Focus is located along the Atlantic Flyway, which extends from Nunavut and parts of the Northwest Territories south through eastern Canada and the US, across the Caribbean Sea (Atlantic Flyway Shorebird Initiative 2016). The coastal and offshore areas of Baffin Bay and Davis Strait serve as important breeding grounds and staging area for millions of waterfowl, seabirds, and shorebirds on their way to and from arctic breeding grounds, with approximately 500 species migrating along the Atlantic Flyway. The integrity of staging habitat during migration, including availability of prey, is a key element in maintaining the viability of global populations (Atlantic Flyway Shorebird Initiative 2016; IBA Canada 2017). Waterbirds may adjust to changes in prey availability by finding alternative foraging sites, using a larger area to sustain feeding requirements, or spending more time in the marine environment (e.g., away from nesting sites) to locate prey.

Interference from artificial light sourced from marine infrastructure or seismic and drilling vessels can disrupt seasonal migration patterns of waterbirds by impairing visibility of the stars used for navigation (Rich and Longcore 2006). Physical or sensory disturbance from marine infrastructure can also impose physical or perceived barriers and exclude waterbirds from access to important resources (e.g., breeding habitat, migratory staging areas, open water foraging sites) (Madsen 1995; Bellefleur et al. 2009; Schwemmer et al. 2011; ECCC 2016) and can have adverse effects on the fitness of displaced individuals (Ronconi and St. Clair 2002; Kaiser et al. 2006; Velando and Munilla 2011).

Discharges of contaminants into the marine environment (e.g., from discharge of drill and mud cuttings, produced water and other waste materials) that can be ingested or absorbed by marine benthos or fish have potential to exert sublethal toxicological effects on internal tissues and organs if regularly consumed and bioaccumulated by waterbirds (Eisler 1987; Leighton 1993). The extent to which sublethal effects may be expressed among waterbirds is influenced by their dependency on those habitats that are exposed to routine discharges, and the duration and seasonality of exposure, in addition to the composition of their diet (Trust et al. 2000; Neff et al. 2006).

To the extent that these residual effects alone or in combination affect the health and mortality risk of species that are of ecological or subsistence in other jurisdictions (e.g., the thick-billed murre hunt in Newfoundland, Labrador, and western Greenland, Frederiksen et al. 2016), transboundary effects may occur. However, as most residuals effects from Scenarios A, B, and C on waterbirds are of low to moderate magnitude, not threatening the long-term viability of these populations, transboundary effects are currently considered to be negligible.

MARINE MAMMALS

Transboundary effects may occur for changes in marine mammal behaviour and changes in mortality risk as a result of hunting, and habitat disturbance associated with a variety of industrial activities, including oil and gas, fishing, tourism and shipping operations within the Area of Focus.

The distributions of individual populations for various species of marine mammal in Baffin Bay and Davis Strait cross international waters between Canada and Greenland. These species include ringed seal (Kelly et al. 2010b), Atlantic bearded seal (Kovacs 2016), Northwest Atlantic harp seal (Kovacs 2015) Atlantic walrus (COSEWIC 2006a), beluga (COSEWIC 2004b), Baffin Bay narwhal (Richard et al. 2014), Davis Strait-Baffin Bay-Labrador Sea northern bottlenose whale (COSEWIC 2011), Eastern Canada-West Greenland bowhead whale (COSEWIC 2009), fin whale (DFO 2012), and Baffin Bay polar bear (COSEWIC 2008b).

Seasonal migrations of the Western North Atlantic population of humpback whale occur between summer feeding grounds in Canadian waters passing through waters of the US down to breeding and calving grounds surrounding various island nations of the Caribbean (e.g., Western North Atlantic humpback population) (Baird 2003).

Individual marine mammal populations (e.g., pinnipeds, beluga, bowhead whale, polar bear) are in some cases subject to hunting in both Canada and Greenland. The Baffin Bay polar bear population has been the subject of co-management discussions regarding abundance and hunting between Nunavut and Greenland (Dowsley and Wenzel 2008).

Habitat disturbance is possible from a variety of industrial activities, including oil and gas, fishing, tourism and shipping operations. These may introduce direct and indirect impacts that can cause population distribution and abundance to shift to other transboundary habitats. Inconsistent commercial fishing management across a marine mammal population’s range can change prey abundance, shifting marine mammals to areas of greater prey abundance. Aquaculture can locally deplete prey’s food supply while increasing metabolic waste in the ecosystem, shifting food webs to different taxonomic groups. Underwater noise generated by various activities (e.g., seismic survey or vessel movements) may result in changes to population distribution through avoidance of disturbed habitats.

It is possible that changes in behaviour or changes in mortality risk that may affect the viability of species present in the Area of Focus could cause transboundary effects. However, most residual effects on marine mammals from activities under Scenarios A, B, and C are of low to moderate magnitude and are not expected to threaten the long-term viability of these populations. As such, transboundary effects are currently considered to be negligible.

7.2.4 Accidents and Malfunctions

Accidents and malfunctions which could introduce spills into the environment are considered to be the biggest risk to VECs associated with oil and gas development; these can include spills during routine operations, spills during equipment failure, or vessel malfunctions or collisions. While medium or large oil spills or blowouts are considered to be unlikely to occur given the types of safeguards used in modern oil and gas exploration and development (Birchard 2017), effects of oil spills are adverse. Potential effects of oil spills include changes in habitat, behaviour, health, and/or mortality risk of VECs. The extent and magnitude of these effects can range from moderate to high depending on the type and amount of hydrocarbons released, the sensitivity of the receptor to crude oil exposure, seasonal and environmental conditions, and oceanographic conditions (e.g., currents, water temperature, extent and type of ice cover). The proximity of the spill to shorelines, and the vulnerability of shorelines to spills is also important (e.g., likelihood that shoreline would be exposed to oil, the shoreline types, the biological communities that they support, and the use of these areas by traditional harvesters, communities and others users).

Inuit from Arctic Bay expressed concern during the SEA community engagement sessions (NIRB 2017) regarding spills of oil and gas near sea ice that could affect animals and their habitat, as well as harvesting areas. Participants from Pond Inlet indicated that Lancaster Sound is home to many animal species and expressed concern regarding oil and gas development in that region (NIRB 2017).

If no oil and gas development were to occur, the largest potential marine pollution incident would likely be a bunker fuel or diesel spill following a vessel collision. Diesel spills would disperse and may evaporate rapidly depending on environmental conditions, resulting in acute effects to plankton and fish (potential for mortality most likely over the following hours to days but may persist longer if spills occur when sea ice is present) that are localized around the spill source. Spills of heavier bunker fuels may be more persistent in marine waters, especially in the Arctic where cold temperatures delay weathering, and especially if the spill occurs when sea ice is present. Depending on the time of year, all VECs could be affected as oil may remain at the surface, form sub-surface tar balls than can be transported by currents over large distances, or settle to the benthos. Furred marine mammals such as seals and polar bear would be susceptible to fouling of fur[118], ingestion of oil, and associated effects on health. Waterbirds would be vulnerable to any spill of hydrocarbons, especially if the spill trajectory was to overlap key habitats or concentration areas during the period of use by these species.

7.2.4.1 Coast and Shorelines

Accidental oil spills from Scenarios A, B and C have the potential to impact the coast and shorelines. Following a spill, the likelihood or degree of effects on coasts and shorelines will depend on a number of incident-specific factors including location, time of year, type of oil, volume spilled, trajectory of the spill

[118] Fouling refers to the contamination of fur or feathers with oil

(whether heading to open water or the coast), the presence of ice, and the weathering processes that compartmentalize the spill (e.g., between in or under ice, in-water, on surface, in sediments, and evaporated fractions). Effects of spills on coastal resources following and oil spill, such as an offshore well blowout, are described and characterized for intertidal and shallow subtidal habitats and species in Sections 7.2.4.3 (benthic flora and fauna), 7.2.4.4 (fish and fish habitat), 7.2.4.5 (waterbirds) and 7.2.4.6 (marine mammals). Discussion of effects on these species and their habitats would also reflect potential effects on Special and Sensitive Areas and Areas of concern where those species occur. Effects of oil spills on sea ice and icebergs are described in Section 7.1.4.3.

7.2.4.2 Plankton

In the event of an accidental oil spill from Scenarios A, B, and C; there may be effects on plankton in the Area of Focus. Plankton rely on currents to move, and so have no ability to avoid an oil spill. Plankton also typically occur in the upper portion of the water column. Oil would float on the top of the water and mix into the shallow water column via wind and wave action. This would expose plankton to contamination, and likely result in their loss or impairment throughout the extent of the spill.

Impacts would be particularly important around regions of high plankton productivity such as ice edges and other biological hotspots. Given the importance of lipid rich zooplankton in Arctic food webs, loss of these plankton resources, even for a single season, would affect higher trophic level organisms. As petroleum levels dissipate, plankton is expected to rapidly recolonize from other areas. The rapid generation time of plankton is expected to repopulate the affected region, with little long term (i.e., multi-year) impact to plankton (Committee on Oil in the Sea: Inputs Fates and Effects et al. 2003; Minerals Management Service 2003; National Research Council 1985).

Overall, effects from oil spills on plankton would be moderate to high, local to regional, restricted to the single event, and be medium to long-term in duration depending on the type of oil and time of year. Climate change is not likely to modify this characterization, or only in as much that the changes in open water season and extent of sea ice would reduce the effect on ice-associated species and perhaps decrease the duration of the effect due to a lower likelihood for the oil to become entrapped in the ice.

Uncertainty about the impact of accidental spills on plankton is relatively low. Studies have generally found that plankton levels re-establish to baseline conditions when toxicity decrease, although particular species of interest may need further study for susceptibility to petroleum contamination.

7.2.4.3 Benthic Flora and Fauna

Benthic flora and fauna would be vulnerable to a potential oil spill in Scenario A, B, or C. Initial concerns would be along shorelines, where petroleum would reach the intertidal and nearshore benthos. Once there, constituents can contaminate invertebrates (e.g., crab, mussels) and associated intertidal zones. Contaminants can persist, buried in intertidal or shallow subtidal sediments for decades (Ballachey et al. 2007; Short et al. 2004; Short et al. 2006) and may be resuspended into the water column following disturbance or erosion.

As time progresses, oil will mix into the water column from wind and wave action and some may settle to the bottom. Even low levels of contaminates can affect filter feeding invertebrates. Effects can be lethal, chronic, and/or passed up the food chain to higher trophic levels. These higher tropic levels can include fisheries for human consumption (e.g., crab and bivalves [Starr et al. 1981; Teal and Howarth 1984]). Seasonal migrations for species can change their vulnerability to spills, such as crab migrating to shallow waters for breeding (Suchanek 1993).

Overall, the benthic flora and fauna would be affected by an oil spill. Without appropriate spill response and cleanup, oil could reach the shore and oil residues could persist in sediments for decades, providing a continual background release. Effects on offshore benthic flora and fauna may be local to regional depending on the extent of horizontal transport and vertical entrainment of spilled oil. Climate change would not modify this effects characterization.

Uncertainty about the impact of spills on the benthic environment is relatively low. Studies have well documented the impact of petroleum spills on arctic, sub-arctic and benthic environments.

7.2.4.4 Fish and Fish Habitat

Exposure to spilled oil may result in direct sublethal or lethal effects to fish through uptake by gills (e.g., of dissolved oil compounds), physical contact, or by ingestion of the oil or oiled prey (Langangen et al. 2017; Moles and Norcross 1998; Sloan 1999). Acute effects of exposure to high oil contamination may include death or debilitation due to nervous system disruption, osmoregulatory or metabolic dysfunction, or tissue damage (e.g., to liver, gills, brain) (Sloan 1999). Oil spills also may cause indirect changes in the abundance of a fish population by affecting the mortality rate of, and therefore abundance of, prey and predators species (Langangen et al. 2017), or by stressing fish to an extent they are less able to escape predation, survive disease, feed or adapt to changing environmental conditions (Sloan 1999).

The effects of oil on fish eggs and larvae became the focus of fish-related research following the Exxon Valdez oil spill in Prince William Sound, Alaska, which occurred in 1989 (Incardona et al. 2015; Olsen et al. 2013). Fish eggs and larvae are believed to be more susceptible to mortality following exposure to high concentrations of oil than other life stages of fish due to their small size, poorly developed membranes and detoxification systems, and typical position in the water column (i.e., near the surface and nearshore environments) (Langangen et al. 2017). Pelagic fish that spend a portion of their lifecycle at the sea surface or near the intertidal zone are considered more vulnerable to adverse effects from oiling than those species that do not (Sloan 1999), although the effects on benthic and meso-pelagic species are poorly characterized. Hydrocarbon concentrations of 1600 µg/g in nearshore sediments have been found to reduce growth in juvenile flatfish by 34-56%, following a 90-day exposure (Moles and Norcross 1998). Hatching success of late-stage Pacific herring embryos, which are laid onto macroalgae in the shallow subtidal and intertidal zones, was found to be lower at oiled nearshore sites than unoiled nearshore sites following the Exxon Valdez oil spill (Sloan 1999). However; the differences between the sites were confounded by the natural processes of desiccation, predation or wave action that also affect egg mortality rates.

Impacts to fish from oil spills are well documented. Following the Deepwater Horizon oil spill in the Gulf of Mexico, numerous studies linked a range of effects of oil to fish health. Low levels of exposure were linked to genomic and physiological changes in fish (Whitehead et al. 2012). Oil was also linked to heart defects in large predatory pelagic fish (Incardona et al. 2014). Dispersants released during response to the incident underwent negligible or slow rates of biodegradation and were present up to 300 km from the well (Kujawinski et al. 2011). There also was evidence of resilience in the marine ecosystem following this spill, as fish abundance was higher immediately following the oil spill and closure of commercial fishing, and quickly returned to normal lower levels after commercial fishing was reinstated (Schaefer et al. 2016).

Spatial variation in natural mortality of eggs and larvae is thought to be an important factor that influences the degree an oil spill affects a population (Langangen et al. 2017). Larval distributions of fishes are typically much larger than the spatial extent of an oil spill. With partial overlap between oil-contaminated water and larval distribution, mortality typically may affect a low proportion of the larval population. Many species also have a protracted spawning period relative to the duration that oil might be present in surface waters. While density dependence is typically not strong in pelagic life stages of fishes, it may be in later life stages. At low densities, the natural mortality rate of density dependent life stages is expected to be reduced (Langangen et al. 2017). This effect is believed to alleviate changes in population following oil-spill related mortalities. The opposite effect (depensation, i.e., a reduction in the productivity and recruitment of the population), however, is conceivable if densities are reduced to a very low level through mortality.

During the community engagement sessions for the SEA, Inuit from Qikiqtarjuaq expressed generalized concerns relative to the potential for oil and gas development including the protection of turbot fisheries, narwhal whales, and birds (NIRB 2017). During the community engagement sessions for the SEA (NIRB 2017) a participant from Kimmirut noted:

> "We all like oil and gas because it provides us with heat. But looking at the map, in the highlighted study area for the SEA, is where we fish. It is not favourable to some of us that there is natural oil seepage, which is also in this area. We can make a living on selling fish and I know that fish, whales, seals, and any marine mammals could be impacted. I think oil and gas development is the future. We have to prepare the future generation. I'd like to discuss action. We have no proper equipment or emergency measures in place. We need to ensure we have people ready if there were to be an accident. This inlet, before it became a community, had a lot of seals. After the community was made, all the seals went away. I know that the seals and the turbot will be impacted. We need to make sure there are mitigation measures in place."

The effects of marine pollution incidents on fish will depend on a large number of incident-specific factors. These factors include the location of the spill relative to fish distribution and abundance, the spill volume, physical and toxicological properties of the spilled product, conditions of the receiving environment (e.g., currents, waves, temperature), weathering and dispersal of the product, and the effectiveness of efforts to contain and recover the spill prior to it reaching important fish habitats.

A large marine pollution incident (e.g., an offshore well blowout) would result in fish mortalities and reduced fish health affecting substantial proportions of regional fish populations, and changes in the local abundance of prey and predator species. Effects to fish from an unmitigated or prolonged spill would be experienced across large areas (potentially with the product travelling hundreds of kilometres). Generally, changes to fish population abundance would be recoverable in the long term (typically within several years but possibly more than a decade), following the natural recovery of fish habitats and prey populations and boosts in recruitment associated with temporary declines in natural mortality rates of density dependent life stages. Marine pollution incidents are not expected to substantially affect the long-term sustainability of regional fish populations, unless those populations are otherwise compromised prior to the incident, or large portions of their range are affected by the incident.

While future changes in the seasonal extent and distribution of sea ice associated with climate change may reduce the productivity of ice-associated biota and prey species for fish in the Area of Focus, corresponding changes in fish distribution or abundance are unlikely to substantially alter the effects of a marine pollution incident on fish.

There is little uncertainty about the impact of spills on fish and fish habitat. Studies have well documented the impact of petroleum spills on fish, although not all effects on arctic and sub-arctic species are known, and species composition, distribution and abundance may be different in the future Arctic from what it is now.

7.2.4.5 Waterbirds

Among marine wildlife, waterbirds are considered particularly sensitive to direct and indirect exposure to oil (Leighton 1993). Potential oil spill effects to waterbirds is dependent upon the volume spilled, spill response mobilization time, effectiveness of containment measures, ecological conditions (e.g., location, time of year), and environmental and oceanographic conditions (e.g., exposure to sunlight, wave action, and currents) (Piatt et al. 1990).

Birds that come into direct contact with oil will readily adsorb particles onto their feathers. Adsorbed oil reduces the waterproofing, insulating, and buoyancy properties that feathers provide; loss of these functions can result in death due to starvation, hypothermia, asphyxiation, or drowning (Leighton 1993; Wiese 2002). Birds can also ingest oil by preening feathers, or through ingestion of contaminated prey. In the days and weeks immediately following a spill, waterbirds that rest on and forage from the ocean surface (e.g., coastal waterfowl, alcids) have potential to have some of the highest direct exposure and vulnerability indices to surface oil since they interact repeatedly with the ocean surface (Piatt et al. 1990; Wiese and Ryan 2003). Gulls, terns, and jaegers are considered less vulnerable to oil spills based on the relative amount of time they are airborne. Shorebirds are more likely to be directly and indirectly affected by oil if a spill event occurs during migratory or breeding periods and oil encounters shoreline habitats (Camphuysen 1998; Szaro 1977; Wiese and Ryan 2003).

Secondary effects of acute or chronic oil spills to waterbirds can also include loss or damage to habitats, reduction in forage opportunities from oil-based mortality among waterbird prey, reduced breeding success due to loss of breeding adults, reduced survivorship of eggs and young from oil transfer at the nest (Szaro 1977), and reduction in overall adult survival rates (Wiese et al. 2004). Reproductive losses would be greater among species with lower productivity (e.g., small clutch sizes, limited availability of nesting habitat), such as thick-billed murre. Localized spills have potential for large, long-term consequences if they occur near active waterbird breeding colonies and result in mortality rates among breeding individuals. Recolonization of an affected breeding colony can take several years and is dependent upon proximity to adjacent colonies, and regional viability of the species and their prey.

Indirectly, oil that is inhaled, absorbed, or ingested can also exert debilitating or sublethal toxicity on internal tissues and organs (Eisler 1987; Leighton 1993). Indirect or long-term exposure to residual oil can result in a wide range of effects on waterbirds, including: immune suppression, oxidative stress in the liver and kidneys, depressed reproductive performance, embryotoxicity, susceptibility to disease, and death (Eisler 1987; Leighton 1993). The extent to which sublethal effects are expressed among waterbirds, for example, is influenced by their annual or seasonal dependency on coastal habitats for foraging, the duration and seasonality of exposure, as well as the composition of their diet (Neff et al. 2006; Trust et al. 2000). Long-term, effects from indirect exposure can have wide-ranging demographic consequences on waterbird populations (Leighton 1993; Szaro 1977; Wiese et al. 2004).

Effects of oil spills on birds could be regional or on a transboundary scale and long-term in duration. In an extreme event, the viability of local or regional waterbird populations could be affected. The extent of these effects would depend on the volume of oil spilled, spill response mobilization time, effectiveness of containment measures, and ecological, environmental, and oceanographic conditions, as well as the extent of temporal and spatial overlap between the spill and use of key habitats by birds. Climate change is not expected to change the assessment of oil spills on waterbirds.

There is little uncertainty in the assessment of accidents and malfunctions on waterbirds based on the quality of available literature to understand effect mechanisms and well-documented direct and indirect effects of exposure of waterbirds to oil.

7.2.4.6 Marine Mammals

Marine mammals may be affected by accidental oil spills and vessel strikes due to oil and gas activity. Oil spills may result in changes in behaviour and change in mortality risk, while vessel strikes may result in change in mortality risk. Hovelsrud et al. (2008) note that increased shipping and oil and gas activities in the Arctic are likely to increase pollution and ship strikes, resulting in the potential for human-marine mammal interactions.

If an oil spill were to occur, fur-bearing marine mammals (e.g., newborn harp seals, polar bear) are generally considered to be at greater risk of exposure to oil than smoothed-skinned marine mammals. Oil can coat the fur, disrupting its insulation capacity, leading to hypothermia (Boyd et al. 2001; St. Aubin 1990). Weaned and adult seals (except fur seals) are less vulnerable to thermal effects from oiling due to the poor insulative capacity of their pelts, relying on blubber instead (St. Aubin 1990). External oiling of fur or skin may also increase the risk of ingestion and inhalation of oil, both of which can lead to potential lethal and sublethal effects (e.g., tissue damage to stomach, intestines, kidneys, eyes, lungs; reproductive problems; and various changes in behaviour) (Boyd et al. 2001; Carpenter et al. 2008; Øritsland et al.

1981; Venn-Watson et al. 2015). The tendency of pinnipeds (including walrus, bearded seal, ringed seal, and harp seal) to aggregate in large numbers along coastlines and ice-edge environments further makes them vulnerable to oil spills that are not rapidly contained near source (Garlich-Miller et al. 2011). Many pinnipeds depend on scent to establish a mother-pup bond and some species (e.g., sea lion) have been observed not recognizing and rejecting their oiled pups (St. Aubin 1990). Seals that become oiled tend to appear disoriented and are often reluctant to reenter the water (St. Aubin 1990). Polar bears also frequent the ice-edge environments and therefore are vulnerable to spilled oil. Polar bears that ingest oil during grooming may be subjected to thermoregulatory and metabolic stresses from toxicity (Mattson 1990). Ingestion of oil by polar bears may lead to changes in behaviour (behavioural abnormalities), tissue damage, anorexia, and death by renal failure (Øritsland et al. 1981). Furthermore, polar bears may be indirectly affected by changes in the abundance of the seals they prey on associated with oil-related mortality (Mattson 1990).

Cetaceans (i.e., whales, dolphins and porpoises) are believed to typically avoid exposure to oil spills by moving from the area; however, there are reports of fatalities from either consumption of contaminated prey, or inhalation of volatile gases (e.g., killer whales) (Fortuna et al. 2002). Following an oil spill, baleen whales (i.e., bowhead, humpback and fin whales) may be exposed to chronic effects of contamination and toxicity associated with effects on their invertebrate and fish prey. Baleen whales that are unable to move away from surface oil following a spill may be subject to acute (direct exposure) effects by fouling[119] of baleen (hair-like projections used to filter prey from the water), eye irritation, and vapour inhalation.

Icebreakers open up artificial channels in the ice that marine mammals occasionally confuse with naturally occurring ice openings and polynyas (Arctic Council 2009). Aggregation of marine mammals in such artificial openings may put them at greater risk of exposure as it is hard to clean up oil spills in ice (Wilkinson et al. 2017), or entrapment if the water freezes.

The probability of a vessel striking a marine mammal depends on the frequency, speed, and route of the marine vessels, and the distribution of marine mammals in the area. The chance of lethal injury to a whale struck by a vessel is approximately 80% at vessel speeds over 15 knots (27.78 km/hr) and approximately 20% at 8.6 kt (15.92 km/hr [Vanderlaan and Taggart 2007]). Data analyzed in Alaska waters documented no ship strikes of bearded or ringed seals over a five-year period (Helker et al. 2016) Examination of historical through to modern large whale strike records has shown that fin whales are hit most frequently (Jensen and Silber 2003; Laist et al. 2001). Among larger whales in Alaskan waters, humpback whales are the most frequent victims of ship strikes, accounting for 86% of all reported collisions, and fin whales accounted for 2.8% of reported collisions (Neilson et al. 2012). One percent of bowhead whales harvested in Alaska had scars from vessel collisions (George et al. 1994, Full publication date: Sep., 1994). Vessel strikes between icebreakers and Caspian seal pups has been documented (Wilson et al. 2017), but a literature search found no records of strikes between icebreakers and the seal species present within the Area of Focus.

Overall, effects of oil spills on marine mammals could be regional to transboundary in extent and long term in duration. Given that oil spills are considered an accident or malfunction they are predicted to be

[119] *Fouling* refers to the accumulation of oil on a substance (e.g. animal fur, feathers, baleen)

irregular in occurrence. There is potential for an oil spill to be a highly adverse and may affect the viability of species in the Area of Focus. Vessel strikes are anticipated to be localized, permanent, and irregular in occurrence given their accidental nature. Although vessel strikes are adverse, they are not likely to affect the viability of species within the Area of Focus. Climate change is not anticipated to change the assessment of oil spills on marine mammals. Changes in the timing of ice formation and extents may increase the potential for vessel strikes with increased shipping and vessel activity during an extended open water season. Although the potential for vessel strikes may increase the assessment remains the same.

Uncertainty in the assessment of accidents and malfunction on marine mammals is low. The effects of oils spills and vessel strikes are well documented for many species and, as a result, the impacts on species found within the Area of Focus are known.

7.2.5 Mitigation Measures and Planning Considerations

General mitigation measures and standard operational procedures are well established for the oil and gas industry, and have been shown to be effective in mitigating potential effects on biological VECs. These include:

- Habitat protection setbacks and timing windows to protect sensitive breeding, rearing, or nesting habitat
- Apply mitigation measures during seismic surveys to be consistent with the *Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment* (SOCP)
- Project associated vessels should use existing and common travel routes where possible and practical
- Vessels should maintain a steady course and safe vessel speed (e.g., less than 10 knots) whenever possible
- Implement a Marine Mammal Management Plan that includes marine mammal monitoring for vessel-related activities
- Establish safe vessel operations protocols to avoid marine mammals and sensitive marine mammal habitats

Details are provided in Appendix B.

7.3 Human Environment

Potential impacts associated with routine activities of offshore oil and gas development and exploration, as described in the hypothetical scenarios, are identified in Table 2.1.

The impacts of routine activities for the oil and gas scenarios that could result in effects on the human environment are:

- **Ice Disturbance** associated with marine traffic and specifically icebreaking

- **Employment and Expenditures** associated with use of local or regional services and infrastructure to support oil and gas activities
- **Exclusion Zones** required to secure a safety radius around seismic vessels, drilling rigs, and production platforms
- **Direct interference** of seismic or drilling operations with commercial fishing gear and equipment, causing damage and lost-time and profit from delays
- **Direct interference** seismic or drilling operations with land and marine use (excluding commercial fishing) and changes pertaining to harvesting, cultural, and spiritual practices, as well as recreational activities
- **Indirect interference** with land and marine use mainly related to potential effects on the biological environment (see Section 7.2), that can affect commercial fishing
- **Indirect interference** with land and marine use resulting in changes to harvesting, cultural, and spiritual practices, as well as recreational activities

Potential effects of accidents and malfunctions on the human environment are discussed in Section 7.3.4.

For the discussion of effects on the Human Environment, the VSECs described in Section 5 (Environmental Setting—Human Environment) have been grouped together to provide a more concise description of potential effects. The following VSEC groupings are used to discuss effects:

- Economy, Employment and Business (includes Economic Development and Opportunities, Employment, Contracting and Business Development)
- Community, Infrastructure and Services (includes Education and Training, Community Infrastructure and Services)
- Community Health and Wellbeing (includes Health and Wellbeing)
- Commercial Harvesting (includes Commercial Harvest)
- Land and Marine Use (includes Traditional Use and Practices, Traditional Harvest, Traditional Foods, Non-Traditional Use, and Marine Transportation)
- Heritage Resources (includes Heritage Resources)

Potential impacts on Human Environment VSECs that could occur as a result of activities associated with oil and gas scenarios are summarized in Table 7.9.

Table 7.9 Summary of Potential Impacts on Human Environment

Valued Socio-Economic Component	Potential Environmental Impacts				
	Ice Disturbance	Employment and Expenditures	Exclusion Zones	Direct Interference	Indirect Interference
Economy, Employment and Business		✓			
Community, Infrastructure and Services		✓			
Perceived Community Health and Wellbeing		✓			
Commercial Harvesting			✓	✓	✓
Land and Marine Use	✓		✓	✓	✓
Heritage Resources				✓	

NOTES:
"✓" = Indicates potential effect from oil and gas activity

These impacts from routine activities could result in potential effects on Human Environment VSECs. Potential effects from routine activities are discussed in Section 7.3.1.

Effects are discussed in the context of the routine activities associated with each of the hypothetical scenarios (Section 2.3.3.1). Potential effects of accidents and malfunctions are also discussed.

If no offshore oil and gas activities were to occur (Scenario D), adverse effects to the human environment associated with offshore oil and gas activity would not occur, nor would the benefits of oil and gas development occur (e.g., employment, capacity building, business expansion and development opportunities, certain infrastructure improvements). Adverse effects on the human environment and benefits would still occur from other anthropogenic activities (e.g., increases in shipping and tourism, port and infrastructure development by government) or impacts associated with climate change (see Section 2.3.4).

The potential for cumulative effects and transboundary effects are discussed in Sections 7.3.2 and 7.3.3. Potential effects of accidents and malfunctions are discussed in Section 7.3.4. Mitigation measures and planning considerations that could be used to reduce or eliminate potential effects are discussed in Section 7.3.5.

Only VSECs that have been indicated in Table 7.9 as having an interaction with an impact associated with the oil and gas activities are discussed below. If a VSEC is not expected to interact with oil and gas activities, or if potential effects from interaction can be mitigated under existing regulations or using standard practices or planning considerations, then it is assumed that residual effects on the VSEC would not occur or be minimal, and the specific effect is not considered further for the VSEC.

7.3.1 Potential Effects from Routine Activities

CHANGE IN ECONOMY, EMPLOYMENT, AND BUSINESS

A change in Economy, Employment and Business is a measurable change in the direct and indirect employment, level of business and economic activity, and government revenues, that is occurring in the specific region or community. This change can result from direct pathways (e.g., direct employment on the activities, business contracts, tax and royalty payments from production), or through indirect pathways (e.g., indirect effects on the economy through increased disposable income in communities and increased local spending).

CHANGE IN CAPACITY OF INFRASTRUCTURE AND SERVICES

A change in Capacity of Infrastructure and Services involves a detectable change in the level of capacity of local infrastructure (e.g., housing and accommodations, grocery stores, hospitals, roads, and airports) and services (e.g., water and wastewater, fire and emergency services, healthcare, education, and waste management) that would result from oil and gas activity in the region. Pathways for this effect include direct pathways (e.g., housing workers in hotels and other temporary accommodations) or indirect (e.g., increased number of workers in the community putting pressure on local healthcare facilities, local grocery stores or water supply services).

CHANGE IN ACCESS TO RESOURCES

A change in Access to Resources is a direct change in the ability to access both commercial fishing resources, as well as land or water for both traditional and non-traditional use. This change in access can be caused by direct pathways such as in establishment of safety zones around offshore infrastructure and activities that may restrict access to commercial fishing grounds. The latter may occur through direct interference with fishing gear resulting in lost time and access, loss of access if oil and gas activities overlap with key commercial fishing windows, and general restrictions on ocean uses when oil and gas activities are taking place. It can also include the use of local harbours related to oil and gas activity, which can result in increased marine traffic and possible ice breaking that may reduce the ability for residents to travel for traditional or non-traditional purposes. The development of shore-based facilities in important harvesting areas could also restrict access to harvesting locations and resources.

CHANGE IN PERCEIVED COMMUNITY HEALTH AND WELL-BEING

A change in Perceived Community Health and Well-being is a change in the perceived health and well-being of local communities and their residents due to oil and gas activity happening in the region. Perceived health and well-being is linked to various aspects of everyday life, and can be influenced by many factors including access to healthcare, food security, financial security and comfort, economic activity, and access to land use for both traditional and non-traditional purposes. Therefore, changes in other aspects of the community, resulting from oil and gas activity, can have an indirect influence on community health and well-being.

CHANGE IN QUALITY OF HARVEST

A change in Quality of Harvest is a change related to the quality of catch that is landed by commercial fishers offshore, or fish or marine mammals harvested by residents. This change is caused by biological effects that oil and gas activities may have on fish and marine mammals, and their habitat. This includes concerns such as fish tainting, which can reduce quality of fish for human use, and through behavioural effects that oil and gas activities may have on marine species. These behavioural effects may cause marine species to leave areas for certain periods, or to change their distribution. This can have indirect effects on harvesters if fish or marine mammals leave areas or change their abundance / distribution during harvesting seasons. This change in quality of harvest can reduce the economic returns for commercial fishers and reduce the harvest for traditional harvesters.

CHANGE IN HERITAGE RESOURCES

A change in Heritage Resources is a change related to loss or reduction in heritage resources of the area. This change is caused by the alteration or destruction of heritage resources during the development of shore-based or near-shore infrastructure to support the offshore activities. Removal or destruction of heritage resources may have a direct effect on the historical record of Nunavut.

Potential effects on Human Environment VSECs are summarized in Table 7.9 and discussed below.

Only potential effects that have been indicated in Table 7.9 as having an interaction with a VSEC that could result in potential residual effects are discussed below. If a VSEC is not expected to interact with oil and gas activities, or if potential effects from an interaction can be mitigated under existing regulations or using standard practices or planning considerations, then it is assumed that effects on the VSEC would not occur and it is not considered further in the discussion of potential effects.

ICE DISTURBANCE

LAND AND MARINE USE

The literature review of publicly-available sources highlighted concerns with the interaction between increased marine traffic and ice formation and break-up, as well as the effects of increased marine traffic on wildlife (Nunavut Environment 2010; Nunavut Environment 2017; Pitsiulak 2000, as cited in NWMB 2000). For example, Inuit from Pond Inlet expressed concern about increasing marine and ice breaker traffic in Baffin Bay, and raised questions on whether the increased traffic may be affecting polar bear habitat and sea ice conditions, including formation and break up (Nunavut Environment 2017). The disturbances created as a result of this activity would be local and unlikely to result in appreciable change to the physical environment over the Area of Focus (see Section 7.1.1.5). The breaking of ice to enable ships to reach harbours on Baffin Island has the potential to affect over ice travel for traditional harvesting and other activities. Section 5.8.1 (Traditional Use and Practices), Section 5.8.2 (Traditional Sites and Travelways) and Section 5.9 (Traditional Harvest) highlight intensive usage along the coasts and adjacent marine areas within the Area of Focus to, approximately, the edge of the outer land-fast ice zone. Changes to traditional use and practices, changes in access to harvesting sites, changes in harvesting site locations, and changes in quality of harvest can also result in changes to perceived community health and well-being.

Under Scenarios A and B, seismic and exploratory drilling activities are anticipated to be conducted primarily in the ice-free period and are expected to have limited interaction with shore-based facilities, it is unlikely that ice breaking would occur during these development phases.

There is a potential for ice breaking to occur during production (Scenario C) which could result in changes to traditional use and practices. Change in access to traditional resources and sites, including increased travel times, increased fuel expenditures and wear and tear on equipment may also occur, as well as changes in access to preferred use areas, resulting in change of the quality of harvest. Discussion between operators and harvesters, hunting and trapping organizations, and the Qikiqtani Inuit Association regarding potential effects and recommended mitigations measures would identify where interactions could occur, and aid in project planning, to reduce the effect of ice breaking on traditional use and practices, including traditional harvesting and travel over ice.

In conclusion, it is predicted that the effects from oil and gas activities on land and marine use would be low in magnitude, short-term in duration, localized to the route of the vessel as it moves, and occurring as multiple regular events as vessels transit to shore. The scenarios presented in Section 2.3.3.1 discuss the reduced interaction with a shore base for both seismic and exploration activities, and the use of a wareship for production activities; this would also reduce the potential for ice breakers to enter coastal waters.

Climate change has the potential to influence effects on land and marine use due to the reduction in spatial distribution, thickness, quality and predictability of sea ice, which can affect the ability of local residents to travel over sea ice and access fishing or hunting grounds, as well as conduct other types of traditional use and practices. Changes in traditional uses and practices, and traditional harvesting activities within the Area of Focus are discussed in Sections 5.8.3 and 5.9.11, respectively. The potential reduced extent of sea ice could also reduce the need for ice-breaking activities, thereby reducing the need for ice-breaking vessel to move inshore.

EMPLOYMENT AND EXPENDITURES

ECONOMY, EMPLOYMENT, AND BUSINESS

An increase in employment and expenditures in local communities related to oil and gas activities will generally have positive economic effects on local communities and regions. The potential for an increase in direct and indirect local employment, and the increase in expenditures on goods and services from local businesses, represents an increase of economic activity in local communities. This includes individuals, families, and households having higher levels of disposable income, which they may spend locally and provide an economic stimulus to local businesses. The income from these businesses can then be further spent and re-invested into the local region, creating further indirect benefits to the area.

For local businesses, servicing oil and gas activities involves working for large new client companies that, especially over the production life of a field, can provide a steady source of business over a long period. Production also provides opportunities for small business to be able to grow their capabilities, and for local workers to develop skills and knowledge needed to service other oil and gas activities that may take place in the future, or apply transferable skills into other industries (e.g., mining). Local and regional governments can also experience positive effects from oil and gas production, given royalty and tax payments from the operator. Effects on Economy, Employment, and Business are generally positive. However, they may be constrained if there are limited effective management and mitigation measures. For example, the standard procurement policies and practices of large construction companies, operators and Tier 1 industry suppliers may make it difficult for small-to-medium sized businesses to participate competitively in the bidding process.

This is also the case for employment; if residents believe they are not receiving employment opportunities, or that the opportunities they are receiving are minor or of limited duration, which can lead to changes in perceived community health and well-being. During the community engagement sessions for the SEA, Inuit from Grise Fiord stated: “there are no real benefits to Inuit; there are few jobs and they don't last. Inuit don't get into management positions; they only get the labour jobs and don't have decision-making responsibilities” (Nunavut Impact Review Board 2017). Monitoring jobs were requested by Inuit of Pond Inlet and Kimmirut; concerns were also raised by Inuit of Pond Inlet regarding equal pay for Inuit staff as well as opportunities for job training and mentorship (Nunavut Impact Review Board 2017).

There can be negative effects on local businesses if they do not have the capacity to meet the requirements of both oil and gas and existing clients. If they lose existing clients in favour of oil and gas-related work, then they can become reliant on the industry and victims of its cyclical nature, especially during exploration and construction. This may threaten the survival of the business once such work is finished. Higher wages that are associated with the oil and gas industry can also affect other sectors of the local economy via labour shortages and wage and salary inflation.

The degree of interaction of oil and gas activity related to Economy, Employment, and Business will be dependent on the ability and capacity of local workers and businesses to take advantage of the opportunities, and on the type of activity (see Section 2.3.3.1 for information on potential employment opportunities associated with each scenario). Seismic and exploration drilling activities (Scenarios A and B) are generally of relatively short duration, and, while they may provide potential for employment and business opportunities, they too are short and often uncertain. In contrast, oil and gas field production and drilling (Scenario C) could have up to a 40-year production life span, and long lead time before production starts. This longer lead time provides more time for training and capacity building, to help local residents and businesses compete for oil and gas-related opportunities.

This lead time is advantageous to local institutions, workers, and businesses that want to invest in training, education, equipment and/or infrastructure to work on these projects, and thereby increase the opportunity for long-term local involvement. This can help provide long-term careers for local individuals in different fields (e.g., construction, maintenance, catering, transportation, and marine services). The type of production and the way that oil and/or gas would be shipped to market would also have an influence on the level of employment and expenditure associated with production. These factors all play a role in determining the extent, magnitude and types of effects on Economy, Employment, and Business. The employment of local community members leading to decreases in the number of available hunters to harvest country foods shared by the community is discussed below under Perceived Community Health and Well-Being.

Scenario C (see Section 2.3.3.1) assumes that an FPSO or FLNG will be used, along with a wareship. This limits the amount of landfall and onshore interaction, which may result in fewer economic opportunities than if oil or gas and vessels were moving between the shore and the drill rig, or if oil or gas was being brought back to Nunavut before export.

Employment and expenditures related to oil and gas activities are not expected to be affected by climate change in a way that would result in a measurable change on the local economy, employment, and business. However, climate change is predicted to affect the ability of traditional harvesters to participate in the local economy (see Sections 5.8.3 and 5.9.11). Changes to permafrost and winds may also result in changes in infrastructure conditions and needs (see Sections 5.7.1.2 and 5.7.2), which may have an effect on the local economy. Depending on the degree of climate change in the future, a measurable effect on Economy, Employment, and Business is also anticipated to continue.

In conclusion, the effects on the local economy, businesses, and employment from oil and gas activities would be positive in nature, low in magnitude, short term in duration for seismic and exploration activities, long-term for production activities, within the local communities and regional governments, and occur continuously for the life of the activity. These predictions have been made based on the scenarios discussed in Section 2.3.3.1, and may change based on specific projects and their design.

COMMUNITY INFRASTRUCTURE AND SERVICES

Effects on community infrastructure and services are related to their ability/capacity to support oil and gas activities in the region. This includes, but is not limited to, infrastructure used to service activities, such as ports for servicing supply vessels and drilling rigs, and airports to transport workers between their home communities and offshore locations, using scheduled flights, charters, and helicopters.

It also includes the ability of community infrastructure and services to support the workers drawn to the region by, or affected by, oil and gas activity. An influx of workers can put a strain on the community's capacity to offer services to its residents. This can include services such as healthcare, policing, fire and emergency services, education, water and wastewater, and waste management. Infrastructure that can be affected includes permanent and temporary accommodations, grocery stores, recreation centres, hospitals, and roads, airports, and other transportation infrastructure. Higher levels of economic activity can lead to increases in housing prices and rents. This can then lead to further negative effects on the local community, discussed below in Perceived Community Health and Well-Being.

The potential effects on local services and infrastructure will be more pronounced in the case of activities that have more interaction with land, and which last longer. Seismic activities (Scenario A) typically involve little onshore interaction, because the vessels are typically based elsewhere in the world, and remain offshore for the relatively short duration of the program. The most common interaction with shore would be to refuel and pick up supplies, or because of a maintenance or medical emergency. Given these characteristics, seismic work is unlikely to result in measurable change to local infrastructure or services.

Exploration drilling programs (Scenario B) have a longer duration than seismic surveys because typically more than one well is drilled per program. These programs often see operators having the opportunity to drill wells over a multi-year period. There is also more involved in terms of interactions with the shore and support services to the drill rig. There is the potential for increased traffic in marine ports that may be used as a base and associated service areas for offshore supply vessels supporting the drilling rigs, and potential effects could occur if marine infrastructure in Nunavut is not able to accommodate the increased level of marine activity. The potential also exists to provide supplies through a wareship, which is a large vessel berthed at or anchored near shore.

Because there is a larger workforce associated with drilling compared to a seismic program, it is likely that workers will be operating in shifts, and potentially on a fly-in fly-out basis. This will result in increased activity at local airports with scheduled or charter flights bringing workers in and out of Nunavut, and helicopters taking them to and from drilling rigs. If flight schedules or adverse weather conditions mean they cannot make connections, workers would likely have to use temporary accommodations and related services.

Given a decision to develop a field (Scenario C) under the assumption that all production and shipment of oil and gas would occur offshore and have limited contact with the shore, the level of interaction with local infrastructure and services would be expected to be limited. Installation activity (i.e., installation of the platform) might see a short peak of activity, but most of it would be offshore with limited effects onshore.

Production itself provides the most potential for interaction with Community Services and Infrastructure, because production systems and related requirements have a much longer duration (10–40 years) than other phases of activity. With such a long lifespan, there is a higher potential for some non-local workers, along with their families, to move to the region to work on or supporting production facilities, and live in local communities. They may place increased pressure on community infrastructure and services but, as described above, there will be lead-time to respond to this; new investments will be justifiable given the duration of the new demand, and personal, company and corporate taxes and royalties will contribute to paying associated costs. New infrastructure built because of such demand may represent a positive legacy after the end of oil and gas activity, providing the costs of maintaining it can be met.

Decommissioning effects would be like those of installation, involving the use of shore based marine facilities (e.g., existing deep-water port, storage facilities, airport) to service the decommissioning operations, and some increase in airport traffic along with temporary accommodations to house workers who may be in transit.

Overall, the effects on local infrastructure and services from oil and gas activity would be low in magnitude, limited to a local or regional area depending on the communities affected, short-term in duration for seismic and exploratory drilling programs, long-term for production activities, and occurring frequently for the life of the oil and gas activity. Upon the completion of the oil and gas activities, conditions would return to previous levels for local infrastructure and services. These predictions have been made using the assumptions of the oil and gas scenarios provided in Section 2.3.3.1. Effects from a specific project may change, depending on the project design and components that could result in higher interactions with local infrastructure and services.

Climate change may have an effect on marine shipping and servicing infrastructure if warming trends in the north continue. With increased open water and access to areas of Nunavut, there could be increased traffic in and out of available ports. Oil and gas activity has the potential to further increase the number of vessel activity out of these ports, which may put a strain on the quality of marine infrastructure, and the ability to service all vessels effectively (see Section 7.3.2).

Perceived Community Health and Wellbeing

Effects on Perceived Community Health and Well-being are difficult to quantify or measure, and can differ based on community composition, existing services and infrastructure, and the level of interaction between the community and the oil and gas activity. Potential effects are linked to multiple factors including those related to Economy, Employment, and Business, Community Services and Infrastructure and Land and Marine Use. Because oil and gas activity is occurring in the offshore environment, outside the range of local communities, there is no direct pathway between routine oil and gas activities and the physical human health of local communities in Nunavut. The discussion of accidental events is described in Section 7.3.4.

In terms of potential positive effects on Perceived Community Health and Well-being, new economic activity and increased disposable income may allow individuals to purchase or upgrade items such as homes, or equipment like snowmobiles to engage in traditional hunting activities. This may improve their sense of well-being because they are able to engage in such activities. It may also allow those providing for families a higher sense of confidence in knowing they can support them through employment, with less or no reliance on social assistance or income support. They may also benefit from greater access to food, both through traditional harvesting and being able to afford market foods, as well as having greater financial flexibility. Taxes, royalties, and benefits agreements may also allow governments to invest in new or upgraded infrastructure and services (e.g., new healthcare services, recreation complexes, schools and training facilities, and more teachers). Such investments may help improve perceived health and well-being, by providing improved infrastructure and services, and easier access to services such as healthcare and recreation.

Negative effects on Perceived Community Health and Well-being are also possible. For example, increases in air and marine traffic and an influx of non-local workers could disrupt regular community life, which could affect community cohesion and identity. While higher levels of disposable income may allow residents to invest in assets such as houses and equipment, it can also lead to drug and alcohol abuse, which can then lead to more crime and/or family problems. This could have negative implications on perceived health and well-being of a community.

Negative effects on the ability of community residents to engage in traditional hunting activities can also occur if those who have historically taken part in them are away working on oil and gas activities. This can lead to increased consumption of non-traditional foods by family members and Elders no longer able to conduct harvesting activities. Absence of community members may also result in a decrease in opportunities for cultural transmission. Their absence from their community and land based activities for an extended period (e.g., three-week rotations) while working offshore can have negative effects on perceived health and well-being, for those who have a strong connection to the land and a strong sense of belonging. Oil and gas activity can also have adverse effects if it results in higher housing costs, further exacerbating the housing issues that currently exist in Nunavut. This can further lead to physical and mental health issues, negatively affecting health and well-being.

As mentioned above, the degree to which these effects could be felt, in the absence of mitigation measures, will be dependent on the oil and gas activity occurring (i.e., seismic, exploration drilling, construction, production, decommissioning) and its duration. Seismic and exploration programs (Scenarios A and B) have shorter time frames than production activities, and so effects on Perceived Community Health and Well-being may only occur for the duration of the program. Production activities (Scenario C) have a much longer timeframe, and the potential effects on Perceived Community Health and Well-being may be felt longer based on the level of interactions that these activities have with local communities, through economic activity and potential changes in the regular day-to-day activities of local residents.

In conclusion, effects on Perceived Community Health and Well-being from oil and gas activities are generally predicted to be low in magnitude, occurring within the local communities that interact with the activity, and occurring continuously throughout the life of the activity. These predictions have been made with the understanding that the level of effects is dependent on the level of interaction that an oil and gas activity has with a local community or communities, and that perceived health and well-being of a community is based on a number of external factors, that may alter the perception of effects.

Exclusion Zones

Commercial Harvesting

During exploration drilling and production activities, exclusion zones would be established around drilling rigs and production platforms while activity is occurring. These zones are designed to provide safety to commercial fishers, other marine users, and oil and gas personnel, to reduce the potential for an accidental event (i.e., a collision or spill). Within these exclusion zones, vessels or other activities, including commercial fishing, are not permitted. This restriction of access to fishing grounds can result in a decrease in the effectiveness and/or efficiency of fishing activities, because harvesters may need to wait for access or redirect their fishing effort (and possibly, their vessel routes). This can translate into a loss of economic returns for fish harvesters. The potential effects of being restricted from certain fishing areas will likely be during the summer months, when there are lower ice levels and fishing activity is at its highest. Mitigative measures, such as ongoing communication with the fishing industry, and the use of a Fisheries Liaison Officer onboard drilling and production facilities, can reduce the potential effects on commercial fishers from the establishment of a safety zone. These measures are considered industry best practice and have been used on past oil and gas activities in Canada.

The effects of exclusion zones on commercial fishers and other ocean users are predicted to be low in magnitude, short- to long-term in duration as production activities have a long life-span, localized to the area surrounding the drill rig or production platform, and continuing continuously while the drill rig or production platform is active offshore. Recovery would be rapid (weeks or as long as the next fishing season), once the safety zone has been removed, as this area would be open to fishers again.

Land and Marine Use

As most oil and gas infrastructure will be offshore, it is anticipated that the effects of exclusion zones would be limited or non-existent to traditional harvesters and other coastal marine users. Development of onshore infrastructure may result in the establishment of a near shore exclusion zone, if required. The potential effects of restriction from near shore areas could cause effects to travel routes and use of harvesting locations. However, based on the scenarios presented in Section 2.3.3.1, development of onshore infrastructure is unlikely. Therefore, little or no interaction with onshore activities is expected.

Offshore marine users such as freighters, tankers, military vessels, coast guard, and research vessels would have to follow the same protocols as commercial harvesters. This would mean that some vessels may have to change routes, or delay activity to avoid the safety zone. Mitigation measures such as ongoing communication with industry would help reduce the potential for an interaction and resulting effect.

Climate change may affect the Commercial Harvesting and Land and Marine Use VSECs in relation to exclusion zones offshore, in that the overall reduction in sea ice distribution may allow for more open water that commercial harvesters and marine users can operate in. However, for commercial fish harvesters, and land and marine users, the uncertainties regarding warming oceans and species distributions may result in species moving to different areas. This may alter trails and travel ways (both on sea-ice and in open water), harvesting locations, timing of harvest, access to cultural, spiritual and recreational areas and timing of cultural, spiritual and recreational activities.

Effects of exclusion zones on land and marine use are expected to be low to moderate in magnitude, short to long-term in duration, localized to the area surrounding the drill rig or production platform, and continuing continuously while the drill rig or production platform is active offshore. Recovery would be rapid, once the safety zone has been removed, as this area would be open to fishers.

Direct Interference

Commercial Harvesting

Seismic vessels for a survey program, as well as supply vessels moving through the area between a shore base and a drilling or production platform, have the potential to contact and damage fishing equipment and other vessels. Seismic programs could also interfere with a specific fishing area for a period of days to weeks (see Exclusion Zones above). Either effect could result in lost time, and potentially a lost fishing season, for commercial harvesters, depending on the severity of the damage to equipment or the overlap with the fishing area. It is expected that seismic operations would have an established compensation policy to deal with such incidents. The scenarios presented in Section 2.3.3.1 limit the use of transits to and from shore, and most employ the use of a wareship. This also would help reduce the distance supply vessels would need to travel, and reduce the potential for an interaction.

Land and Marine Use

Activities associated with the scenarios are predominantly located offshore with limited shore and nearshore interaction. Vessels moving between a shore base and offshore infrastructure have the potential to increase risks of human injury (e.g., breaking though newly formed ice) or cause damage to coastal harvesters and their equipment and other marine users resulting in lost time and equipment or potential injuries. Damage to coastal ice could also alter travel routes for residents who use the ice to move along the coast. This change in route could result in longer travel times, increased expenses on fuel, and more wear and tear on equipment. Establishment of a communication protocol between operators and community organizations, as has been done in other northern locations, would reduce the potential for direct interference between oil and gas activities and other marine uses.

Climate change could affect the potential for interaction on these VSECs, as lower sea ice distribution may create more open water for vessels to navigate. This can then provide space and reduce the potential for direct interference. However, the increase in vessel traffic to the north may also increase the chance for an interaction between oil and gas activities, and commercial harvesters and other marine users.

Direct effects on land and marine use from oil and gas activities are predicted to be low to moderate in magnitude, short-term to long-term in duration, localized to where the interference occurred, and occurring infrequently.

Heritage Resources

Current and past Inuit land and marine use intensity is greatest within the land-fast ice zone and adjacent onshore areas. As noted in Section 5.11, Heritage Resources are protected under the *Nunavut Act*, with the Nunavut Archaeological and Palaeontological Sites Regulations governing the investigation and protection of archaeological or palaeontological resources. Any onshore development would be subject to the environmental assessment process which would include investigation of heritage resources and, if necessary their preservation.

Direct effects on Heritage Resources from oil and gas activities are predicted to be low in magnitude, short-term to long-term in duration, localized to where the interference occurred, and occurring infrequently. The potential destruction of a heritage resource would be long-term and permanent. However, with oil and gas activity occurring far offshore, and the reduced likelihood of nearshore interaction in the described scenarios, the potential for an interaction is low. Implementation of mitigative measures and best practices described in Section 7.3.5 would further reduce the potential for an interaction with the VSECs.

Indirect Interference

Commercial Harvesting

As mentioned in Section 7.2 oil and gas activities have the potential, in the absence of mitigation measures, to result in environmental effects on fish species. This can indirectly affect the success of commercial harvesters if the species affected are commercially important such as shrimp or turbot. This includes fish reacting to underwater sound and moving away and avoiding certain areas for periods of time. If species begin to avoid certain areas that have historically been productive fishing grounds, it has the potential to result in lower catch rates for harvesters, who then have to take time to take up gear and move to another location to try and find fish. Another issue that may indirectly affect the success of commercial harvesters is fish taint, where fish absorb hydrocarbon particles and store it in their fat (however, as oil discharge during routine operations is not permitted, the potential for taint is negligible). If commercial fish species that are harvested by fishers are present with taint, this can affect the value that a fisher would receive when the product is sent to market, or they may not be able to sell the product at all. Both scenarios can result in economic losses for commercial harvesters if the quality of their catch is compromised. The effects conclusion for fish species are provided in Section 7.2.

LAND AND MARINE USE

Section 7.2 notes that Nunavummiut have expressed concern over contamination of harvested species and changes in their distribution due to oil and gas activities. Actual or perceived contamination of species or a change in their distribution could result in a decrease to harvesting activity or consumption of country foods, as well as effects to other activities such as wildlife focused marine tourism. These potential changes could also affect the economy, food security and perceived well-being. For discussion on the effects of oil and gas activities on these harvested species, see Section 7.2.

Indirect effects on land and marine use from oil and gas activities are predicted to be low to moderate in magnitude, short-term to long-term in duration, localized to where the interference occurred, and occurring infrequently.

7.3.2 Cumulative Effects

Table 7.10 below outlines the past, present, and future activities in the Area of Focus that have the potential to interact with oil and gas activities and affect the Human Environment.

Table 7.10 Potential Cumulative Effects—Human Environment

Other Projects and Physical Activities with Potential for Cumulative Environmental Effects	Potential Cumulative Environmental Effects-Routine Activities					
	Change in Economy, Employment, and Business,	Change in Capacity of Infrastructure and Services	Change in Access to Resources	Change in Quality of Harvest	Change in Heritage Resources	Change in Perceived Community Health and Well-being
Past and Present Physical Activities and Resource Use						
Mining—Baffinland Mary River Mine (marine transportation)	✓	✓	✓			✓
Commercial Shipping	✓		✓	✓		
Commercial Fishing	✓	✓	✓			✓
Tourism (cruise ships)		✓	✓			✓
Research (Military, Academic)		✓	✓			
Traditional Use and Practices, Traditional Harvest, Traditional Foods	✓		✓	✓		✓
Oil and Gas—Greenland			✓			
Oil and Gas—Atlantic Canada						
Future Physical Activities						
Mining (marine transportation)	✓	✓	✓			✓
Deepwater Port (Iqaluit)	✓	✓	✓			✓
Commercial Shipping	✓			✓	✓	
Commercial Fishing	✓		✓	✓		✓
Tourism (cruise ships)	✓	✓	✓	✓		✓
Research (Military, Academic)	✓	✓		✓		
Traditional Use and Practices, Traditional Harvest, Traditional Foods	✓		✓	✓		✓
Oil and Gas—Greenland				✓		
Oil and Gas—Atlantic Canada						
Oil and Gas – Baffin Bay and Davis Strait (Scenario A, B, and C)	✓	✓	✓	✓		✓

NOTES:
✓ = those "other projects and physical activities" whose residual effects are likely to interact cumulatively with residual environmental effects associated with oil and gas activities in the Area of Focus.

A summary of the discussion of potential cumulative effects is provided below, for each environmental effect listed in Table 7.10.

CHANGE IN ECONOMY, EMPLOYMENT, AND BUSINESS

In terms of effects on Economy, Employment, and Business, other major projects such as mining activity and increases in shipping and tourism due to declining sea ice will have some effects on employment, because of the likely requirement of local workers. This will draw down both the trained and entry level resources, which may lead to labour shortages and wage inflation. Other activities that require both skilled and unskilled labour, although smaller in scale, will have similar effects in that they will further reduce the available labour pool.

The construction of the deep-water port in Iqaluit, and improvements to the port in Pond Inlet, will improve marine infrastructure in the Area of Focus, and may attract more use by the oil and gas industry and other sectors, further drawing from the labour force.

Inuit participating in non-traditional employment opportunities may have less time to participate in local economies, and conduct traditional use and practices, including traditional harvest. A decrease in availability of harvesters and time spent harvesting may reduce the amount of traditional food shared with and consumed by the community. It also may adversely affect cultural transmission.

Regional businesses may face challenges related to capacity, if they are serving multiple projects and activities at the same time. There may be a strain on capacity of local businesses to support oil and gas operations if they are already providing support to other projects.

Regional government (i.e. Government of Nunavut) may stand to benefit from cumulative effects of other projects and activities alongside oil and gas projects if these projects pay royalties or taxes. Operating mines, in addition to producing oil and gas fields, stand to provide governments with added sources of income, which can help support community and regional infrastructure and services, along with cruise ship visits to local communities.

CHANGE IN CAPACITY OF INFRASTRUCTURE AND SERVICES

Current projects, alongside future oil and gas activities and other future projects, have the potential to affect community infrastructure and services. Increases in shipping and tourism due to declining sea ice, new mining activities requiring a marine component to ship product to market, together with potential oil and gas activities, could put a strain on the capacity of marine infrastructure to support these different industries. However, it is likely that increases in the use of marine infrastructure in most potentially interested communities will be limited, primarily due to the lack of harbour infrastructure and support services (e.g., accommodations, visitor services, and maintenance capacity). Additionally, such future developments as new mines are likely to be remote from communities and, as is the case with the Mary River Iron Ore Project, establish their own dedicated marine facility. The construction of the deep-water port in Iqaluit, and improvements to the port in Pond Inlet, will improve marine infrastructure in the Area of Focus and may attract more use by the oil and gas industry and other sectors. However, depending on the pace of development, there may still be an effect on marine infrastructure if the demand for service outpaces the capacity to provide service.

CHANGE IN ACCESS TO RESOURCES

Change in access to resources resulting from new oil and gas development can be compounded by multiple projects or activities taking place offshore. If multiple oil and gas activities, such as seismic surveys and exploration drilling projects, are taking place simultaneously offshore, then the presence of vessels, equipment, and associated safety zones may limit the access of commercial and traditional fish harvesters to grounds at certain times of the year. Additional shipping activity and tourism, and research activities in offshore waters, can also further increase cumulative effects on access to resources. Traditional uses and practices can also be affected by changes in access to resources or areas.

Increased marine traffic in the nearshore and land-fast ice zone has the potential to increase the cumulative effect on traditional travel routes and access to harvesting locations. This can influence the ability for residents to take part in traditional harvesting activities, and their ability to acquire country foods as part of their traditional diet.

CHANGE IN QUALITY OF RESOURCES

Change in quality of resources can be affected by multiple projects or activities that may be taking place offshore. Additional marine activity can increase potential negative effects to the quality of resources as a result of emissions from these activities. This potential change in quality of resources can result in effects on both traditional and non-traditional harvests.

CHANGE IN PERCEIVED COMMUNITY HEALTH AND WELL-BEING

Cumulative effects on Perceived Community Health and Well-being can be affected both positively and negatively, with cumulative interactions with other activities. Changes in Economy, Employment and Business; Changes in Capacity of Infrastructure and Services; Change in Access to Resources; and Change in Quality of Harvest can negatively affect traditional use and practices, traditional harvest, and the consumption of traditional foods; however, positive effects could also occur. Perceptions of health and well-being are intangible and would be difficult to mitigate.

7.3.3 Transboundary Effects

Transboundary effects from routine oil and gas activities on human environment VSECs are not anticipated, other than inter-provincial/territorial migration of workers, and transboundary economic effects (e.g., purchase of goods and services outside of Nunavut).

7.3.4 Accidents and Malfunctions

Potential accidents and malfunctions were described in Birchard (2018) and include: fire and explosions; loss of life (falling off the vessel); downed aircraft (helicopter); vessel collisions; major weather and sea ice conditions; vessel strike with marine mammals; and hydrocarbon spills.

Fire and explosions, loss of life, downed aircraft and vessel collisions could adversely affect the capacity of infrastructure and services for periods of days to months. Short-term employment opportunities may also be created.

Hydrocarbon spills have the greatest potential to affect VSECs for the Human Environment and are the focus for the remaining discussion. This could include small accidental spills from ships or platforms, spills during equipment failure or vessel malfunctions, or large events such as a subsea blowout.

Commercial Harvesting

Direct interference with commercial fishing activity could occur if areas are closed to fishing due to a spill of oil or other contaminants in or near popular fishing grounds, or during times of the year when commercial fishing activity is high. With respect to commercial fishing, these closures could translate into direct economic effects because fishers may have to delay or cease fishing activity until the area has been deemed safe to re-enter. They may also have to move to other fishing grounds that may be available, delaying their fishing schedule further, which can also result in unexpected costs (European Union Parliament 2013). The magnitude of these effects would depend on the size of area closed to commercial fishing, time of year, and the length of closure time.

Damage to fishing vessels and equipment could result from fouling[120] from contact with surface oil from a spill, which may then affect the quality of harvest for commercial fishers or cause them to stop fishing due to the equipment being damaged. Fouling could also affect commercial fishers' harvests and have direct economic effects on their operations if a spill ceases or delays fishing operations for a period (IPIECA 1997).

Effects from accidental events on fish species of commercial value could indirectly affect commercial fishers through issues such as tainting, or fish avoiding an area for periods. The assessment of accidents and malfunctions on Fish and Fish Habitat is discussed above in Section 7.2.4.4.

Spills can also affect consumer perceptions on quality, which may influence the volume of catch that harvesters can sell to the market, and the price they get for it (IPIECA 1997; ITOPF 2004, n.d.). Tainting or potential tainting may lead to reduced economic returns from fish harvests if the catch is deemed unfit (IPIECA 1997). The potential for tainting varies depending on the species affected; many free-swimming fish can metabolize hydrocarbons rapidly, while other species such as shell fish cannot readily do so (ITOPF 2004). Even if an oil spill does not reach commercial fishing grounds and fish species are determined not to be tainted, accidental events can affect consumer perceptions on fish harvested in the surrounding area, potentially reducing the market value of the product and subsequent economic returns.

[120] Fouling refers to the accumulation of oil on a substance (e.g., fishing gear, vessels)

Consumer behaviour, and resulting effects based on consumer perceptions of fish that may be caught in an area near a spill, are difficult to predict. Loss of confidence in the market and public health concerns can have direct effects on the marketability and value of commercial fish landings (ITOPF n.d.).

CHANGE IN PERCEIVED COMMUNITY HEALTH AND WELL-BEING

Changes in perceived community health and well-being could occur as the result of an accidental event, such as the release of hydrocarbons into the marine environment, if it prevents local residents from undertaking traditional or recreational fishing and hunting activities for marine species. Local residents have a connection to the land, and if oil spilled was to reach coastal areas or the shoreline, then it is likely that there would be consumption warnings or bans put in place to reduce the potential for effects on human health. This ban, and subsequent inability to use lands for hunting or fishing, as well as the use of sea-ice and icebergs for drinking water could lead to negative effects on perceived health and well-being, including decreases in food sharing and a reduction in cultural transmission. This lack of country food source in the diet of Nunavut residents could also lead to negative effects, and influence food security in certain areas. All of these things could have resulting negative effects on both physical and mental health and well-being of local residents.

LAND AND MARINE USE

The accidental release of oil or other contaminants could directly interfere with marine based tourism, traditional use and practices, traditional harvest and the consumption of traditional foods. Depending on its location and magnitude, an accidental spill could result in actual or perceived effects on the availability or quality of the marine environment, and result in loss of access to areas that may be used for both traditional and non-traditional harvesting activities. The associated negative effects could include a reduction of harvesting activity and consumption of country foods, and reduced tourism activity.

7.3.5 Mitigation Measures and Planning Considerations

MITIGATION MEASURES

In addition to general commitments and mitigations, the following is a list of mitigation and management measures that apply to the Human Environment to help reduce or prevent potential adverse effects and enhance potential positive ones. These are summarized in Appendix B.

- Early discussions with stakeholders to alert them to and discuss employment and business opportunities that may arise from oil and gas activity
- Partnerships with educational institutions to train and develop local capacity for employment on future oil and gas activity
- Supplier development initiatives to help local businesses prepare to support potential oil and gas activity

- A Benefits Plan developed by operators and approved by government (territorial and/or federal), outlining initiatives and programs to enhance benefits to local residents, communities, and businesses.
- The use of a Fisheries Liaison Officer and/or fisheries guide vessels during certain activities (e.g., on seismic vessels, and during movement of a drilling rig).
- Providing Notice to Shippers of planned oil and gas activity through the Canadian Coast Guard.
- A compensation program for loss or damages to commercial fishers, including Commercial-communal fishers, and traditional harvesters that are attributable to the operator resulting from an accidental release of oil or other contaminants, or debris, or expenses incurred in taking remedial action. Actual loss or damage can include: loss of income or future income; loss of hunting, fishing, or gathering opportunities; and costs and expenses incurred for action taken to remedy a situation involving a spill, including measure to control or clean it.

PLANNING CONSIDERATIONS

In undertaking the effects assessment on the Human Environment, it is important to look at some of the considerations of these activities and their general nature. These include:

- The oil and gas activities in the scenarios take place offshore and away from land and communities.
- Some activities, such as seismic surveys and exploration drilling, would only take place during open water seasons, while other activities such as production would occur year-round.
- The Government of Canada would regulate projects, and likely require a Benefits Agreement between it and the operator(s).
- Onshore components of oil and gas activities include supply and servicing work, and use of existing infrastructure.
- Timelines for each activity, and the subsequent potential duration of interactions with the human environment, vary:
  - Seismic activity has a short timeframe (2 to 3 months to complete a survey).
  - Exploration drilling can also have a short timeframe (35 to 65 days per well), but can be extended depending on the number of wells being drilled per drilling program.
  - Production has the longest timeline, approximately 10 to 40 years for a producing field, which can increase the level of interaction between the project and the human environment.

The type of oil and gas activity also dictates the level of potential interaction with the human environment, based on the components involved with the oil and gas scenarios. These are summarized below:

- Seismic activities typically take place offshore, and seismic vessels are usually brought in from another part of the world and are not local. During a seismic program, these vessels only come to shore when they need fuel, or in the event of an emergency. Therefore, the potential for interaction with local communities is low.
- Exploration drilling activities may involve more interaction with onshore infrastructure, because there usually needs to be a port that is accessible and can provide laydown areas for equipment, and supply and servicing support for offshore supply vessels and the drilling rig itself. However, in some cases many of these functions may be provided by a wareship tied up or anchored at a coastal location. Despite the relatively short and uncertain duration of exploration drilling, and the specialized nature of much of the related employment, there may be onshore and offshore opportunities for residents, for example in shore base, marine, and catering positions.

7.4 Effects of the Environment on Oil and Gas Activities

Potential effects of the environment on offshore oil and gas activities in the Area of Focus are primarily associated with risks of natural hazards and influences of nature (e.g., weather, climate, climate change, or seismic activity). In addition, aspects of the human environment (public perception, available infrastructure and global factors) could influence the timeline, regulatory process and overall nature of oil and gas activities in the region.

Public and Indigenous interest and concern with potential oil and gas activities in the Area of Focus would need to be considered and addressed throughout the planning and regulatory phase so that issues and challenges can be identified early and resolved. Public perception of the impacts and potential effects of oil and gas activities can be a large impediment to gaining regulatory approval and social license for the operation of oil and gas activities.

Major resource development projects often require a baseline level of infrastructure in the region where they intend on operating. In the case of offshore oil and gas, advances in technology, engineering, and operational management have resulted in the ability to operate in a largely self-sustaining manner. In the case of scenario A (seismic exploration), support from local infrastructure and services is minimal and would be limited to use of an airport or airstrip for transferring crew to the worksite and local hotels for crew to stay in as they are travelling to and from the vessel. Scenarios B and C would potentially benefit from a larger reliance on local infrastructure, but given the remoteness and distance from shore that offshore exploration and production platforms are operating globally, they are becoming less and less reliant on onshore infrastructure for operations. In addition, the Area of Focus is adjacent to other jurisdictions with well-established offshore oil and gas industries (i.e. Atlantic Canada and Greenland), so an offshore oil and Gas operation in the Area of Focus could utilize existing infrastructure from either one of these jurisdictions. In general, a lack of specific infrastructure in the Area of Focus is not expected to be a limiting factor for offshore oil and gas activities.

As the global population increases and average standard of living grows, the National Petroleum Council (NPC 2007) estimates that the global demand for energy will grow by 50-60% by 2030 (from 2008). As technology advances with time and the need for reducing GHG emissions increases, it is predicted that there will be an increased reliance on the use of renewable resources (e.g., wind and solar power). Should energy resources follow this path, the intermediate concentration pathway (RCP 4.5; see Section 6.0) would be the best reflection of this scenario. Alternatively, if oil and gas continue to be the primary source of energy, there would be an increase demand and reliance for oil and gas exploration and development activities. This scenario would be best reflected in the maximum concentration pathway (RCP 8.5).

Potential effects of the biophysical environment on the scenarios are typically addressed through design and operational procedures developed in consideration of expected normal and extreme environmental conditions. Effects of the environment, if unanticipated or unmanaged, could result in adverse changes to scenario components, schedule, and/or economic viability.

As a matter of generally-accepted engineering practice, designs and design criteria tend to consistently overestimate and account for possible forces of the environment. Therefore, engineering design inherently incorporates a considerable margin of safety so that oil and gas activities are safe and reliable throughout a projects lifetime.

Environmental Impacts on oil and gas activities could include:

- Climate and climate change, such as severe weather, including:
    - Air temperature
    - Winds
    - Precipitation
    - Visibility
    - Icing
    - Extreme weather events (e.g., storms, winds, waves, and tsunamis)
    - Sea ice and icebergs
- Seismic activity
- Bathymetry

Potential effects of these impacts on oil and gas activities in the Area of Focus may include:

- Reduced visibility and inability to maneuver equipment
- Delays in the ability to meet planned schedules for activities such as mobilization or production
- Changes to the ability of workers to access the site (e.g., high winds, or if sea ice melts earlier in the season)
- Increased structural loading

- Damage to equipment (e.g., reduced ductility of components, increased susceptibility to brittle fracture from extreme low temperatures)
- Corrosion of exposed oxidizing metal surfaces and structures, perhaps weakening structures and potentially leading to malfunctions to structures

Some effects, such as damage to equipment can also result in subsequent effects on the environment (e.g., spills or other releases to the environment).

7.4.1 Effects of Climate and Climate Change

In assessing the potential effects of the environment on the scenarios, both current climate and climate change must be considered (refer to Section 6 for a detailed discussion on climate change predictions). While climate is defined as average weather conditions over 30 years, climate change is the change in climate over two or more 30-year periods (Catto 2006). The IPCC defines climate change as a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer.

A combination of observed trends, theoretical understanding of the climate system, and numerical modeling demonstrates that global warming is increasing the risk of extreme weather events today (Huber and Gulledge 2011). Numerous climate-related conditions, linked primarily to global warming, have been observed across the Arctic and globally. Many believe that these changes to the climate regime will accelerate over the next century, as has occurred with global temperatures over the past two decades (IPCC 2007). For example, increased temperatures, and changing precipitation patterns and intensity, could lead to more storm events, increasing storm intensity, rising sea levels, storm surges, and coastal erosion and flooding, all of which could affect infrastructure. Those most relevant to the SEA over the next 50 to 100 years are changing precipitation patterns, and increased number and intensity of extreme storms (Vasseur and Catto 2008).

7.4.1.1 Pathways of Effects of Climate on the Scenario

The potential effects of climate and climate change, or more specifically severe weather, must be considered during exploration and development and production activities. Extreme temperatures and severe precipitation, visibility, winds, icing, extreme weather events, and geohazards could potentially cause:

- Reduced visibility and inability to maneuver equipment
- Delays in activities
- Inability of personnel to access the site
- Damage to infrastructure and equipment
- Increased structural loading

AIR TEMPERATURE

Extreme low temperatures have the potential to reduce the malleability of materials used during exploration and appraisal, and development and production activities (e.g., ancillary facilities) and increase susceptibility to brittle fracture. Extreme low temperatures can be a concern with respect to icing (discussed below).

PRECIPITATION

Precipitation can affect other variables including visibility and icing events (discussed below), and result in delays in activities and hazardous or unsafe working conditions. The presence of snow (icing events are frequently accompanied by flurries or snow squalls) can add to the ice loading on offshore structures and vessels,[121] although it does not affect the spray itself. Ice fog or arctic sea smoke occurs when cold air is blown over relatively warmer waters. This fog is composed of tiny super-cooled water droplets, which freeze on contact with a structure. Ice fog poses a serious icing risk only when atmospheric conditions are just right.

VISIBILITY

Reduced visibility due to ice fog could make maneuvering of equipment difficult. Operators are typically required to submit an ice management plan, as per the Guidelines Respecting Physical Environmental Programs during Petroleum Drilling and Production Activities on Frontier Lands (NEB 2011). The guidelines clearly indicate all reporting requirements associated with the plan.

Wind storm events could potentially cause reduced visibility (due to blowing snow or rain) and interfere with maneuvering of equipment or transporting materials or staff movements. Wind also has the potential to increase loadings on infrastructure and cause possible damage.

ICING

As discussed above, precipitation in combination with extreme temperatures can result in ice formation on offshore structures and vessels. Icing is a consideration for operations during certain periods of the year as the excessive accumulation of ice on the superstructure of ships or other surface facilities may cause instability and impedes other aspects of operations. Severe icing tends to be limited to the months of October to December, when air temperatures typically range from freezing (0°C) to -15°C. Factors such as the size, weight, hull design, and amount of equipment and superstructure exposed to the elements, and the vessel's speed and heading into the wind will determine the amount of icing experienced. Risks associated with icing can be mitigated by limiting activities during this period or implementing a program to monitor and control the excessive accumulation of superstructure ice.

[121] Ice loading is the accumulation of ice on a structure resulting from freezing rain, snow, and/or ice fog.

EXTREME WEATHER EVENTS

Extreme weather events (i.e., storms, winds, waves, and tsunamis) have the potential to limit operations and activities. Although offshore infrastructure and vessels would be designed to operate in extreme Arctic offshore conditions, extreme weather events could still result in operational delays or increased risk of accidents and malfunctions. Having an appropriate forecasting and monitoring program in place would help mitigate this type of risk.

SEA ICE AND ICEBERGS

Sea ice has the potential to increase loadings of the components associated with exploratory and production platforms. Pack ice is an important constraint for ships and floating structures. The beginning of the drilling season during exploration activities in the 1970s and 1980s was dictated by the end of the pack ice season. Future exploration, shipping, construction, and production will likely be affected in a similar manner, unless special measures are in place to deal with pack ice. Pack ice loads will affect vessel station-keeping ability and may result in excessive forces on moorings and risers. Fixed or semi-fixed structures (e.g. semi-submersible drilling platform), which would be designed for iceberg impact loads, would not be influenced to the same extent, but would face issues related to re-supply and evacuation in pack ice.

The presence of icebergs represents an important hazard for offshore activities, both for surface and subsea structures. Icebergs can be present on a year-round basis, and the frequency of icebergs is such that, without effective ice management, impacts with surface structures could occur. Iceberg impact loads, both in terms of global loads and local ice pressures, represent an important design consideration for surface structures. Iceberg interaction with the seabed poses a hazard to pipelines and subsea structures, requiring measures such as pipeline burial, glory holes or other approaches to reduce risk to acceptable levels. Ice management systems must be established to ensure that any iceberg within radar range is tracked (e.g. with helicopter or real-time satellite data) to determine its proper path.

If an iceberg is on a collision course, the ice management vessels will attempt to deflect the iceberg by towing, water jetting or pushing the iceberg to alter its course. With the implementation of ice management measures, several hours warning would be available and only a moderate deflection is required to avoid a collision then this strategy is quite feasible. Tests have shown that there is an 86% success rate for such attempts; however, these are based on temperate locales and it is unknown how subarctic environments will affect these procedures, particularly with the high probability of severe weather (Husky Energy 2012).

Ice management techniques can be used to break up pack ice floes and tow icebergs when they threaten installations. However, ice management is not 100% effective and, therefore, the result of ice management is to reduce, rather than eliminate, ice loads and the associated risk. At present, it is not possible to quantify the magnitude of this reduction, in particular for icebergs, since the ability to detect and manage icebergs in heavy pack ice conditions is uncertain.

7.4.1.2 Mitigation for Climate and Climate Change

To address the potential effects of climate and climate change (air temperature, precipitation, visibility, winds, extreme weather events, and ice and icebergs), all aspects of designing the scenario, materials selection, planning, and maintenance should consider normal and extreme conditions that might be encountered throughout the life of the development activities.

Work should also be scheduled, where feasible, to avoid predicted times of extreme weather for the safety of crews and infrastructure.

The effects of severe weather should be further mitigated through:

- Careful and considered design in accordance with factors of safety, best engineering practice, and adherence with standards and codes
- Engineering design practices that will consider predictions for climate and climate change
- Inspection and maintenance programs that will reduce the deterioration of the infrastructure and will help to maintain compliance with applicable design criteria and reliability of the transmission system
- Establish ice management systems to reduce ice loads and associated risks

Further to responsible design and ongoing inspection and maintenance, the selection of equipment and infrastructure that are able to withstand temperatures and loads are expected to adequately address climate concerns. The selection of materials that withstand potential environmental stressors related to climate will include engineering specifications that contain design specific provisions, such as:

- Critical infrastructure and equipment (e.g., vessels and rigs) that will be constructed with resilient materials to prevent brittle fracture at low ambient temperature conditions
- Critical infrastructure and equipment (e.g., vessels and rigs) that will be constructed to withstand the structural loading expected with high winds and weight associated with ice and snow
- Winterization and freeze protection

7.4.2 Effects of Seismic Activity

7.4.2.1 Pathways of Effects of Seismic Activity on Potential Oil and Gas Projects/Activities

The Baffin Bay and Davis Strait region is unique from other passive margins in Canada because it is very seismically active (Bennett et al. 2013).

The Baffin Island shelf is crossed by several transverse troughs located at the mouths of major inlets and fiords (Bennett et al. 2013). Bylot and Devon Islands are both surrounded by steep slopes from the shoreline of the Baffin Fan, which covers the bottom of northern Baffin Bay and Lancaster Sound (Aksu and Hiscott 1989; Bennett et al. 2013).

Seismic events greater than 6.0 M may trigger slope failures on the steep slopes along the margins of transverse troughs, but would not have much effect on the bank tops (Bennett et al. 2013). As recent events indicate, tsunamis could also be created by those seismic events.

As a result, seismic activity could potentially damage infrastructure and equipment in the Area of Focus.

7.4.2.2 Mitigation for Seismic Activity

Infrastructure and equipment related to the scenario would be designed according to the Canadian Standards Association and other applicable standards and guidelines for earthquakes in this area.

The intent of these design standards is to maintain the integrity of the facilities based on the level of risk for an earthquake or a tsunami in the area. Design-base earthquake magnitude values are selected based on probability of occurrence of such an earthquake. However, an earthquake with a magnitude substantively greater than the design-base earthquake could result in damage to infrastructure and equipment.

7.4.3 Effects of Bathymetry

Due to the unique bathymetry of Baffin Bay, bathymetric barriers (i.e., shallow sills in the north and south) must be considered during tow-out of the equipment in the nearshore environment, as movement of the equipment has the potential to disturb the ocean floor.

The Davis Strait does not have obvious bathymetric barriers, therefore, equipment tow-out would not be an issue in this area.

7.4.3.1 Mitigation for Bathymetry

Proper design, dredging and ballasting to the appropriate towing draft will allow equipment to mobilize in the tow-out route without disturbance to the ocean floor.

7.4.4 Accidents and Malfunctions

Accidents or malfunctions that result from effects of the environment on oil and gas activities would be addressed through the Proponent’s Environmental Management Plan. The Environmental Management Plan would be developed for the management and prevention of accidents and malfunctions, and include emergency response protocols and worker training requirements.

7.4.5 Information Gaps

Confidence in the conclusions for potential effects of the environment on oil and gas activities are based on future climate projections reported by the IPCC, the climate projections made as part of this assessment, and from the existing climate data specific to Baffin Bay and Davis Strait where available. Confidence in many of these projections is medium or high (e.g., increase in surface temperature, reduction in sea ice extent as the climate warms). However, confidence in projections on iceberg prevalence and distribution, storm tracks, and the strength and frequency of storms, and on height of surface waves is low. This uncertainty may hinder the design of equipment with specifications and strengths needed to withstand the variability in future weather and storms in the Area of Focus.

7.4.6 Summary

The potential effects of the environment on the scenario are considered in the infrastructure decisions and the lifecycle assessment including the design, construction, and operation and maintenance of equipment to be used in the scenario activities. The equipment will be designed, constructed, and operated to maintain safety, integrity, and reliability in consideration of existing and reasonably projected environmental forces that may occur in the Arctic and specifically in the Area of Focus.

Proponents will need to use the adaptive management approach in its activities throughout exploration and production. Given the climate projections presented herein, there is an ongoing need for ice management to predict sea ice extent and iceberg locations and trajectories, and the potential for extreme weather. There is a need to continually monitor weather elements and equipment performance, in relation to observed effects of the environment on the scenario, and adapt (e.g., move, tow, repair/replace) infrastructure or operations as needed.

8 INFORMATION GAPS AND RECOMMENDATIONS

8.1 Physical Environment

Information gaps and recommendations for components of the physical environment in the Area of Focus are presented in the following section. These include gaps in the understanding of the climate, meteorology and climate change, air quality and greenhouse gases, bathymetry, oceanography, sea ice and iceberg conditions, the acoustic environment, geology, and marine sediment.

8.1.1 Climate, Meteorology and Climate Change

Weather forecasting is an essential element in planning activities related to oil and gas exploration and development. In addition, a clear understanding of climate and meteorology is needed so that equipment can be designed for successful operation in the cold environment of Baffin Bay and Davis Strait.

The gaps in weather forecasting and understanding relate largely to the analysis and prediction of extreme events in the context of a relatively sparse network of monitoring stations in the region. A good understanding of risk associated with project development requires a quantitative assessment of probabilities of severe consequences from extreme weather events.

The addition of more observation stations to make a denser network is a desirable and necessary step to increase the accuracy of forecasting, particularly at a mesoscale (smaller than large weather systems, e.g., sea breezes) to microscale level. These types of improvements will aid in the future analysis of climate, but they do not add to data in the past (which is important for detecting the signature of climatic change in the observations).

Improvements in long-term modelling will be essential to decreasing the risk and consequence of forecasting necessary to support developments in this region as the climate changes in response to anthropogenic activities in the future.

As surface air temperatures increase, the rate of ice loss in Greenland is likely to increase, producing more icebergs in the near term. This may mean more icebergs in Baffin Bay and Davis Strait initially, but it is recognized that with sufficient warming this number may eventually decrease due to more rapid melting. There is little information available to suggest when this might happen.

Confidence in the conclusions for potential effects of climate change on the scenarios are based on future climate projections reported by the IPCC, from the climate projections made as part of this assessment, and from the existing climate data specific to Baffin Bay and Davis Strait where available. Confidence in many of these projections is medium or high (e.g., increase in surface temperature, reduction in sea ice extent as the climate warms). However, confidence in projections on storm tracks, and the strength and frequency of storms, and on height of surface waves is low. This uncertainty may hinder the design of equipment with specifications and strengths needed to withstand the potential variability in future weather and storms in the Area of Focus.

8.1.2 Air Quality and Greenhouse Gases

Baseline information on air quality is required to support modelling of potential effects of oil and gas activities on air quality and sensitive receptors.

Knowledge gaps for Air Quality include a lack of ambient air quality data for areas over the water in the Area of Focus. Dispersion of air contaminants in the Arctic atmosphere (i.e., the troposphere near the surface), which is a cold, stable atmosphere for an extended period of time, is also not well understood. This includes the influence of International Maritime Organization requirements on the control of air pollution and GHGs in the future, as well as an understanding of the best available control technologies for air contaminants and GHGs, for the equipment used in the scenario.

Information on the likelihood of methane releases, and quantities from under the sea ice and from warming of frozen tundra is also required; this information will help improve our understanding of projected increases in air and sea temperature.

8.1.3 Bathymetry

Bathymetric information is required to support planning and design of oil and gas projects, as well as to complete assessments of potential effects to the physical and biological environments.

The general bathymetry of the Baffin Bay and Davis Strait and the seafloor in the Area of Focus was first explored as a result of hydrocarbon exploration activities in the 1970s (Blasco et al. 2010). Since then, there have other, but limited, geophysical, sediment, and seismic surveys. While some areas have been investigated in detail (e.g., the Scott Seep), most areas within the Area of Focus require further investigation. While surveys, such as those conducted by the Geological Survey of Canada and Arctic Net, have increased understanding of smaller localized areas in the Baffin Bay and Davis Strait region through detailed multi-beam surveys, there are areas that have not been adequately surveyed.

8.1.4 Oceanography

Information on chemical and physical oceanography is required to assess potential effects of oil and gas developments, as well as to better understand important oceanographic processes in the Area of Focus, and potential effects of climate change.

The location of polynyas in the Area of Focus are known and these represent areas with localized upwelling events; however, a greater understanding of upwelling in the region is needed. A better understanding of wave heights, tides, and wind in the Area of Focus is also needed; especially as it relates to public safety in the case of extreme events and the potential impacts on communities in the Area of Focus.

8.1.5 Sea Ice and Iceberg Conditions

An understanding of the temporal and spatial occurrence of sea ice, as well as sea ice characteristics is required to plan and design project stages (e.g., seismic programs), as well as assess potential environmental effects (routine activities and accidents and malfunctions), and better understand potential effects of climate change.

While current ice management procedures are generally effective, there is a need for additional knowledge related to the following areas:

- Iceberg towing in pack ice
- Detection of small icebergs in pack ice
- Improved methods of detection and monitoring of icebergs

The National Research Council has developed a reliable iceberg drift forecasting model in collaboration with the Canadian Ice Service, academia, and other consulting firms. This model is called the National Research Council Iceberg Drift Model, and incorporates comprehensive physics of iceberg motion, deterioration and calving, and a robust numerical method. This helps to increase the accuracy of forecasts over previous methods. However, efforts are still needed to improve the monitoring, detection, and forecasting of icebergs. For example, the use of more satellite data, and improvement in iceberg detection algorithms are needed.

8.1.6 Acoustic Environment

Knowledge gaps for the Acoustic Environment are related to airborne noise, including ambient sound pressure level measurements in the air over the water in the Area of Focus. Dispersion of noise in the Arctic atmosphere is not well understood.

8.1.7 Geology

Gaps identified in the general understanding of the geology of the Area of Focus are related to seismic events and other geohazards that occur, or may occur. Such information is of use in planning and designing oil and gas projects, especially in regard to reducing potential effects of the environment on the project.

Since the Baffin Bay and Davis Strait region is seismically active and there are known hydrocarbon seeps, information on how events are seismically triggered and preconditioned by hydrocarbon migration is required (Bennett et al. 2013). This includes an understanding of seabed stability during earthquakes, the effects of global warming on seismic events, and consequential tsunami events (Bennett et al. 2013).

A better understanding of the naturally occurring oil seeps in the Area of Focus is needed, such as further investigations of areas where pockmarks are known to occur and where surface oil slicks have been observed.

Bennett et al. (2013) have identified geohazards on the northern Baffin Island shelf that require more research prior to exploratory drilling programs in the region. Such research would act to support community, Nunavut Government, and regulatory decisions on the use of offshore areas and provide northern coastal communities with better knowledge for improving public safety. Improved understanding of geohazards in Baffin Bay would provide the following benefits: (1) understanding the seabed stability during earthquakes, the effect of global warming on seabed stability, and potential tsunami hazard; (2) informing decision making for potential hydrocarbon development projects; and (3) understanding hazards that affect the routing and integrity of communications cables and other seabed uses (Bennett et al. 2013).

Other gaps are summarized in Table 8.1.

Table 8.1 Issues and Gaps Relating to Geohazards on the Northern Baffin Island Shelf

Geohazard	Issues and Gaps
Iceberg Scour	The rate of iceberg scouring in the region is unknown, as is the impact of enhanced melt rates in Greenland.
Slope Instability	There is concern about events in the area that are seismically triggered and preconditioned by hydrocarbon migration. Global warming may increase the influx of hydrocarbons from gas hydrates.
Ocean Currents	The role of the Baffin Island Current in eroding the upper slope, remobilizing sediment, and building sediment drifts is not known, nor is the contribution of currents to upper slope instability.
Gravity-driven Currents	The role of cascading cold, dense water flows, sediment accumulation in gully and canyon heads, and remobilization in storms is not known.
Sediment Movement	Sediment movement, scour in storms, and tidal currents could lead to scour around seabed infrastructure.
Spatial Distribution of Foundation Conditions	Knowledge of rock or sediment type, strength, permeability, and lateral continuity is required for the placement of structures on the seafloor, and exploratory drilling.
SOURCE: Bennett et al. (2013)	

8.1.8 Marine Sediment

Additional data are required to confirm the presence of sediment failure and gullies, including data to determine if the trough margin gullies present in the Area of Focus are active conduits for sediment transport (Bennett et al. 2013). A better understanding of the overall distribution of different sediment types and thicknesses in the Area of Focus is required to determine seabed stability in areas of planned development.

8.2 Biological Environment

Confidence in the assessment of potential effects on fish, birds and marine mammals may be improved by further monitoring and research into their distributions, abundance, prey dependency and availability, and key habitat availability and quality in the Area of Focus, and throughout their range.

Data gaps exist for waterbird distribution (i.e., migration patterns and seasonal distribution) and abundance, and sea ice biota in the Area of Focus, particularly in southeastern Baffin Bay (Pomerleau et al. 2014). A review of available literature found a lack of detailed information on the status of the Nunavut population of king eider, harlequin duck (COSEWIC 2013; Sea Duck Joint Venture 2015b; CESCC 2016), Atlantic puffin (CESCC 2016) and most of the Nunavut population of common eider (Robertson and Gilchrist 1998; ECCC 2015; CESCC 2016). Population estimates for red phalarope are coarse (Tracy et al. 2002). Migratory patterns of eastern king eiders are largely unknown (Abraham and Finney 1986; Sea Duck Joint Venture 2015a), as is the distribution of king eider along the east side of Baffin Island. Similarly, specific migration routes and behaviour for Eastern Canadian Arctic puffins are not well known (Lowther 2002).

To better understand the current status of and potential impacts to important waterbird populations and sensitive habitats (e.g., MBSs, IBAs, key habitat sites, risk intolerant sites), further research is recommended on waterbird population densities and breeding success, and monitoring of seasonal waterbird migration patterns, sensitive waterbird breeding and foraging habitat, oceanographic data, productivity, and prey abundance and distribution (e.g., of plankton and fishes).

Data on some species of marine mammals in the Area of Focus has been collected on a regular basis (Pomerleau et al. 2014); however, confidence on the potential effects to populations is dependent on ongoing monitoring and IQ collection regarding their body condition, prey availability, key habitat availability, abundance and distribution. This is particularly the case for ice-associated species (e.g., seals and polar bear) that are considered the most vulnerable to loss of habitat through sea ice loss that is associated with climate change. Increased monitoring of the distribution and seasonal movements and habitat use of bearded seals and ringed seals throughout the year, the winter distribution of beluga, and the wintering grounds and calving areas of fin whale will increase the level of confidence regarding potential effects on these species in the Area of Focus.

Confidence in the potential effects and cumulative effects of underwater noise from oil and gas activities on marine fishes, waterbirds, and marine mammals would be improved by increasing the collection of ambient sound data specific to the Area of Focus, and in particular Davis Strait. Although it is generally believed that underwater noise has little effect on arthropods or shellfish (Andriguetto-Filho et al. 2005; Day et al. 2016) further research is needed to better understand potential effects of underwater noise on invertebrates (Hawkins et al. 2015). There are few studies that characterize effects to waterbirds from acute or chronic in-air or underwater noise, and species-specific differences remain poorly described in the literature.

There are different views among bioacousticians about the best method for estimating injury and disturbance effects on marine animals, and there is little consensus on how to perform those assessments across different taxa. Canada has not developed prescribed sound level criteria for assessing injury or behavioural responses of waterbirds or marine mammals to underwater noise. In the absence of defined criteria or thresholds, potential noise-based effects on waterbirds and marine mammals are best characterized based on the available information in peer-reviewed scientific literature (e.g., SAIC 2011). Additional research is needed to more confidently characterize the effects of in-air and underwater noise on waterbird species and to develop more relevant threshold criteria for assessing injury and behavioural disturbance.

Confidence in prediction of effects on marine mammals would be increased with further studies on the behavioural responses of these species to underwater noise and habitat alterations. The behavioural response of marine mammals to disturbance is often context dependent; further information on habitat use in the Area of Focus and how species respond to disturbance would be valuable. Further to this, expanded research on how the impacts of individual changes in behaviour are transferred, if they are, to population level effects will increase confidence in the assessment of potential and cumulative effects on population viability.

The ability to effectively contain and recover spills close to the source is important to impede the migration of marine pollution to various species and habitats. If potential sources of marine pollution could increase in the Area of Focus, so too should research into emergency planning, preparedness, and response, including available technologies, equipment, and human resources for offshore oil spill containment, recovery, and management. Risks to marine species and habitats associated with marine pollution incidents may be reduced by identifying and implementing enhanced measures for spill prevention, and techniques for containment and recovery in Arctic environments.

Of note, during 1990-2004, as part of the Arctic Environmental Sensitivity Atlas System, Environment Canada developed coastal sensitivity atlases for three regional areas: Lancaster Sound, the Canadian Beaufort Sea, and Amundson – Queen Maude Gulf Areas (e.g., Beaufort Regional Coastal Sensitivity Atlas, Environment Canada, 2015). Each atlas contains spatial information on resources that are vulnerable to oil spills, as well as information to inform operational prioritization and coordination of onsite spill response activities. Site specific maps (hard copy and digital) provide information such as shoreline form, substrate and vegetation type. If oil and gas development was to proceed in Baffin Bay and Davis Strait, a coastal sensitivity atlas, similar to these three atlases, should be developed for the Area of Focus.

8.3 Human Environment

8.3.1 IQ and Traditional Land and Marine Use

Inuit Qaujimaningit, specifically to the SEA, was not available prior to submission of this report. A literature review was conducted to collect available written IQ relevant to the Area of Focus; however, the literature reviewed was primarily the results of government, academic, and Inuit organizations working in concert on regional policies and initiatives, and is not specific to hypothetical scenarios of the SEA. The literature reviewed for the SEA reflects traditional use and practices dating from approximately 1913 to 2013, and does not necessarily reflect the specific needs and current interests of residents in the Area of Focus. For instance, the fact that there is a weight of information on bowhead and beluga whales does not mean that these are the only species of concern or interest. Similarly, the weight of information on thinning sea ice does not mean that there are not also concerns regarding marine sediment, or suspended particulate, or greenhouse gas emissions.

Where shapefiles or mapped information on land use, occupation, or resources was available from a publicly available source, permission to use that information in the SEA was sought. However, permission to use the shapefiles from The Nunavut Atlas, Nunavut Land Use Plan Community Priorities and Values, Nunavut Climate Change, and Pikialasorsuaq Commission—Pikialasorsuaq pillugu Isumalioqatigiissitat websites had not been received prior to submission. Incorporating shapefiles or mapped IQ information from these sources would contribute to a more fulsome understanding of traditional use and practices within the Area of Focus.

Intangible values relate to beliefs, perceptions, values and qualitative experience, and include experiential values such as cultural transmission, language retention, governance systems, and patterns of cultural behavior. Intangible values are subjective, experiential and conditional, often reflecting matters of conviction or articles of faith. Consequently, intangible values can only be meaningfully assessed by individuals and communities experiencing these values in their cultural context. Therefore, intangible values cannot be assessed in the same manner as tangible values, that is, intangible values cannot usefully be assessed as objective, measurable phenomena from a Western scientific perspective. Intangible values should be considered narratively.

Inuit Qaujimaningit specific to the potentially interested communities is essential to successfully completing this SEA, and has the potential to further inform the assessment of all valued components pertaining to the physical, biological and human environments.

8.3.2 Housing in Nunavut

While the information provided in the Nunavut Housing Needs Survey is valuable and does give a good overview of the housing situation in Nunavut and the Baffin Region, the information is becoming out of date. The survey was conducted in 2009 and 2010, and there have been larger amounts of economic activity and growth in Nunavut since that time. Another survey or wide-scale assessment should be completed to determine whether changes have occurred in the housing situation in Nunavut. More recent housing information in the Baffin Region may help provide a clearer picture of the current housing situation in the Baffin Region..

8.3.3 Business Investment

There has been difficulty acquiring publicly available business investment information at a community, or regional level for Nunavut. There has been some public information on public and private investment from the Government of Nunavut, and investment in residential construction. However, the data is limited. This was the same for contracting and business development, which has some information available. Strategic

8.3.4 Perceived Health and Well-Being

Information on the perceived health and well-being of Nunavut residents was collected using different sources, such as Statistics Canada, academic journals, and government reports. However, collection from these sources may not give an accurate description or representation of the perceived health and well-being of a community, or of local residents. Collection of information from public consultation sessions would help aid and strengthen this section, as perceived health and well-being can be interpreted differently by region, community, and individuals.

8.3.5 Discrepancies in Data Sources

There are certain information topics where data from one source does not agree or match with another. For example, according to Statistics Canada's 2016 census, the unemployment rate in Nunavut was 21.5%. In a labour force statistics update provided by the Government of Nunavut Bureau of Statistics, the unemployment rate for Nunavut in 2016 was 14.9%. There are some discrepancies in numbers, and sources of information, which causes confusion. In these instances, data provided by Statistics Canada has been used for consistency. Further evaluation of these sources is recommended to better understand the reasons for these differences, and allow a more thorough interpretation of these information sources.

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APPENDIX A

Air Quality and Greenhouse Gas Regulatory Requirements

The ambient air quality standards for Nunavut are provided in Table A-1 (Nunavut DOE, 2011).

Table A-1 Ambient Air Quality Standards (Nunavut DOE 2011)

Pollutant	Averaging Time	Ambient Air Quality Standard		Description
		µg/m³	ppb	
$PM_{2.5}$	24-hour	30	-	The size classes of particulate matter or PM are referenced to the particle aerodynamic diameters in microns, or micrometers (µm). Inhalable particulate matter (PM_{10}) consists of particles with aerodynamic diameters less than or equal to 10 µm. Respirable particulate matter ($PM_{2.5}$) consists of particles with aerodynamic diameters less than or equal to 2.5 µm. Nunavut specifies only $PM_{2.5}$.
TSP	24-hour	120	-	Total suspended particulate matter, commonly from dust or other mechanical abrasion processes - annual geometric mean - the average of the logarithmic values of a data set converted back to a base 10 number
	Annual	60	-	
NO_2	1-hour	400	213	Nitrogen dioxide (NO_2) is an orange to reddish gas formed by the oxidation of NO emitted directly by combustion processes, particularly those processes occurring at high temperature and pressure, such as with internal combustion engines; average
	24-hour	200	106	average
	Annual	60	32	Arithmetic mean
SO_2	1-hour	450	172	Sulphur dioxide (SO_2) is a colourless gas with a characteristic pungent sulphur odour. It is produced in combustion processes by the oxidation of sulphur compounds, such as hydrogen sulphide (H_2S), contained in the fuel.
	24-hour	150	57	
	Annual	30	11	
O_3	8-hour		65	Ground level ozone, is not released by the scenario activities; however, it is a secondary pollutant, formed as a result of a reaction of oxides of nitrogen and VOCs with sunlight during warm weather.

As noted in the guideline, the standards for ozone and particulate matter have been adopted from the Canada Wide Standards approved by the Canadian Council of Ministers of the Environment (CCME), while the standards for TSP, NO_2, and SO_2 have been adopted from the Canadian National Ambient Air Quality Objectives. The standards are science-based and take into account both ability to achieve the standards in terms of best available control technology and the economics to do so (Nunavut DOE, 2011).

There are limited options available in Nunavut to manage solid waste because settlements are small and remote, and waste sites are difficult to set up because of the permafrost and lack of good cover material. Incineration at high temperature is the preferred method. Nunavut has published a guideline for burning solid waste which defines roles, the incineration process, pollutants of concern, the preferred methods and technologies, best management practices, and air emission standards. The emission standards are based on the CCME approach, for dioxins and furans and mercury (Nunavut DOE 2012). These standards are applicable to in stack exhaust gases being released from an incinerator unit and are shown in Table A-2.

Table A-2 Emission Standards for Solid Waste Incineration (Nunavut DOE, 2012)

Emission	Standard	Description
Dioxins and Furans	80 pg I-TEQ/m^3	Pictograms of International Toxicity Equivalents, per cubic metre of air
Mercury	20 µg/Rm^3	Micrograms per cubic metre—volume adjusted to 25°C and 101.3 kilopascals

An in-stack opacity requirement, although not a standard, is set at less than 5%.

The government of Nunavut published a guideline for managing solid waste containing mercury such as fluorescent lamps. Preferred waste handling procedures are described. There are no emission standards presented in the guideline (Nunavut DOE 2010).

The federal (i.e., national) air quality criteria are the National Ambient Air Quality Objectives (NAAQOs), Canada Wide Standards (CWSs) and the Canadian Ambient Air Quality Standards (CAAQS). The NAAQOs were established by the federal government in the early 1970s to protect human health and the environment by setting objectives for the following common air pollutants, among others: carbon monoxide, nitrogen dioxide, ozone, sulphur dioxide and total suspended particulates. The objectives are denoted as “Desirable”, “Acceptable” and “Tolerable”.

The CWSs are based on intergovernmental agreements developed under the CCME Canada-wide Environmental Standards Sub-Agreement, which operates under the broader CCME Canada-wide Accord on Environmental Harmonization. The CWSs are intended to address key environmental protection and health risk issues that require concerted action across Canada. The CWSs represent co-operation toward a common goal, but confer no specific authority to any federal, provincial or territorial government.

The CAAQS for $PM_{2.5}$ and ozone were developed through a collaborative process involving the federal, provincial and territorial governments and stakeholders, as directed by the CCME (CCME 2012). The CAAQSs have replaced the CWS for $PM_{2.5}$ and ozone. The CAAQSs for $PM_{2.5}$ and ozone have been developed for years 2015 and 2020 as shown in the table below (Table A-3). On October 3, 2016, the CCME announced a new CAAQS for SO_2 with effective dates of 2020 and 2025. These values are also shown in Table A-3.

Table A-3 Summary of Federal Air Quality Objectives and Standards

Pollutant and Units (alternative units in brackets)	Averaging Time Period	Canada Wide Standards	Canadian Ambient Air Quality Standards	National Ambient Air Quality Objectives		
				Maximum Desirable	Maximum Acceptable	Maximum Tolerable
Sulphur dioxide $\mu g/m^3$ (ppb)	1 hour	-	200 (70) D 186 (65) E	450 (158)	900 (315)	-
	24 hour	-		150 (53)	300 (105)	800 (280)
	Annual	-	14.3 (5) D 11.4 (4) E	30 (11)	60 (21)	-
Nitrogen dioxide $\mu g/m^3$ (ppb)	1 hour	-		-	400 (195)	1,000 (487)
	24 hour	-		-	200 (97)	300 (146)
	Annual	-		60 (29)	100 (49)	-
Carbon Monoxide mg/m^3 (ppm)	1 hour	-		15 (12)	35 (28)	-
	8 hour	-		6 (5)	15 (12)	20 (16)
Total Suspended Particulate (TSP) $\mu g/m^3$	24 hour	-		-	120	400
	Annual	-		60	70	-
$PM_{2.5}$ $\mu g/m^3$	24 hour	30[A]	28 [B] 27 [C]	-	-	-
	Annual		10.0 [B] 8.8 [C]			
Ozone (O_3) $\mu g/m^3$ (ppb)	1 hour	-		100 (47)	160 (75)	300 (140)
	8 hour	139[A] (65)	135 (63) [B] 133 (62) [C]	-	-	-
	24 hour	-		30 (14)	50 (23)	-
	Annual	-		-	30 (14)	-

NOTES:

[A] CCME (2000), Canada-Wide Standards for Respirable Particulate Matter and Ozone, effective by 2010. The Respirable Particulate Matter Objective is referenced to the 98th percentile over three consecutive years; the Ozone Objective is referenced to the on 4th highest 8-hour average annual value, averaged over three consecutive years.

[B] CCME (2012), CAAQS for $PM_{2.5}$ and ozone for 2015. The 24-hour standard is referenced to the 98th percentile over three consecutive years, and the annual standard is referenced to the 3-hear average of the annual average concentration. The Ozone Objective is referenced to the on 4th highest 8-hour average annual value, averaged over three consecutive years.

[C] CCME (2012), CAAQS for $PM_{2.5}$ and ozone for 2020. The 24-hour standard is referenced to the 98th percentile over three consecutive years, and the annual standard is referenced to the 3-hear average of the annual average concentration. The Ozone Objective is referenced to the on 4th highest 8-hour average annual value, averaged over three consecutive years.

[D] CCME (2016). CAAQS for SO_2 effective 2020. The 1-hour standard is referenced to the 3-year average of the annual 99th percentile of the SO_2 daily maximum 1-hour average concentrations. The annual standard is the arithmetic average of all 1-hour average SO_2 concentrations.

[E] CCME (2016). CAAQS for SO_2 effective 2025. The 1-hour standard is referenced to the 3-year average of the annual 99th percentile of the SO_2 daily maximum 1-hour average concentrations. The annual standard is the arithmetic average of all 1-hour average SO_2 concentrations.

Federally, all facilities that emit more than 10,000 t CO_2e per year are required to quantify and report GHG emissions to the federal government (ECCC 2018; Canada Gazette 2017). It is noted in the guidance, that starting with reporting in 2017, the federal Greenhouse Gas Reporting Program will apply to a wider range of GHG emitting operations in Canada. All facilities that emit the equivalent of 10,000 tonnes or more of GHGs in carbon dioxide equivalent units (CO_2 eq) per year will be required to submit a report.

There is no federal regulatory requirement to reduce GHGs from a particular industrial facility or sector. The federal government; however, has indicated it will implement federal legislation that will mandate a national carbon pricing program by 2018, if individual provinces and territories do not do so by then (ECCC 2016a).

The Pan-Canadian Framework on Clean Growth and Climate Change was developed by the federal government with the provinces and territories and in consultation with Indigenous peoples, to meet emissions reduction targets, grow the economy, and build resilience to a changing climate. This plan includes a Pan-Canadian approach to pricing carbon pollution, and measures to achieve reductions across all sectors of the economy (Government of Canada 2016). Such a program may impose a carbon tax on fossil fuel use, establish a cap-and-trade mechanism, or other means acceptable to ECCC. Any province that does not set its own carbon price will be mandated to use the federal government's minimum floor price.

In the Copenhagen Accord meeting in January 2010, the Government of Canada set a target of reducing GHG emissions by 17% by 2020 (compared with 2005 levels). Even longer term targets were set in May 2015, when Canada submitted its Intended Nationally Determined Contribution to the United Nations Framework Convention on Climate Change in which a 2030 target of 30% below 2005 levels was announced. Since then, the federal government has signed and ratified the agreement put forward at the December 2015 Paris Climate Conference in which countries around the world agreed to limit the global increase in temperature to 1.5°C (ECCC 2016b).

For climate change and GHG emissions considerations in the context of environmental assessment, national guidance is provided by the CEA Agency (CEA Agency 2003) and includes guidance on the environmental assessment of GHG emissions from the Project and from the related industrial sector. In the guidance document it is suggested that, where Project emissions are medium or high, preparation of a GHG Management Plan is required. Further regulation at the federal level is anticipated to occur in the future. The intentions are described in the Regulatory Framework for Air Emissions by the Government of Canada in 2007, and Turning the Corner: Regulatory Framework for Industrial GHG Emission (Government of Canada 2008).

The government of Nunavut has long recognized the need to address climate change and in 2003 published a strategy to get this started (Government Nunavut 2003). Back then the challenges to reducing GHGs and adapting to climate change were noted as:

- Cold climate
- Long distances between small communities

- Limited energy supply options
- Cost of energy
- Awareness of issue
- Economic growth

Taking a phased and balanced approach, and with precaution, the concept is to work closely with other stakeholders and develop a path forward. A framework was established in 2011 which built on the 2003 Strategy and provided more direction on impacts, mitigation and adaptation. Several initiatives are underway, and progress and goals were presented where the "Government of Nunavut aims to increase adaptive capacity to ensure a resilient Nunavut" (Government Nunavut 2011).

Following on from this directional guidance, the Government of Nunavut prepared a more focused Strategic Plan to address climate change over a five-year period from 2017 to 2021 (Government of Nunavut 2016). As stated in the plan the main goals are to:

- Ensure that the government's climate change perspective and priorities are represented globally and its considerations are incorporated into National and International policies
- Demonstrate measurable progress towards climate change knowledge mobilization
- Demonstrate measurable progress towards climate change adaptation
- Achieve a measurable reduction in the rate of carbon emissions with minimal costs to Nunavummiut

There has been considerable success in achieving those goals. For example, to date, at least seven communities in Nunavut now have climate change adaptation plans, including one on the east coast of Baffin Island at Clyde River.

As noted above, the substances considered in the assessment of GHGs include CO_2, CH_4, and N_2O. GHGs are often rolled up and presented in combined units of tonnes of CO_2 equivalents (t CO_2e). This is achieved by multiplying each gas by its GWP to provide a common unit of measure and allows to sum emission estimates of different gases. Carbon dioxide has a GWP of 1, and is used as a reference gas for other GHG GWPs. The larger a GWP, the more that gas is capable to absorb energy and warm the atmosphere. Additional GHG details including GWPs are provided in Table A-4.

Table A-4 Definition of GHGs

Species	Definition
CO_2	Carbon dioxide is a naturally occurring gas (e.g., volcanic eruptions) but is also released by human activities (e.g., by-product of burning fossil fuels, burning of biomass, land use changes, and other industrial processing).
CH_4	Methane is a hydrocarbon gas produced through natural sources (e.g., wetlands) and is also the main component of natural gas. It is also produced by human activities (e.g., burning of fossil fuels, fugitive sources, raising livestock, decay of organic waste in landfills). Methane has a higher GWP than CO_2 but is much less abundant in the atmosphere (GWP of CH_4 is 25).
N_2O	Nitrous oxide occurs naturally and from human activities. Nitrous oxide is produced as a by-product of the combustion of fossil fuel and biomass burning as well as during industrial and agricultural activities. Nitrous oxide has the highest GWP of the three GHGs listed here (GWP of N_2O is 298).

APPENDIX B Mitigations and Planning Considerations

Table B.1 Summary of Standard Mitigation and Planning Considerations for Routine Activities

No.	Operator Commitment
General*	
1	Adherence to all applicable acts, regulations and guidelines (environmental and drilling/production), as applicable.
2	Operators should provide proposed plans (and updates as required) of planned activities to fishers and harvesters that will include timing of exploration activities and locations of planned wells.
3	Operator should provide an Environmental Impact Statement (EIS) update to regulatory authorities each year that offshore operations are planned. The EIS update will provide an overview of planned activities as defined by the scope of the Project, update on recent and on-going engagement activities and their outcomes, and an overview of any new information regarding traditional or commercial fishing or harvesting activities and updates to Species at Risk, if applicable, as well as outlining the proposed work for the coming year and evaluating the continued applicability and validity of EIS predictions and mitigation measures.
4	Establish an environmental compliance and cultural awareness training program for program personnel
5	Conduct permit compliance training with all employees
6	Conduct periodic safety, security, health and environment compliance assessment
7	The Proponent shall not harass wildlife. This includes persistently worrying or chasing animals, or disturbing large groups of marine mammals or seabird colonies. The Proponent shall not hunt or fish, unless proper Nunavut authorizations have been acquired.
8	All field operations staff should be made aware of the proponents' commitments to the committed mitigation measures and provided with appropriate training prior to commencement of the project.
9	The Proponent should, to the extent possible, hire local people and to consult with local residents regarding their activities in the region.
10	Use of existing and common travel routes for vessels and helicopters will be used where possible and practicable.
11	Low-level aircraft operations will be avoided where it is not required per Transport Canada protocols.
12	The Proponent shall not deposit, nor permit the deposit of any fuel, chemicals, wastes or sediment into any waters, and shall managed wastes on board the vessel prior to final disposal at an approved port facility.
13	The Proponent shall keep and manage any waste waters generated from the project on board the vessel, and dispose of waste water only in port facilities in accordance with approved ship procedures and protocol.
14	Operational discharges will be treated prior to release in accordance with the OWTG (2016) and other applicable regulations and standards.
15	The selection and screening of chemicals to be discharged, including drilling fluids, should be in accordance with applicable and available guidelines (i.e., Offshore Chemical Selection Guidelines for Drilling and Production Activities on Frontier Lands developed by NEB, C-NLOPB and CNSOPB).
16	During formation flow testing with flaring, produced hydrocarbons and produced water will be flared. If there is a large amount of produced water encountered, it will be treated in accordance with the relevant regulatory requirements prior to ocean discharge, or shipped to shore for appropriate disposal.
17	Appropriate handling, storage, transportation and on-shore disposal of solid and hazardous waste.
18	The Proponent shall report all spills of fuel, or other deleterious materials immediately to the 24 hour Spill Line at (867) 920-8130.

Table B.1 Summary of Standard Mitigation and Planning Considerations for Routine Activities

No.	Operator Commitment
Climate and Climate Change	
19	All aspects of designing the scenario, materials selection, planning, and maintenance should consider normal and extreme conditions that might be encountered throughout the life of development activities.
20	Work should also be scheduled, where feasible, to avoid predicted times of extreme weather for the safety of crews and infrastructure.
21	The effects of severe weather should be further mitigated through: • Careful and considered design in accordance with factors of safety, best engineering practice, and adherence with standards and codes • Engineering design practices that will consider predictions for climate and climate change • Inspection and maintenance programs that will reduce the deterioration of the infrastructure and will help to maintain compliance with applicable design criteria and reliability of the transmission system • Establish ice management systems to reduce ice loads and associated risks
22	Equipment and infrastructure will be selected that are able to withstand temperatures and loads to adequately address climate concerns. The selection of materials that withstand potential environmental stressors related to climate will include engineering specifications that contain design specific provisions, such as: • Critical infrastructure and equipment (e.g., vessels and rigs) that will be constructed with resilient materials to prevent brittle fracture at low ambient temperature conditions • Critical infrastructure and equipment (e.g., vessels and rigs) that will be constructed to withstand the structural loading expected with high winds and weight associated with ice and snow • Winterization and freeze protection
Ice Breaking	
23	Require discussion between operators and harvesters, hunting and trapping organizations, and the Qikiqtani Inuit Association regarding potential effects and mitigations measures to minimize the effect of ice breaking on traditional harvesting and travel over ice.
Seismic Activity	
24	Infrastructure and equipment will be designed according to the Canadian Standards Association and other applicable standards and guidelines for earthquakes in this area.
Bathymetry	
25	Proper design, dredging and ballasting will be required for equipment, to allow mobilization without disturbance to the ocean floor.
Air Quality and Greenhouse Gas Emissions	
26	Sulphur content in diesel fuel will meet the *Sulphur in Diesel Fuel Regulations* and will comply with the sulfur limits in fuels for large marine diesel engines, per the *Vessel Pollution and Dangerous Chemicals Regulations* under the CSA.
27	Require adherence with the Canadian *Environmental Protection Act* for specified criteria air contaminants in exhaust emissions, relevant regulations under MARPOL, and use of the National Ambient Air Quality Objectives as the benchmark for assessing air quality

Table B.1 Summary of Standard Mitigation and Planning Considerations for Routine Activities

No.	Operator Commitment
28	Require adherence to best practices and use of best available technologies regarding fuel combustion and emission controls including: • Use of high quality fuels, e.g., low sulphur fuel oil, or natural gas as primary fuel • Minimize vessel and aircraft traffic where possible • Maintenance, inspections and efficient operation of equipment • Monitor the number of flaring events, reduce where possible • Use of efficient/reduced emission technology and incorporate into design where technically and economically feasible
29	Avoid or reduce effects of air contaminants and GHGs to the atmosphere. Mitigation measures include: • Use of best available technologies regarding fuel combustion and emission controls • Use of high quality fuels, e.g., low sulphur fuel oil, or natural gas as primary fuel • Minimize vessel and aircraft traffic through planning • Maintenance, inspections and efficient operation of equipment • Monitor the number of flaring events, reduce where possible • Use of efficient/reduced emission technology and incorporate into design where technically and economically feasible
Marine Fish and Fish Habitat	
	Use of existing and common vessel and aircraft travel routes for vessels and helicopters should be used where possible and practicable, and low-level aircraft operations should be avoided where it is not required by Transport Canada protocols;
30	Conduct an EEM that includes fish health baseline information for future effects to be measured against.
31	Prior to the start of a drilling campaign, a pre-drill survey of sensitive habitats will be undertaken. A report summarizing the mapping, risk assessment and planned mitigation measures (if sensitive habitats are identified) will be prepared and submitted for review and acceptance.
	The selection of chemicals to be discharged, including drilling fluids, should be in accordance with the Offshore Chemical Selection Guidelines for Drilling and Production Activities on Frontier Lands;
32	Relocation of well and/or redirection of WBM cuttings discharge location in the event that the survey and risk assessment identifies the need to protect sensitive benthic habitat (i.e., corals and sponges)
33	SBM-related drill cuttings will be returned to the drilling installation and treated in accordance with the OWTG. WBM-related drill cuttings will be discharged without treatment.
34	Dispose of dredge waste and waste from well head excavations away from sensitive habitats and in accordance with current regulations.
	Operational discharges should be treated prior to release in accordance with the OWTG (Offshore Waste Treatment Guidelines) and other applicable regulations and standards;
	Appropriate handling, storage, transportation, and on-shore disposal of solid and hazardous waste;
	During formation flow testing with flaring, produced hydrocarbons and produced water should be flared. If there is a large amount of produced water encountered, it should be treated in accordance with the relevant regulatory requirement prior to ocean discharge, or shipped to shore for appropriate disposal
35	Use of explosives will not be employed for removal of wellheads.
36	At the time of decommissioning a well, the well will be inspected in accordance with applicable regulatory requirements.

Table B.1 Summary of Standard Mitigation and Planning Considerations for Routine Activities

No.	Operator Commitment
Waterbirds	
37	To comply with the *Migratory Bird Convention Act* and the Migratory Bird Regulations, Environment and Climate Change Canada guidelines for disturbance to waterbirds should be followed
38	Aerial, marine, and terrestrial setbacks will be adhered to for key habitat sites and known breeding colonies, including the following: • Helicopters and other aircrafts should avoid, where feasible, established for waterbird colonies. Within the Nunavut Settlement Area, aircrafts should maintain a vertical distance of greater than 1.1 km and a horizontal distance of greater than 3 km from concentrations of waterbirds, including breeding colonies. • Vessels (e.g., seismic ships, platform and supply vessels) and drilling rigs should maintain a distance of greater than 500 m from known active waterbird colonies. Within the Nunavut Settlement Area, vessels and drilling rigs should maintain a distance of 2 km from active ivory gull breeding colonies. • On land, a setback distance of greater than 300 m should be maintained from waterbird colonies. High-disturbance activities (e.g., drilling, blasting) should maintain a distance of greater than 1 km from waterbird colonies. • Environment and Climate Change Canada setback guidelines for protected areas (e.g., National Parks, National Wildlife Areas, Migratory Bird Sanctuaries) with known waterbird breeding colonies should be followed. Canadian Wildlife Service should be contacted to obtain information on specific restrictions for aerial, marine, and terrestrial setbacks pertaining to waterbirds in protected areas.
39	All vessels, including seismic ships and platform and supply vessels, should travel parallel to shore when approaching setback distances around known active waterbird colonies (i.e., not moving directly towards a colony). In addition: • Vessels should maintain a steady course and safe vessel speed (e.g., <10 knots). • The use of loud horns or whistles should be avoided.
40	A Noise Management and Marine Activities Plan should be established and include mitigation measures for seismic surveys that are consistent with the *Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment*.
41	Exploration and development activities that can result in disturbance (i.e., physical and sensory disturbance) to waterbirds (e.g., seismic surveys, drilling, vessel and air traffic) should be avoided in key habitat sites for waterbirds (e.g., known breeding colonies) during sensitive periods for waterbirds.
42	Science Applications International Corporation's interim recommendations pertaining to pile driving and associated onset of injury to marbled murrelet should be followed.
44	During seismic and drilling operations, routine observations of waterbirds should be conducted, following applicable international and federal guidance specific to Canadian waters.
45	All air gun start-up procedures should include a ramp-up or soft-start period at a rate not exceeding 5 dB per 5 minute period.
46	To reduce the risk of injury or mortality to waterbirds, artificial lighting sourced from marine infrastructure or seismic and drilling vessels should be limited, to the extent feasible. A Wildlife Management Plan should be established and include the following mitigation measures: • Use shielded or directional lighting to reduce potential adverse interactions of artificial light emissions with waterbirds. • Routine searches for stranded waterbirds should be conducted on vessels and marine infrastructure. Appropriate protocols for the handling and release of waterbirds should be implemented for any birds that become grounded and stranded on vessels or marine infrastructure. A waterbird handling permit should be obtained from Environment and Climate Change Canada. • Waterbird injuries or fatalities will be documented and reported to the applicable regulator(s) (e.g., Environment and Climate Change Canada).

Table B.1 Summary of Standard Mitigation and Planning Considerations for Routine Activities

No.	Operator Commitment
47	Routine flaring should be conducted only when necessary and should occur outside periods of peak movement for waterbirds (e.g., migration, during inclement weather). The duration of flaring events should be limited, to the extent feasible, and maintenance flaring events should be scheduled during daylight hours to reduce the risk of injury or mortality to waterbirds.
48	To comply with the *Migratory Bird Convention Act* and the Migratory Bird Regulations, which prohibit the deposition of harmful substances in areas frequented by migratory birds, A Waste Management Plan should be established and include the following mitigation measures: • Sewage and kitchen waste from vessels should be macerated in accordance with applicable *Offshore Waste Treatment Guidelines* (NEB et al. 2010) and other applicable regulations and standards. • National Energy Board guidelines on approaches for identification of less toxic drilling mud additives and production chemicals should be followed. • Other than residual base fluid retained on cuttings, no synthetic-based mud or enhanced mineral oil-based mud fluid, or any whole mud containing these constituents, should be discharged to the sea, and under no circumstances should oil base fluid or whole mud containing oil base fluid be discharged. • To minimize the quantity of oil discharged into the marine environment, the National Energy Board recommends operators use water-based mud or low polyaromatic hydrocarbon content, non-toxic and biodegradable synthetic-based mud.
Marine Mammals	
49	Project associated vessels should use existing and common travel routes where possible and practical. Vessels should maintain a steady course and safe vessel speed (e.g., <10 knots) whenever possible.
50	Time seismic surveys to avoid overlap with migration routes during specific times of the year
51	Time seismic surveys to avoid overlap with hunting activities
52	Plan around or avoid key habitats (e.g., NW Polynya) and sensitive times of year (e.g., pupping)
53	Complete marine mammal surveys prior to icebreaking activities to minimize risk of disturbing pupping lairs
54	Use of explosives should not be employed for removal of wellheads.

Table B.1 Summary of Standard Mitigation and Planning Considerations for Routine Activities

No.	Operator Commitment
55	Apply mitigation measures during seismic surveys to be consistent with the *Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment* (SOCP) (DFO 2007). The following is a partial list of those mitigation measures. • Trained MMOs will be used to monitor and report on marine mammal sightings during surveys where seismic source arrays are used. • A ramp-up of the source array (i.e., gradually increasing seismic source elements over a period of at least 20 minutes until the operating level is achieved) starting from a single source element. • Ensure that all air gun start-up procedures include a "soft start/ramping up" period. The rate of ramping up will be monitored so that it will not exceed more than 5db per 5 minute period. • MMOs will implement a pre-ramp up watch of 30 minutes prior to the start of the air source. Ramp-up will be delayed if any marine mammal is sighted within the safety zone. • Ensure that all air gun start-up procedures will not commence unless a full 1000 metre safety zone is clear of any marine mammal or colonies of seabirds by visual inspection by a trained Marine Mammal Observer for a continuous period of at least 30 minutes. Air guns must be shut down if any marine mammal enters or is anticipated to enter the 1000 metre safety zone. • Shut down of the seismic source array if a marine mammal listed as endangered or threatened on SARA Schedule 1. • Only operate the air gun array when the visibility is sufficient to allow MMOs to do their job effectively. The Proponent shall suspend all project activities should any dead fish or wildlife, or any injured wildlife be observed in the wake of the vessel. Resumption of activities will be dependent on the results of discussions with Fisheries and Oceans Canada (DFO) and Government of Nunavut – Department of Environment representatives, and the circumstances leading to the injuries or mortalities.
56	Implement a Marine Mammal Management Plan that includes marine mammal monitoring (to be undertaken by qualified observers) for all vessel-related activities. Establish safe vessel operations protocols (including safety perimeters, speed and course restrictions and suspension of work requirements) to avoid marine mammals and sensitive marine mammal habitats.
57	Develop and implement program specific polar bear interaction and management plan that includes procedures and protocols for polar bear interactions
58	Establish and implement an air operations plan to provide minimum operational altitudes and speeds and other operating procedures and protocols (including mapping locations of sensitive marine mammal habitat and locations along potential flight paths) to minimize potential interactions with marine mammals.
59	Establish oiled wildlife response plans – immediate in the field and longer term (through engagement of oiled wildlife rehabilitation organization)
60	Research response technologies applicable to offshore oil containment and recovery to reduce the risk of oiling of the sea ice edge and coastal environments that provide key habitat to various marine mammals (e.g., pinnipeds and polar bear)
Human Environment	
61	Use of a Fisheries Liaison Officer (see **Commercial Fisheries and Other Ocean Users**).
62	Providing Notice to Shippers of planned oil and gas activity through the Canadian Coast Guard.
63	Compensation program for loss or damages to commercial fishers, including Commercial-communal fishers, attributable to the operator resulting from an accidental release of oil or other contaminants, or debris, or expenses incurred in taking remedial action. Actual loss or damage to include: loss of income or future income; loss of hunting, fishing, or gathering opportunities; and costs and expenses incurred for action taken to remedy a situation involving a spill, including measure to control or clean it
64	Early discussions with stakeholders to alert them to and discuss employment and business opportunities that may arise from oil and gas activity.

Table B.1 Summary of Standard Mitigation and Planning Considerations for Routine Activities

No.	Operator Commitment
65	Partnerships with educational institutions to train and develop local capacity for employment on future oil and gas activity.
66	Supplier development initiatives to help local businesses prepare to support potential oil and gas activity.
67	A Benefits Plan developed by operators and approved by government (territorial and/or federal), outlining initiatives and programs to enhance benefits to local residents, communities, and businesses.
68	Projects be regulated by the Government of Canada and require a Benefits Agreement between it and the operator(s).
69	Regulations should anticipate timelines for each activity, and the subsequent potential duration of interactions with the human environment: • Seismic activity has a short timeframe (2 to 3 months to complete a survey) • Exploration drilling can also have a short timeframe (35 to 65 days per well) but can be extended depending on the number of wells being drilled per drilling program. • Production has the longest timeline, approximately 10 to 30 years for a producing field, which can increase the level of interaction between the project and the human environment.
Commercial Fisheries and Other Ocean Users	
70	Establishment of a safety zone around drilling installations
71	Providing Notice to Shippers of planned oil and gas activity through the Canadian Coast Guard.
72	Schedule appropriate project activities based on information acquired from consultation with local residents, so as to ensure that project activities will not interfere with Inuit wildlife harvesting or traditional land use activities.
73	Ongoing communications with commercial fishers through traditional and commercial fisheries liaisons and seafood producers regarding planned project activities, including timely communication of drilling locations, safety zone and decommissioned wellsites. This information will also be communicated to Indigenous commercial fishers in accordance with the Indigenous Communities Fisheries Communication Plan.
74	Ongoing communications with the NAFO Secretariat, through DFO as the Canadian representative, regarding planned project activities, including timely communication of drilling locations, safety zone and decommissioned wellsites.
75	Require a Fisheries Liaison Officer (FLO) and/or fisheries guide vessels during drilling installation movement from port to its offshore location, and/or geophysical programs.
76	A single point of contact (SPOC) will be established during project activities to facilitate communications between fishers and the operator regarding gear loss/damage and other compensation matters.
Consultation and Engagement	
77	A copy of the EIS update will be sent to all Indigenous groups and stakeholders. The Operator will follow up with Indigenous groups and stakeholders on any questions arising from the EIS update.
78	Communicate with relevant Indigenous communities and representative organizations, through established and/or informal engagement processes, as required and requested. The specific nature, frequency, subject matter and format of such future engagement will be determined in discussion with the Indigenous organizations and outlined in an Indigenous Communities Fisheries Communication Plan.
79	Conduct meaningful public consultation in potentially interested communities in the North Baffin region by providing clear, non-technical information and an opportunity for additional mitigation measures to be developed to address public concerns prior to commencement of the project.

Table B.2 Summary of Standard Mitigation and Planning Considerations for Accidents and Malfunctions

No.	Operator Commitment
General*	
1	Adherence to all applicable acts, regulations and guidelines (environmental and drilling/production), as applicable.
2	Maintain adequate oil spill response equipment and personnel to respond to terrestrial and marine spills
3	Train personnel in acceptable refueling procedures and establish specific refueling locations
4	Use secondary containment at temporary fuel storage and transfer locations including using drip pans and liners, which should be mandatory.
5	Develop and implement an Oil Spill Response Plan that covers incidents at sea and onshore.
6	Spill prevention plans and procedures as required by regulatory authorities, will be developed and submitted for approval to regulatory authorities as a requirement of the Operations Authorization.
7	Develop a shoreline sensitivity atlas for the region to identify resources that are vulnerable to oil spills. The atlas should include: • baseline coastal information such as shoreline form, substrate and vegetation type • biological resources and sensitive human use resources from both scientific and traditional knowledge sources. • Indication of potential oil residency in different shoreline/substrate types
8	Identify and analyze potential risks and design/implement engineering controls and procedures to reduce or eliminate hazards
9	Monitor, maintain and repair equipment
10	Use comprehensive internal and external reviews, inspection, testing and audit programs of facilities, equipment and processes
11	Train workers to recognize and respond to potential emergencies
12	Evaluate and implement new research and technology as they become available
13	Evaluate marine transportation risks and develop marine transportation strategy for the region

APPENDIX C Underwater Noise Thresholds

C.1 Underwater Noise Thresholds

Underwater noise has the potential to mask (e.g., changes in communication space), change behaviour or cause injury to species exposed to it (e.g., Popper et al. 2014; Southall et al. 2007). The level of the effect is based on several factors including: distance of the animal from the noise source, sound levels produced by the source and received by the animal, and duration of exposure to the noise.

Thresholds for the effects of underwaters noise have been developed for some species. The extent to which these thresholds have been developed is largely dependent on available information on hearing levels for different species, information on the effects of underwater noise (e.g., will behavioural effects occur), available information on species use of sound, and relevant noise sources and their sound levels that species may be exposed to.

Canadian regulatory agencies have not established underwater noise thresholds for marine fish, waterbirds or marine mammals, although to date, for marine mammals, DFO generally follows those established by NOAA (2016), and other guidelines for fish and waterbirds have been put forward (SAIC 2011; Popper et al. 2014). In addition, underwater noise effects are characterized using the best available information in peer reviewed literature and will be applied to this Project to provide further understanding of potential effects of underwater noise on marine fish, waterbirds, and marine mammals in the Area of Focus.

C.2 Noise Metrics

Underwater noise is typically characterized using two main metrics: received sound pressure level (SPL), measured in dB re 1 µPa, and/or sound exposure level (SEL), a measure of sound energy over time measured in dB re 1 $\mu Pa^2 s$. These metrics are further categorized as:

- Peak SPL (SPL_{peak}): the maximum sound pressure level at any given moment produced by a particular activity
- Root mean square SPL (SPL_{RMS}): average root mean square pressure level over a given amount of time
- Cumulative SEL (SEL_{cum}): cumulative energy exposure over a given period of time

The effects that noise may have will vary by species group, species and noise source. For each species group developed thresholds are outlined below.

C.3 Marine Fish

Recent research on the effects of underwater noise and potential injury thresholds for marine fish were reviewed and published by Popper et al. (2014). The authors determined that aside from sounds levels and exposure as detailed above, effects of underwater noise on fish varies depending on the physiology of the species. As a result, fish were grouped into three categories listed in increasing susceptibility to sudden pressure changes caused by underwater noise.

- Fishes with no swim bladder or other gas chamber (e.g., Greenland halibut and other flatfish): hearing involves particle motion not sound pressure, and as a result species in this group are generally considered less susceptible to barotrauma from sudden pressure changes caused by underwater noise
- Fishes with swim bladders that do not involve hearing (e.g., Atlantic salmon): hearing involves particle motion not sound pressure, and thus relatively more susceptible to barotrauma from sudden pressure changes caused by underwater noise
- Fishes in which hearing involves a swim bladder or other gas volume (e.g., Atlantic cod, herring and relatives, Otophysi): hearing involves particle motion and sound pressure, and thus considered the most susceptible to barotrauma from sudden pressure changes caused by underwater noise

In addition, fish eggs and larvae, regardless of category, are susceptible to underwater noise which may affect development and survival (Popper and Hastings 2009).

Injury and behavioural guidance on the effects of underwater noise for marine fish have been separated based on source type of effect as well as by fish category (Table C-1). For noise sources or effects that have limited information available, a qualitative risk of the effect is provided by Popper et al. (2014), rather than specific sound level thresholds. The effects, as defined by Popper et al. (2014), are as follows:

- Mortality and potential mortal injury—immediate or delayed death.
- Recoverable injury—injuries, including hair cell damage, minor internal or external hematoma, etc. None of these injuries are likely to result in mortality.
- Temporary Threshold Shift—short or long term changes in hearing sensitivity that may or may not reduce fitness.
- Masking—impairment of hearing sensitivity by greater than 6 dB, including all components of the auditory scene, in the presence of noise.
- Behavioural effect—substantial change in behavior for the animals exposed to a sound. This may include long-term changes in behavior and distribution, such as moving from preferred sites for feeding and reproduction, or alteration of migration patterns. This behavioral criterion does not include effects on single animals, or where animals become habituated to the stimulus, or small changes in behavior such as a startle response or small movements.

Table C-1 Underwater Noise Thresholds (Root Mean Squred [RMS], SEL, and SPL), by Noise Source, Causing Mortality, Recoverable Injury, Temporary Threshold Shift (TTS), Masking, and Change in Behaviour in different Types of Fish

Type of fish	Noise source	Mortality and potential mortal injury	Recoverable injury	TTS	Masking	Behaviour
Fish with no swim bladder (particle motion detection)	Impact pile driving	>219 dB SEL_{cum} or >213 db SPL_{peak}	>216 dB SEL_{cum} or >213 db SPL_{peak}	>>186 dB SEL_{cum}	(N) Moderate (I) Low (F) Low	(N) High (I) Moderate (F) Low
	Seismic airguns	>219 dB SEL_{cum} or >213 dB SPL_{peak}	>216 dB SEL_{cum} or >213 dB SPL_{peak}	>>186 dB SEL_{cum}	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low
	Low frequency sonar*	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	>193 dB SPL_{rms}	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low
	Mid frequency sonar**	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	NA	NA	NA
	Shipping and other continuous sound[t]	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) Moderate (I) Moderate (F) Low
Fish with swim bladder (particle motion detection)	Impact pile driving	>210 dB SEL_{cum} or >207 dB SPL_{peak}	>203 dB SEL_{cum} or >207 dB SPL_{peak}	>186 dB SEL_{cum}	(N) Moderate (I) Low (F) Low	(N) High (I) Moderate (F) Low
	Seismic airguns	>210 dB SEL_{cum} or >207 dB SPL_{peak}	>203 dB SEL_{cum} or >207 dB SPL_{peak}	>>186 dB SEL_{cum}	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low
	Low frequency sonar*	>193 dB SPL_{rms}	>193 dB SPL_{rms}	>193 dB SPL_{rms}	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low
	Mid frequency sonar**	>210 dB SPL_{rms}	>210 dB SPL_{rms}	NA	NA	NA
	Shipping and other continuous sound[t]	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) Moderate (I) Moderate (F) Low
Fish with swim bladder involved in hearing	Impact pile driving	>207 dB SEL_{cum} or >207 dB SPL_{peak}	>203 dB SEL_{cum} or >207 dB SPL_{peak}	>186 dB SEL_{cum}	(N) High (I) High (F) Moderate	(N) High (I) High (F) Moderate
	Seismic airguns	>207 dB SEL_{cum} or	>203 dB SEL_{cum} or >207 dB	>186 dB SEL_{cum}	(N) Low (I) Low (F) Moderate	(N) High (I) High (F) Moderate

Table C-1 Underwater Noise Thresholds (Root Mean Squred [RMS], SEL, and SPL), by Noise Source, Causing Mortality, Recoverable Injury, Temporary Threshold Shift (TTS), Masking, and Change in Behaviour in different Types of Fish

Type of fish	Noise source	Mortality and potential mortal injury	Recoverable injury	TTS	Masking	Behaviour
		>207 dB SPL_{peak}	SPL_{peak}			
	Low frequency sonar*	>193 dB SPL_{rms}	>193 dB SPL_{rms}	>193 dB SPL_{rms}	(N) Moderate (I) Low (F) Low	>197 dB SPL_{rms}
	Mid frequency sonar**	>210 dB SPL_{rms}	>210 dB SPL_{rms}	>210 dB SPL_{rms}	(N) Low (I) Low (F) Low	>209 dB SPL_{rms}
	Shipping and other continuous sound[t]	(N) Low (I) Low (F) Low	>170 dB SPL_{rms} for 48 h	>158 dB SPL_{rms} for 12 h	(N) High (I) High (F) High	(N) High (I) Moderate (F) Low
Eggs and larvae	Impact pile driving	>210 dB SEL_{cum} or >207 dB SPL_{peak}	(N) Moderate (I) Low (F) Low	(N)Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low
	Seismic airguns	>210 dB SEL_{cum} or >207 dB SPL_{peak}	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low
	Low frequency sonar*	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low
	Mid frequency sonar**	NA	NA	NA	NA	NA
	Shipping and other continuous sound[t]	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low	(N) Moderate (I) Moderate (F) Low

NOTES:
Relative risk of an effect (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N), intermediate (I), and far (F). There is insufficient data to quantify the distances and relative terms further.
NA – If an effect is considered not likely to happen
*primary frequency of 1 kHz and less
**primary frequency of 1 kHz to 10 kHz
[t] other sounds such as vibratory pile driving and dredging

ADAPTED FROM: Popper et al. 2014

C.4 Waterbirds

There are few studies that characterize effects to waterbirds from acute or chronic underwater noise, and species-specific differences remain poorly described in the literature. Birds are considered visual hunters and not thought to use underwater sound emissions for communication or foraging. Many bird species, however, are excellent divers and may be able to spend extended periods of time underwater or dive to great depth (>200 m). Such foraging strategies may expose them to underwater noise with the potential to cause injury (SAIC 2011) or changes in habitat use or behaviour (Ronconi and St. Clair 2002; Bellefleur et al. 2009; SAIC 2011).

Interim recommendations were developed by Science Applications International Corporation (SAIC, 2011) on behalf of the US Navy, specifically for evaluating the onset of injury to marbled murrelet (a protected species) from pile driving. The SAIC determined that an underwater cumulative SEL of 202 dB re 1 $\mu Pa^2 s$ can cause auditory injury (e.g., loss of cochlear hair cells) to marbled murrelet, and that cumulative SELs exceeding 208 dB re 1 $\mu Pa^2 s$ SEL could result in non-auditory injury (e.g., barotrauma). We are not aware of other studies that have suggested potential injury thresholds for waterbirds.

Behavioural underwater noise thresholds for waterbirds have not been developed, even though displacement has been observed. The degree of this behavioural disturbance observed has varied by species, age, and seasonal sensitivity (Bellefleur et al. 2009; Schwemmer et al. 2011; Velando and Munilla 2011; Agness et al. 2013).

Given best available scientific evidence, SAIC (2011) concluded that terrestrial and marine mammals represent reasonable surrogates for characterizing auditory injuries to marbled murrelets, while thresholds for fish are useful for estimating non-auditory injuries to marbled murrelets.

C.5 Marine Mammals

Underwater noise thresholds for marine mammals, for both injury and behavioural disruption, have been established by the National Oceanic and Atmospheric Administration (Table C-2). The thresholds are divided based on hearing group, type of effect and noise type. The potential effects specified for the thresholds include:

- Permanent Threshold Shift: an elevated hearing threshold (i.e., a loss of hearing sensitivity) that remains elevated after some extended period of time (NOAA 2016).
- Behavioural: Disruption: disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering

Impulsive: Noise types, as defined by NOAA (2016), are:

- Impulsive: produce sounds that are typically transient, brief (less than 1 second), broadband, and consist of high peak sound pressure with rapid rise time and rapid decay.
- Non-Impulsive: produce sounds that can be broadband, narrowband or tonal, brief or prolonged, continuous or intermittent and typically do not have a high peak sound pressure with rapid rise/decay time that impulsive sounds do.

Table C-2 NMFS Marine Mammal Underwater Noise Thresholds for Injury and Behavioural Disruption

	PTS onset[a]		**Behavioural disruption[b]**	
Hearing group	**Impulsive**	**Non-impulsive**	**Impulsive**	**Non-impulsive**
Low-frequency cetaceans (baleen whales)	>219 dB SPL_{peak}; >183 dB $SEL_{cum24hr}$	>199 dB $SEL_{cum24hr}$	>160 dB SPL_{rms}	>120 dB SPL_{rms}
Mid-frequency cetaceans (dolphins, toothed whales, beaked whales, bottlenose whales)	>230 dB SPL_{peak}; >185 dB $SEL_{cum24hr}$	>198 dB $SEL_{cum24hr}$		
High-frequency cetaceans (true porpoises)	>202 dB SPL_{peak}; >155 dB $SEL_{cum24hr}$	>173 dB $SEL_{cum24hr}$		
Phocid pinnipeds (underwater) (true seasl)	>218 dB SPL_{peak}; >185 dB $SEL_{cum24hr}$	>201 dB $SEL_{cum24hr}$		
Otariid pinnipeds (underwater) (sea lions and fur seasl)	>232 dB SPL_{peak}; >203 dB $SEL_{cum24hr}$	>219 dB $SEL_{cum24hr}$		
NOTE: SEL_{cum} thresholds are weighted by the hearing group auditory weighting function.				
SOURCES: [a]NMFS (2016); [b]NOAA (2016)				