Biophysical and Ecological Overview Summary of the Qikiqtait Study Area and Adjacent Waters

David J. Yurkowski, Kelsey F. Johnson, Paloma C. Carvalho, Michael W. Johnson, Angèle Watrin Prodaehl, Theresa Mackey, Kathleen Dawson, Lauren Candlish, David W. Capelle, Karen Dunmall, Les N. Harris, Steven H. Ferguson, Marianne Marcoux, Darcy McNicholl, Arnaud Mosnier, Andrea Niemi, John O'Brien, Marie Pierrejean, Cortney Watt

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BIOPHYSICAL AND ECOLOGICAL OVERVIEW SUMMARY OF THE QIKIQTAIT STUDY AREA AND ADJACENT WATERS

by

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ABSTRACT

Yurkowski, D.J., Johnson, K.F., Carvalho, P.C., Johnson, M.W., Prodaehl, A.W., Mackey, T., Dawson, K., Capelle, D.W., Dunmall, K., Harris, L.N., Ferguson, S.H., Marcoux, M., McNicholl, D., Mosnier, A., Niemi, A., O'Brien, J., Pierrejean, M., Watt, C. 2023. Biophysical and Ecological Overview Summary of the Qikiqtait Study Area and Adjacent Waters. Can. Tech. Rep. Fish. Aquat. Sci. 3565: ix + 148 p.

The Government of Canada has committed to protect 25% of its marine waters by 2025. Qikiqtait is an area within the Belcher Island Ecologically and Biologically Significant Area in Nunavut waters in southeast Hudson Bay and has been identified for conservation protection. This unique area is comprised of valuable ecosystem components that includes: 1) strong upwelling and a recurrent biologically important polynya system in the winter, 2) large river plume and estuaries, 3) a productive benthic invertebrate community, 4) large aggregations of Common Eider (*Somateria mollissima sedentaria)*, 5) migratory Arctic char (*Salvelinus alpinus*) and subsistence foods, 6) resident marine mammals such as Atlantic Walrus (*Odobenus rosmarus rosmarus*), Bearded Seal (*Erignathus barbatus*), Beluga (*Delphinapterus leucas*), Polar Bear (*Ursus maritimus*), and Ringed Seal (*Pusa hispida*), as well as 7) feeding and calving areas for a proportion of these marine mammal species. This report provides a comprehensive synthesis of the unique physical, biological and ecological features that characterize the Qikiqtait area and its adjacent waters, as well as known vulnerabilities and knowledge gaps.

RÉSUMÉ

Yurkowski, D.J., Johnson, K.F., Carvalho, P.C., Candlish, L., Capelle, D.W., Johnson, M.W., Prodaehl, A.W., Mackey, T., Dawson, K., Dunmall, K., Harris, L.N., Ferguson, S.H., Marcoux, M., McNicholl, D., Mosnier, A., Niemi, A., O'Brien, J., Pierrejean, M., Watt, C. 2023. Biophysical and Ecological Overview Summary of the Qikiqtait Study Area and Adjacent Waters. Can. Tech. Rep. Fish. Aquat. Sci. 3565: ix + 148 p.

Le gouvernement du Canada s'est engagé à protéger 25 % de ses milieux marins d'ici 2025. La région de Qikiqtait, qui a été cernée aux fins de conservation et de protection, fait partie de la zone d'importance écologique et biologique des îles Belcher, située dans les eaux du Nunavut, au sud-est de la baie d'Hudson. Cette région unique comprend des composantes importantes de l'écosystème, notamment : 1) de fortes remontées d'eau froide et un système de polynie important sur le plan biologique qui revient chaque hiver; 2) des panaches fluviaux et des estuaires de grande taille; 3) une communauté d'invertébrés benthiques productive; 4) de grands rassemblements d'Eiders à duvet (*Somateria mollissima sedentaria)*; 5) des populations migratrices d'ombles chevaliers (*Salvelinus alpinus*) et des aliments de subsistance; 6) des mammifères marins résidents, comme le morse de l'Atlantique (*Odobenus rosmarus rosmarus*), le phoque barbu (*Erignathus barbatus*), le béluga (*Delphinapterus leucas*), l'ours polaire (*Ursus maritimus*) et le phoque annelé (*Pusa hispida*); 7) des zones d'alimentation et de mise bas pour certains de ces mammifères marins. Le présent rapport fournit une synthèse détaillée des caractéristiques physiques, biologiques et écologiques uniques de la région de Qikiqtait et des eaux adjacentes, et présente les lacunes dans les connaissances et les vulnérabilités connues.

INTRODUCTION

Under the authority of the *Oceans Act* (1996), with Indigenous partners, Fisheries and Oceans Canada (DFO) is working to establish a national system of marine protected areas (MPAs) to conserve and protect Canada's marine resources. Under this commitment, 25% of Canada's marine waters will have protection by 2025 and then 30% by 2030. The National Framework for Establishing and Managing MPAs outlines four major steps as follows: 1) select the Area of Interest (AOI); 2) conduct an overview and assessment of the (AOI); 3) develop regulatory intent and documents; and 4) manage the MPA (DFO 1999, 2010a). The identification and characterization of Ecologically and Biologically Significant Areas (EBSAs) is an important component of the AOI assessment process and follows the scientific criteria endorsed by the Convention on Biological Diversity (UNEP/CBD 2008). EBSAs are unique areas in the ocean that have special importance in its ecological and biological characteristics that supports the healthy functioning of oceans and provides essential habitat, food sources or breeding grounds for certain species (DFO 2011).

The Belcher Islands EBSA was identified in 2011 as part of a larger evaluation conducted by DFO to identify EBSAs throughout Canada's Arctic (DFO 2011). It is located in the southeastern corner of Hudson Bay, extending approximately 250 km out from the mainland Quebec shoreline, spanning from the north end of James Bay in the south to Inukjuak in the north, and encompasses the Belcher Island Archipelago (Figure 1). The proposed 2,866 km^2 Qikiqtait Study Area (QSA) (QIA Prospectus 2022), which includes the Inuit community of Sanikiluaq on the northern tip of Flaherty Island (Government of Canada 2016), falls within the boundaries of the Belcher Islands EBSA. For purposes of this report, information from the QSA and adjacent waters within the Belcher Islands EBSA will be summarized.

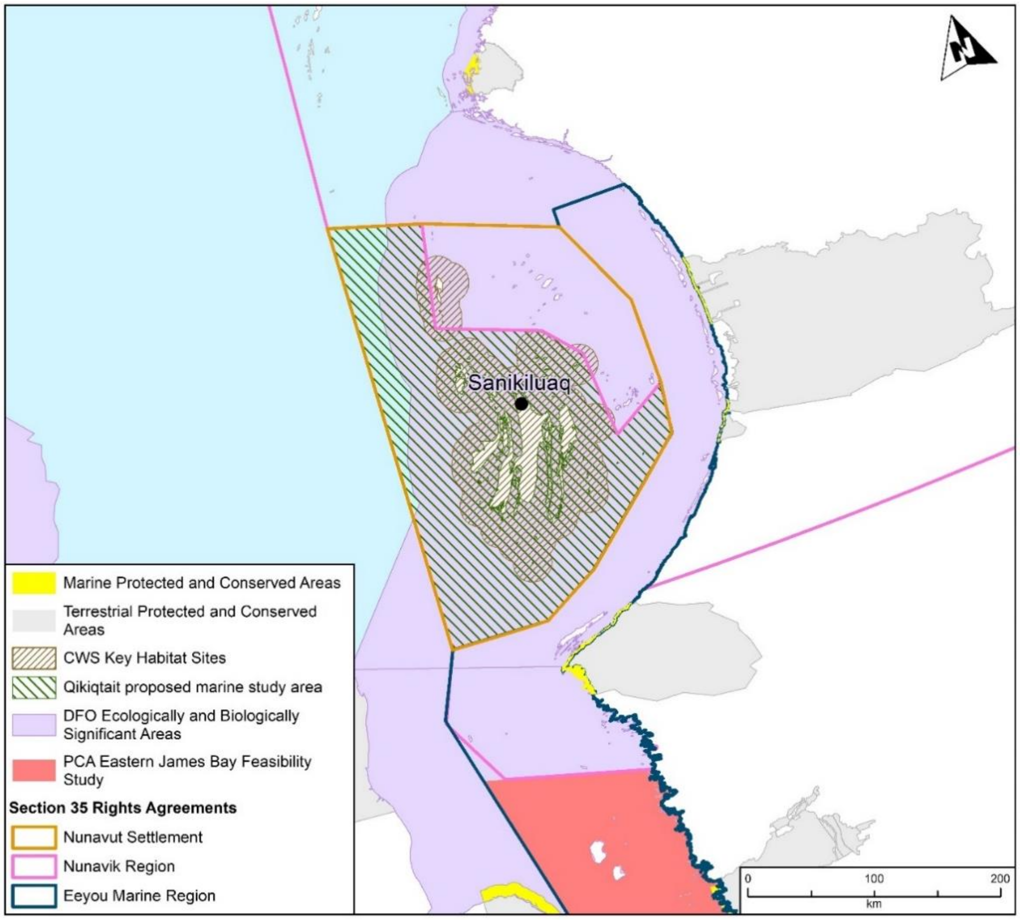


Figure 1. The proposed Qikiqtait Study Area (QSA) and Ecologically and Biologically Significant Area in southeastern Hudson Bay. Source: DFO (2022) and QIA Prospectus (2022); CWS: Canadian Wildlife Service

The QSA consists of a rich marine ecosystem that continues to support specialized maritime culture. One of the more important physical features of this area are the several annually recurring polynyas that are due to the presence of small estuaries, strong inter-island currents, and local oceanography (DFO 2011). These polynyas are key habitats for Polar Bears (*Ursus maritimus*), sea birds, and seals during winter (Gilchrist and Robertson 2000). The QSA is also critical habitat for overwintering Beluga (*Delphinapterus leucas*) and Atlantic Walrus (*Odobenus rosmarus rosmarus*) populations and is vital for their fitness consequences and feeding (DFO 2011). The Belcher Islands region also has some the coldest summer sea-surface temperatures in coastal Hudson Bay south of Southampton Island, suggesting strong vertical mixing that sustains high primary productivity (Galbraith and Larouche 2011).

This document provides a summary of existing scientific information and where possible incorporates Inuit Qaujimajatuqangit (IQ) compiled in reports and books relevant to the QSA and adjacent waters within the Belcher Islands EBSA.

ENVIRONMENTAL AND ECOLOGICAL INFORMATION

REGIONAL CONTEXT

The QSA is located in southeastern portion of the Hudson Bay Complex (HBC) (Figure 2). The HBC consists of Hudson Bay, James Bay, Hudson Straight, and Foxe Basin (DFO 2009). The QSA boundaries extend from Inukjuak on the Québec coast southward to the entrance to James Bay by Long Island and includes the coastal communities of Umiujaq, Manitounuk Islands, Kuujjuarapik-Whapmagoostui. The western boundary of the QSA encompasses the Belcher Islands, which are comprised of approximately 1,500 islands, and include a number of long and narrow islands and peninsulas that are separated by narrow channels and fjords that are oriented in a northeast-southwest direction (Petrusevich et al. 2018). This area features four large islands (Kugong Island, Flaherty Island, Tukarak Island, and Split Island). The largest island, Flaherty Island, is 70 km long and 40 km wide, another 14 islands range from 9-29 km long, and a large number of islands including the Bakers Dozen and King George Islands are small (Figure 3) (Jackson 2013). In its entirety, Belcher Islands covers about 3,000 km^2. Within the QSA are unique physical features such as annual reoccurring polynyas, several small estuaries, and cooler water temperatures than surrounding Hudson Bay waters (DFO 2011). Draining into the area are also significant rivers from the coast of Québec and James Bay including the Great Whale River (GWR) and La Grande River (LGR).

There are a number of communities within or along the borders of the QSA that use marine resources in the area. The town of Inukjuak is the northernmost community along the Québec coast within the Belcher Islands and it has a population of 1,820 people (Art Nunavik 2022a). Located to the southeast of the Belcher Islands, near the outlet of the GWR, is the town of Kuujjuarapik. Kuujjuarapik is a community of approximately 800 people located at the southern edge of ancestral Inuit hunting grounds and at the northern edge of Cree territory (Art Nunavik 2022b). This town includes two distinct municipalities, Kuujjuarapik (Inuit) and Whapmagoostui (Cree).

Sanikiluaq, on the northern tip of Flaherty Island, is the only town in the Belcher Islands. It is an Inuit community with a population of about 900 people and a Dorset Inuit culture dating back 3,000 years (Lynch 1990; Oakes 1991; Qikiqtani Inuit Association 2015). As a community, Sanikiuarmiut integrate their traditions and knowledge to sustainably hunt and harvest for their people, resulting in a deep understanding of and a reliance on the environment (Nakashima 1991; Oakes 1991; Stewart and Lockhart 2005; Arctic Eider Society 2011).

Figure 2. The Belcher Islands (Sanikiluaq) regional reference within southeastern Hudson Bay. Source: (Kuzyk and Candlish 2019).

Figure 3. The Belcher Islands. Source: Google Earth, 2023.

CLIMATE VARIABLES AND DATA SOURCES

Weather and climate are two distinct but related concepts that describe different aspects of the Earth's atmosphere. Weather refers to the short-term atmospheric conditions in a particular area, typically observed over a period of hours, days, or weeks. It encompasses variables such as temperature, humidity, precipitation, wind speed, and atmospheric pressure. Weather conditions are highly variable and can change rapidly, often influenced by local factors, such as air masses, fronts, and topography. Weather forecasts aim to predict these short-term atmospheric conditions to assist with daily planning and decision-making. On the other hand, climate refers to the long-term average of weather patterns in a specific region over a period of decades, centuries, or even longer. Climate takes into account factors like temperature, precipitation, wind patterns, and other climatic elements. Climate change refers to shifts in these long-term averages and patterns, often caused by natural processes or human activities. Climate observations are typically gathered over a minimum of 30 years to establish robust statistical averages and identify meaningful trends.

To meet the World Meteorological Organization's (WMO) standards for weather stations, certain requirements must be fulfilled. These guidelines ensure the quality, accuracy, and reliability of weather data collected by stations worldwide. Some key requirements include location, high quality instrumentation, observation practices, data management, and quality control.

Standardized observation practices and protocols must be followed to ensure consistency and comparability of data. This includes using specific time intervals for observations and reporting. Rigorous quality control procedures must also be in place to identify and correct any errors or anomalies in the collected data.

WMO has also established that climate normals (arithmetic means or averages over a minimum of 30 years) should be calculated for each month or the year from daily data. If data is missing for more than 3 consecutive days or a total of 5 days per month, that month of data cannot be used for climate normals. Within the HBC only 4 weather stations meet these rigorous standards for calculating climate normals (Kuzyk and Candlish 2019). As of 2019, the nearest weather station to the QSA to meet WMO standards was in Kuujjuarapik.

Precipitation is inherently hard to measure due to several factors. Precipitation can vary significantly in space and time. It can be unevenly distributed across a given area, with some locations experiencing heavy rainfall while others remain dry. Precipitation events can also be short-lived and occur sporadically, making it difficult to capture the full range of precipitation patterns accurately. Precipitation can occur in various forms, including rain, snow, sleet, and freezing rain. Each type has its own unique properties, making their accurate measurement more complex. Measuring snowfall can be challenging due to factors such as wind effects, snowdrifts, compaction, and melting (Goodison et al. 1997). Precipitation measurement instruments are also prone to errors and limitations. Rain gauges can be affected by wind-induced splashing, evaporation, and gauge undercatch (when some precipitation is missed due to wind effects). Within the HBC precipitation measurements are very sparse. This limited coverage can impacts the accuracy and representation of precipitation patterns in the region.

CLIMATE

The HBC is abnormally cold compared to other areas at the same latitude and has a strong influence on the surrounding land and extent of permafrost (Thompson 1968; Danielson 1969; Maxwell 1986; Ecoregions Working Group 1989). The Belcher Islands are located within the high sub-Arctic climate zone and consists of short, cool summers, followed by long snow-covered winters. Permafrost is discontinuous throughout the islands and surface materials consists of bedrock with some organic cover (Jackson 1960b). Seasonal changes in Arctic air masses and warm water influence the weather patterns on the islands. In summer, thunderstorms and cloud cover are common in the Belcher Islands as storms frequently move across central Hudson Bay from the west or southwest (Stewart and Lockhart 2005). In fall, cold Arctic air masses move southward and accumulate heat and moisture, resulting in cloudiness and snowfall (Stewart and Lockhart 2005). During winter, the Belcher Islands experience consistently low temperatures [mean of -18.5°C] and snow cover; however, they do not experience the extreme windchills like the west coast of Hudson Bay (Stewart and Lockhart 2005). The coastlines of the Belcher Islands are relatively dry in comparison to low-lying areas along the Hudson Bay, including decreasing organic cover and vegetation heading northward on the islands with a shallow layer of rocky soil (Stewart and Lockhart 2005).

The average air temperatures and mean precipitation data by month for Sanikiluaq used in this report were only measured between 1988-2022 and 2014-2022, respectively. Average temperatures in the HBC range from 2–12°C in the summer and between -16 to -30°C in the winter (Kuzyk and Candlish 2019). In the Belcher Islands, annual average temperature is -4.5°C (ClimateData.ca 2018), with daily high temperatures ranging from -23°C in February to 10°C in August (Figure 4). From late October to late May, daily temperatures remain below freezing. Prevailing winds are from the north/northeast (ECCC 2022). Mean annual precipitation from 1951–1980 was 493 mm (ClimateData.ca 2018). Daily precipitation is lowest in January at 0.2 mm and highest in October at 1.8 mm with general increased precipitation (above 1.0 mm) from

June to November (Figure 5). Along the coast of Québec, Inukjuak experiences cooler temperatures than the Belcher Islands area with an annual average of -7°C, and has annual precipitation ranging from 400–500 mm (Stewart and Lockhart 2005). At Kuujjuarapik, temperatures are generally warmer than the Belcher Islands and Inukjuak areas. From 1981–2010, Kuujjuarapik annual average temperature was -4.0°C with daily maximum temperatures ranging from -28.3°C in February to 16.1°C in August (Government of Canada 2022). Mean annual precipitation was 660 mm from 1990 to 2010 (Government of Canada 2022).

Climate change has affected Hudson Bay and in turn QSA in a number of ways. In recent decades, there has been evidence of warming temperatures across Hudson Bay, especially in the west (Cohen 1994; Stewart and Lockhart 2005; Galbraith and Larouche 2011; Hochheim et al. 2011; IPCC 2013; Steiner et al. 2013; Kuzyk and Candlish 2019). This warming trend includes the QSA; however, this area experiences overall cooler temperatures compared to western Hudson Bay. There has also been an annual increase in precipitation (Stewart and Lockhart 2005; Steiner et al. 2013; Diaconescu et al. 2017; Kuzyk and Candlish 2019). The recent warming trend is predicted to continue with a projected increase of average annual air temperature in Sanikiluaq to -2°C and an approximate 11% increase in annual precipitation under high emissions scenario from 2021–2050 (ClimateData.ca 2018). This trend of increasing air temperature and precipitation is also true for Québec coastal areas.

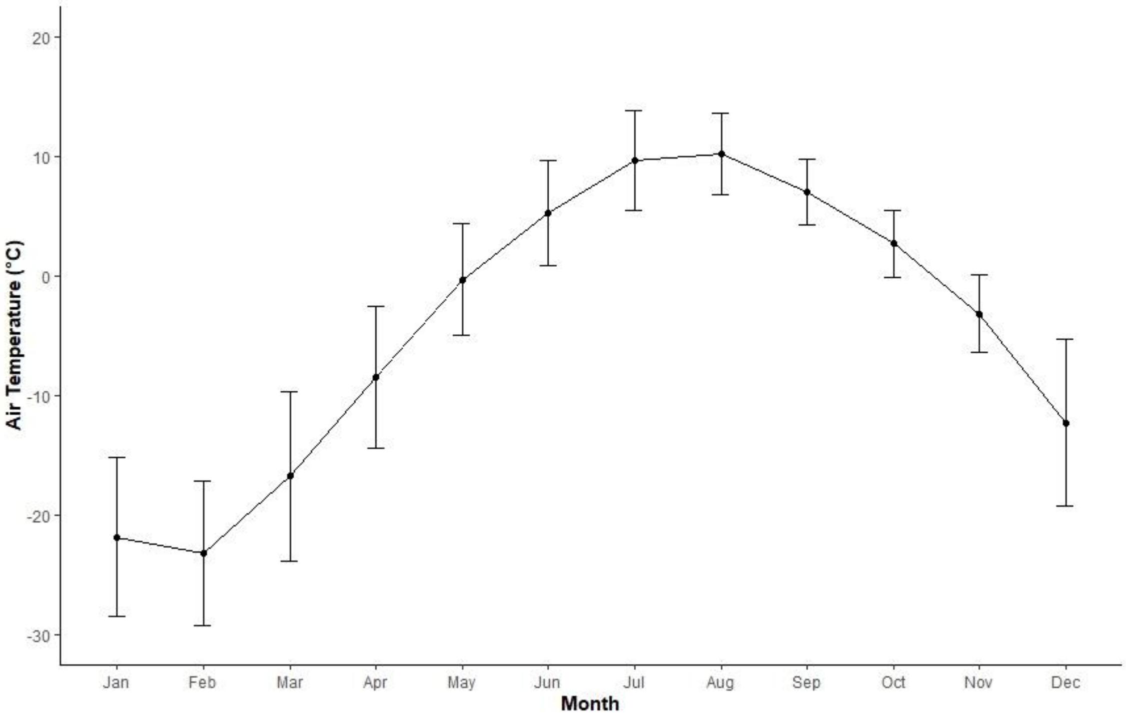


Figure 4. Average air temperatures ± standard deviation by month (1988–2022) collected from the Environment and Climate Change Canada (ECCC) meteorological station located at Sanikiluaq, NU. Source: ECCC (2022).

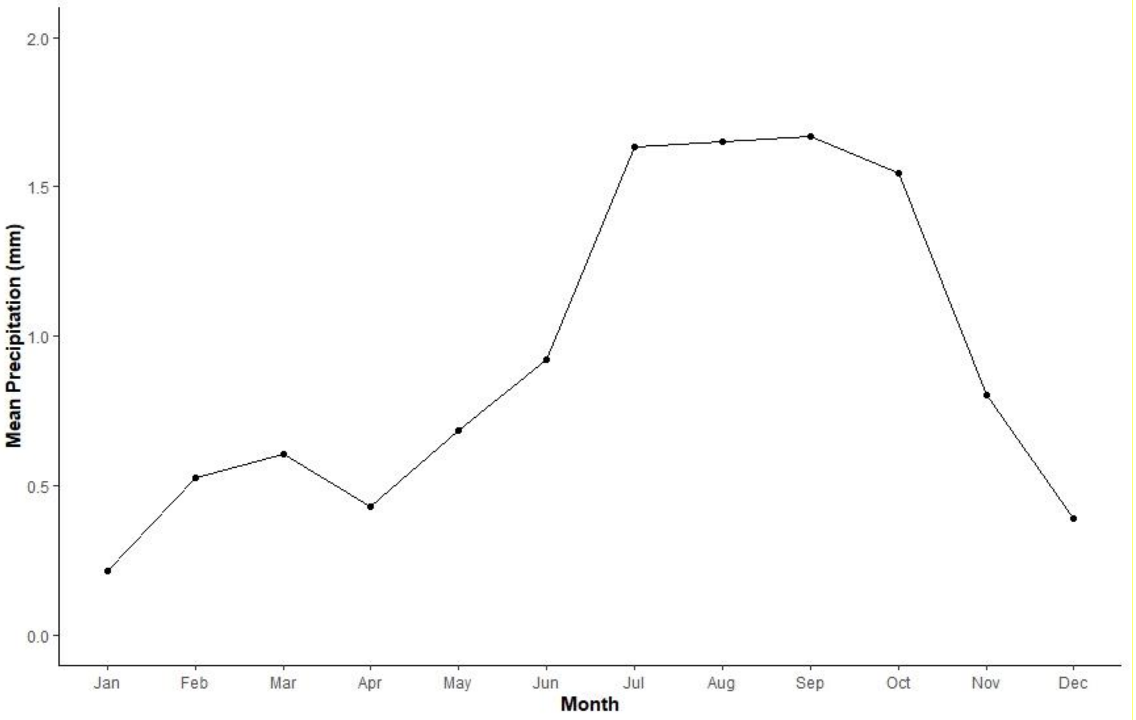


Figure 5. Average amount of precipitation by month (2014–2022) collected from the Environment and Climate Change Canada (ECCC) meteorological station located at Sanikiluaq, NU. Source: ECCC (2022).

GEOLOGY AND BATHYMETRY

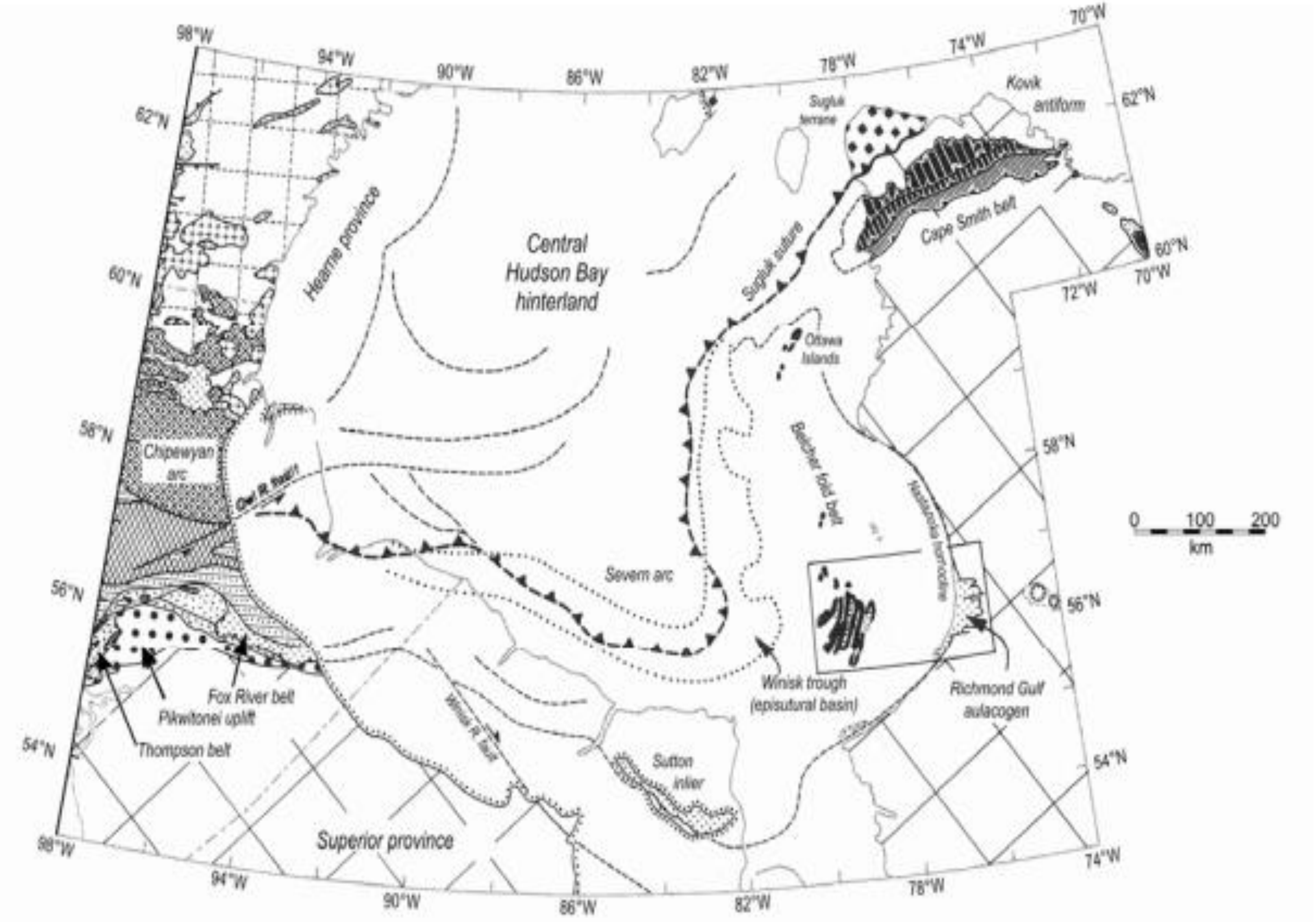
The Belcher Islands is a group of long narrow islands and peninsulas that are spread out across approximately 3,000 km^2, elongated in the north-northeast direction. These islands contain some of the best-preserved geological records of the Orosirian period (2.05 – 1.8 Ga) in northern Canada (Hodgskiss and Sperling 2020). At the base layers of the islands, under the entire basin, is the Superior Province Base, which consists of plutonic rock formed during the Archaean eon (Stewart and Lockhart 2005). Post Archaean eon, the bedrock of the islands formed in the Proterozoic era, including a subdivision called the Belcher Fold Belt that formed in southeastern Hudson Bay adjacent to the Richmond Gulf (Figure 6). The Belcher Fold Belt consists of deformed and unmetamorphosed sedimentary and volcanic rock, including doubly plunging folded strata (Donaldson 1986). These folds are north-south striking and create a pattern of sub-parallel sinuous islands that are concave to the west and a centre of curvature west of Belcher Islands (Jackson 2013). Within the Belcher group the geology can be divided into six depositional phases and includes levels of basalt, limestone, dolomicrite, sandstone, shale, and iron formations (Ricketts and Donaldson 1979, 1981). Large iron deposits of mining grade occur across the Belcher Islands and consists of 25–40% iron in the forms of magnetite and hematite, these deposits can also be found in rivers of importance to the QSA such as Great Whale River and La Grande River (Buck et al. 1968; Johnson et al. 1986; Stewart and Lockhart 2005). About half of the Belcher Islands is underlain by the Flaherty Formation, a mix of basalt flows, pyroclastics, and volcaniclastics (Jackson 2013). The Flaherty Formation also outlines most of the islands and peninsulas in steep-sided ridges that can reach as high as 60 m (Jackson 2013). As you move inland, the Eskimo Formation underlies parallel ridges, including a dome on Tukarak Island in the Tukarak Anticline, that reaches a height of 175 m, which is the highest elevation on the Belcher Islands (Jackson 2013). This Eskimo Formation contains basalt flows, sedimentary rocks, and pyroclastics (Jackson 2013). East of the Belcher Islands, beginning at Long Island to the northwestern tip of Ungava Peninsula, features a complex bathymetry due to the presence of shoals, islands, troughs and basins (Zevenhhuizen 1996) all coinciding with the Precambrian terrain (Dyke et al. 1989).

Glaciation has played an important role in the development of the Belcher Islands. There is a unique type of subspherical glacial erratic found on the islands called an “omar” that is derived from the Belcher Group and consists of a massive dark siliceous greywacke with light-toned calcareous concretions (Prest 1990). Omars from the Belcher Group were deposited northwestward and westward across the Hudson Bay Paleozoic basin by Labrador sector ice and then also moved westward and southwestward across ice into Northern Ontario and Northern Manitoba (Prest et al. 2002). In southeastern Hudson Bay, the QSA area, major glaciogenic landforms observed onshore are products from the Labradorean Ice Dome and division of it into the Hudson and New Québec Ice Domes that form the glacofluvial Harricana Interlobate Moraine (Zevenhhuizen 1996).

The Belcher Islands has cliff coasts and headlands where elevation rarely exceeds 200 m asl, and areas of low relief with rocky coastlines (Jackson 1960a; Stewart and Lockhart 2005). Topography of the Belcher Islands is mostly rounded and undulating, to flat. Low flat topography is especially prevalent on southern Kugong Island and the southwestern part of the Flaherty Islands where most elevation is less than 60 m asl (Jackson 2013). Elevation is even lower on the King George Islands, Bakers Dozen, and other parts of the North Belcher Islands where the elevation peaks at 30 m asl (Jackson 2013). In general, higher elevations on the islands occur in areas that are underlain by mafic igneous rocks while lower elevation areas are underlain by sedimentary rocks (Jackson 2013). Along the coast western coast of Québec, within the Belcher Island EBSA, well-developed cliff coasts and headlands are also present from near Kuujjuarapik and up northwards towards the Hopewell Islands and Inukjuak (Stewart and Lockhart 2005).

Manitounuk Island and the Nastapoca Islands also feature cuesta formations with low relief on the westward side of the islands and steep slopes on the eastward side (Martini 1981; Laverdière and Guimont 2011). These cuesta ridges, with a southwest-northeast orientation, also extend offshore up to 40 km west of GWR and 20 km west of Little Whale River (Zevenhhuizen 1996). Elevations along the Québec coastline can reach heights of 500 m with local relief at 100 m and includes exposed bedrock and absence of tidal flats (Gilbert et al. 1985).

Most of Hudson Bay has water depths between 100 m to 200 m (Pelletier 1998). However, in southeastern Hudson Bay, depth to the bottom rarely exceeds 120 m (Stewart and Lockhart 2005). A coarse bathymetry of Hudson Bay and more detailed bathymetry of the Belcher Islands area are illustrated in Figure 7. Off the immediate coasts of the Belcher Islands, water depths range from 40–80 m. Along the coastlines of Québec, depths range from 40–80 m near Inukjuak and 120–160 m near Kuujjuarapik. In general, off the coast of Québec in the Belcher Island EBSA there is a broad coastal shelf that extends to 80 m followed by a gradual slope where depth drops to 160 m (Stewart and Lockhart 2005).


98°W
94°W
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86°W
82°W
78°W
74°W
Sugluk terrane
Kovik antiform
Cape Smith belt
Hearne province
Central Hudson Bay hinterland
Sugluk suture
Ottawa Islands
Belcher fold belt
Nastapoka homocline
Chipewyan arc
Owl R. fault
Severn arc
Fox River belt
Pikwitonei uplift
Thompson belt
Winisk R. fault
Winisk trough (episutural basin)
Richmond Gulf aulacogen
Sutton inlier
Superior province
0
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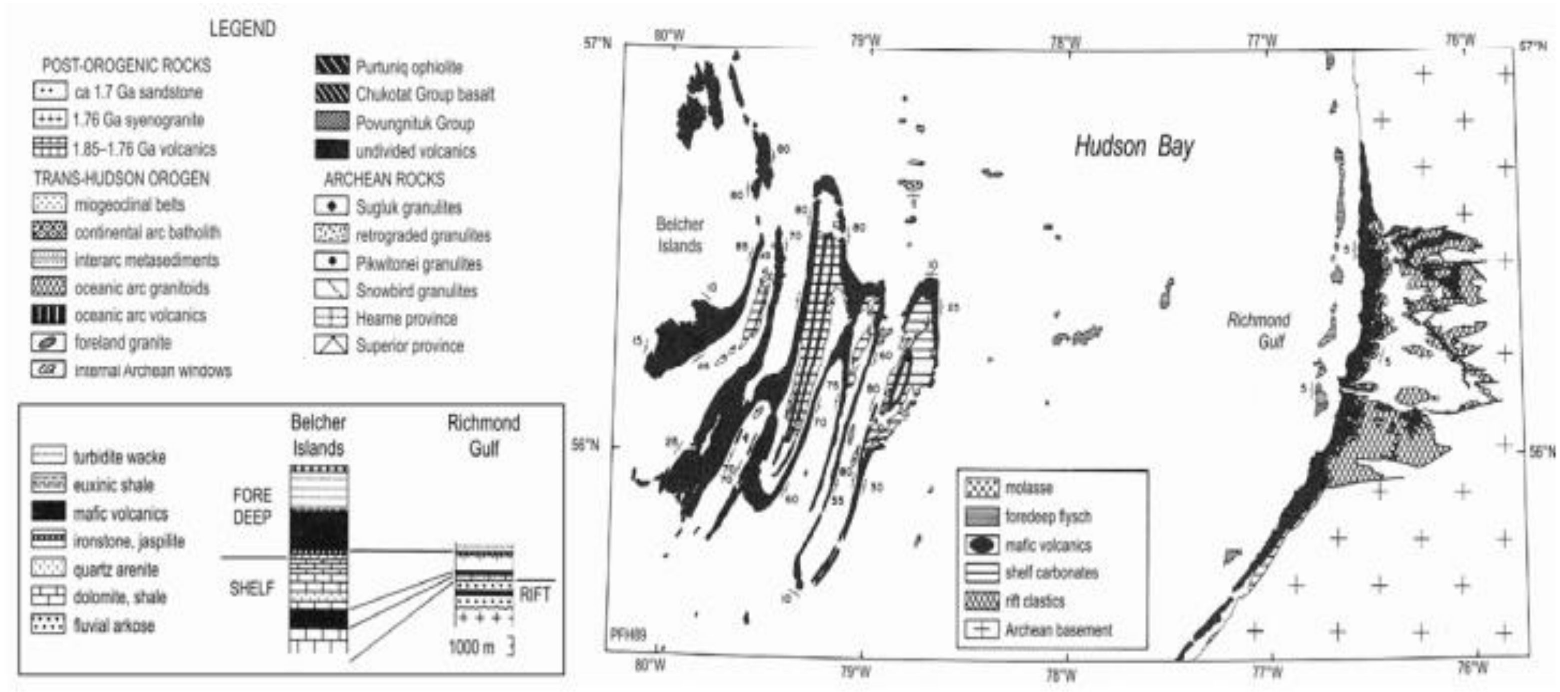


Figure 6. The Trans-Hudson Orogen as exposed east and west of the Paleozoic Hudson Bay. Source: Modified by Jackson (2013), originally obtained from Hoffman (1990).

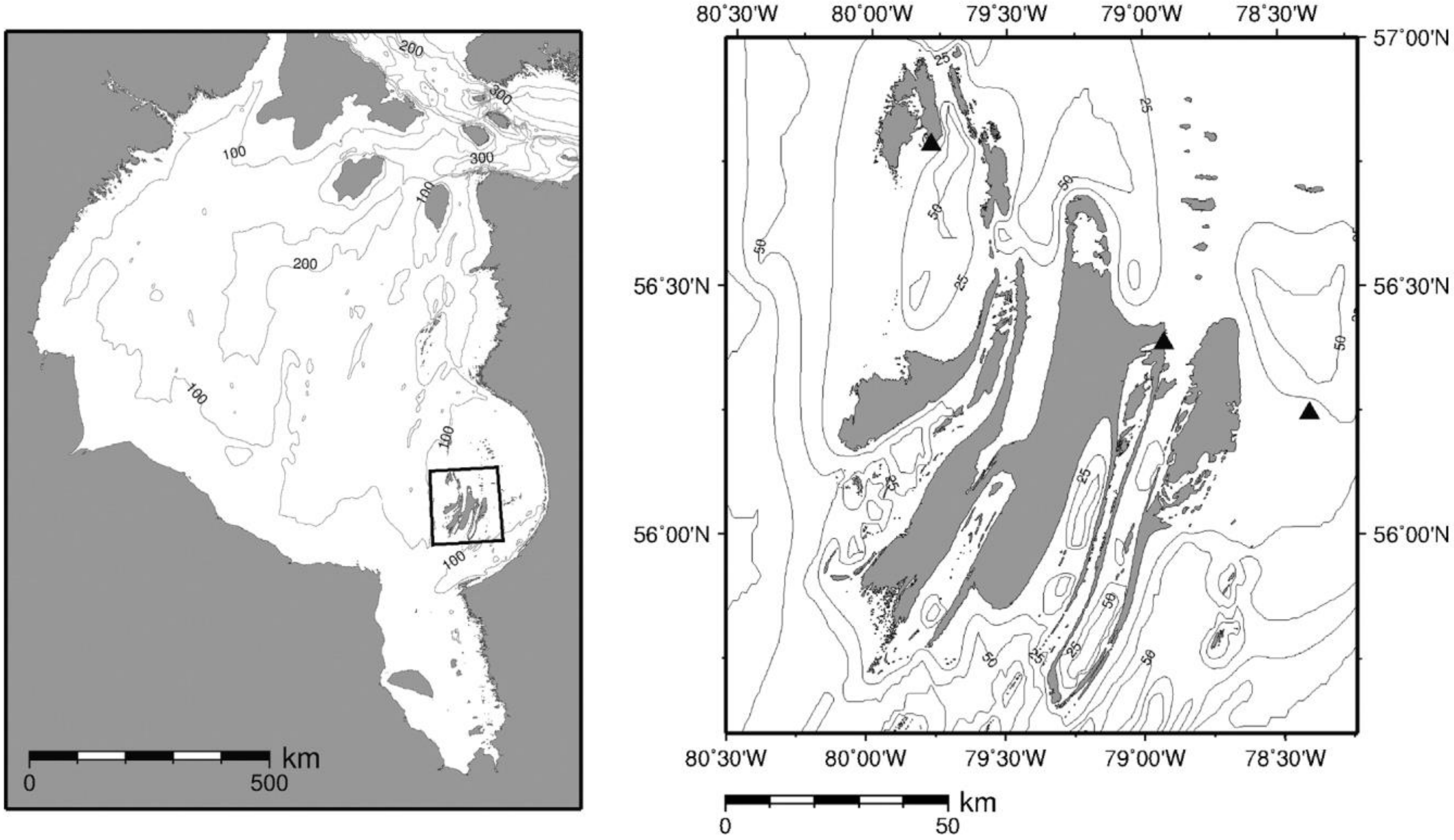


Figure 7. Bathymetry of Hudson Bay and the area around the Belcher Islands. Source: Luque et al. (2014)

OCEANOGRAPHIC SYSTEMS

Water Masses and General Circulation

The HBC is an inland sea region that includes James Bay, Foxe Basin, Hudson Strait and Ungava Bay (Prinsenberg 1986b). To the east, the HBC is connected to the Atlantic Ocean by the Labrador Sea and to the north it is connected to the waters of the Canadian Arctic via Fury and Hecla Strait (Prinsenberg 1986b). Generally, Arctic surface waters of Pacific origin flow southeastward through the channels of the Canadian Arctic Archipelago (CAA) into Foxe Basin via Fury and Hecla Strait, while a much larger contribution of Pacific and Atlantic waters enter from Baffin Bay via Hudson Strait (Ingram and Prinsenberg 1998). Shallow depths (>250m) prevent most of the relatively dense, Atlantic waters from entering Hudson Bay, where the general circulation is counter-clockwise, transporting mostly Pacific water south along the western half of the bay, then eastward along the southern coast, receiving significant quantities of river runoff from the large rivers along the southern coast of Hudson and James Bay before flowing northward along the eastern coast of Hudson Bay towards Hudson Strait and out into the Labrador Sea (Stewart and Lockhart 2005; Ridenour et al. 2019a; Ridenour et al. 2021). Across the top of Hudson Bay, there is a western wind-driven return flow (Murty and Yuen 1973; Wang et al. 1994).

In the HBC, surface water circulation is cyclonic with freshwater runoff transported in a counter-clockwise direction around Hudson Bay before it is exported to Hudson Strait (Wang et al. 1994; Saucier et al. 2004; St-Laurent et al. 2011; Ridenour et al. 2019a) (Figure 8). Deep water also moves in the same general direction but is influenced by bottom topography (Stewart and Lockhart 2005). Stable cyclonic circulation occurs in the HBC for a few reasons. This includes the presence of a weak coastal current that has limited coastal development along with strong density stratification as a result of intense freshening in the summer months (Wang et al. 1994). Further, there is a strong Coriolis effect that stabilizes the flow pattern where freshwater outflow is directed cyclonically around Hudson Bay (Wang et al. 1994). Due to its relative shallowness (average depth in HBC of 125 m) and distance from the Atlantic Ocean, Hudson Bay circulation and water mass characteristics depend mainly on local wind stress, runoff, radiant heat flux, and annual ice cover (Prinsenberg 1986b). Total transport around the HBC is 0.55 Sverdup (Sv), with 0.25 Sv resulting from inflow/outflow induced transport, 0.23 Sv from wind-driven transport, and 0.12 Sv from buoyancy-driven transport (Stewart and Lockhart 2005).

Circulation patterns and water mass characteristics shift seasonally within the HBC. During summer, two factors drive circulation: freshwater input and wind. In the beginning of summer, increased freshwater river discharges into Hudson bay during spring. This circulation includes multiple small cyclonic and anticyclonic features with a mean flow directed through the center of Hudson Bay (Ridenour et al. 2019b). The water mass characteristics of the summer current include a summer surface mixed layer (SSML) that contains seasonal freshwater inputs and extends to a depth of 30–60 m (Eastwood et al. 2020). Underneath this layer is cold water that can extend to as deep as 125 m and was part of the previous winter's surface mixed layer (WSML) (Granskog et al. 2011). Bottom waters of Hudson Bay are cold and saline and are partially derived from the brine-rich bottom waters from Foxe Basin (Defossez et al. 2010). Later into the summer season, long after the spring thaw, circulation becomes predominantly wind-driven towards the southeast (Prinsenberg 1986b) where southerly winds reduce inflow on the western shore but increase the outflow along the eastern shore (Prinsenberg 1982). During fall, winds shift, including a dominant northwesterly wind that produces a strong southeasterly surface flow (Prinsenberg 1986b).

Water masses within the QSA have been characterized as belonging of two domains: the coastal domain to the east of the Belcher Islands, which includes a narrow, swift, river-water rich flow that originates in James Bay, and the interior Hudson Bay domain to the west of the Belcher Islands that has slower transport velocities (Saucier et al. 2004; St-Laurent et al. 2011, 2012). Between these two domains there is an exchange of freshwater via Ekman transport (St-Laurent et al. 2011, 2012; Ridenour et al. 2019a). The Belcher Islands deflect the surface ocean currents of these two domains toward Hudson Strait, creating two parallel northward-flowing currents: the coastal waters flow north from James Bay until they reach the southern end of the Belcher Islands, where they turn east and then north along the mainland Québec shoreline, while the interior waters flowing east across the centre of Hudson Bay turn north when they reach the western shoreline of the Belcher Islands (Figure 8) (Wang et al. 1994; Saucier et al. 2004). During the summer, the Belcher Islands forms a boundary between fresh surface waters coming from James Bay and the saline interior surface waters of Hudson Bay (St-Laurent et al. 2011). In the winter, the interior domain is characterized by a strongly mixed layer down to 40–60 m due to the addition of brine from sea-ice production (Prinsenberg and Ingram 1991; Saucier et al. 2004; Granskog et al. 2011).

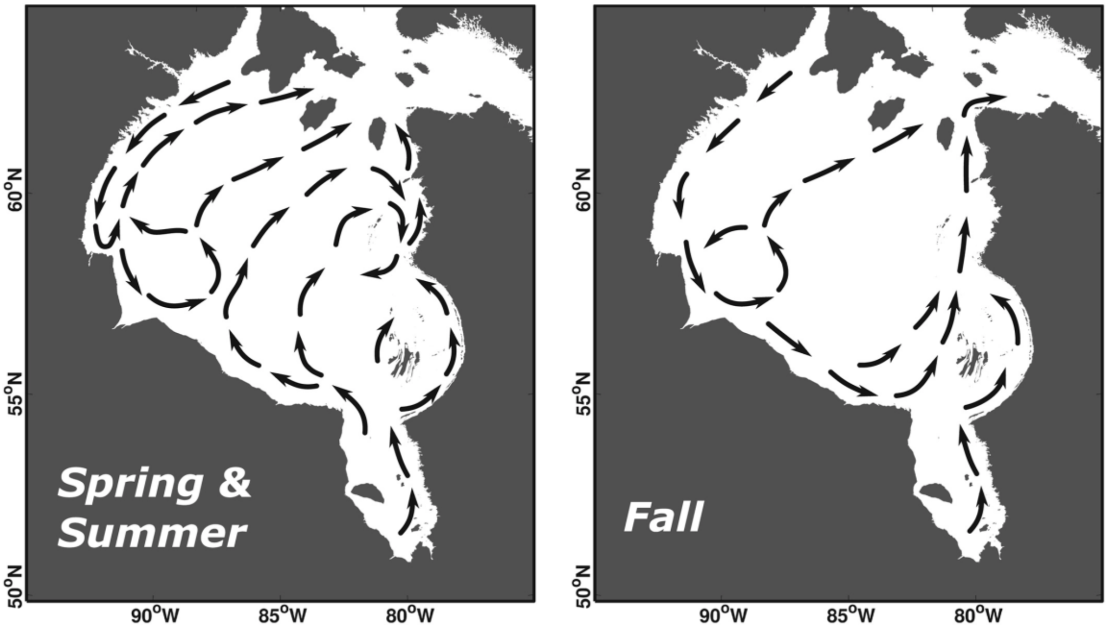


Figure 8. Surface layer circulation pattern for spring/summer and fall in Hudson Bay and James Bay based on Aviso satellite altimetry data and model output. Source: Ridenour et al. (2019a).

Currents in the HBC consist of periodic oscillations in the semidiurnal tidal band with a twice daily oscillation that occurs equally at all depths throughout the year (Prinsenberg 1986b). Flow velocities have not been measured in the QSA; however, there are general patterns of current and flow that are applicable to the area. In the summer and fall, surface velocities move southward, while in winter and spring the surface current moves eastward towards the Belcher Islands (Prinsenberg 1986b). The velocity of the current around Belcher Islands during summer months is approximately 4–6 cms (Wang et al. 1994). Additionally, the summer outflow from James Bay is very strong (19 cms) due to high freshwater discharge (Wang et al. 1994). Winter months are expected to have weaker velocities in comparison to summer months, but have not been recorded in this area.

Upwelling and Downwelling

Water mass characteristics are determined by the input of sea water from the Arctic Ocean at the northern boundary of Hudson Bay and the freshwater flux from the surrounding drainage basin along with *in situ* ice melt (Ingram and Prinsenberg 1998). As sea-ice melts, positive buoyancy is promoted in the Arctic estuaries, while the freezing of the surface water and coincident release of brine (dense saline water) promote negative buoyancy (Macdonald and Carmack 1991; Macdonald et al. 1995). Brine values in the Belcher Islands have been found to be high, extending from intermediate depths to the bottom (Granskog et al. 2011). Large brine percentages in the Belcher Islands were also noted by Granskog et al. (2009) and point to a mechanism that produces brine convection in the area which may be related to the recurring flaw lead near the Belcher Islands (Barber and Massom 2007; Stewart and Barber 2010). Further, this release of brine and changes in buoyancy and freshwater flux contribute to a semi-continuous cyclonic nearshore coastal current (Ingram and Prinsenberg 1998). This strong buoyancy driven current originates in James Bay and feeds into the eastern coast region in the QSA (Wang et al. 1994).

The presence of negative estuaries is common during winter due to the rapid growth of sea ice. These estuaries form in regions of open water, such as polynyas and flaw leads (MacDonald 2000). As discussed in later sections, the Belcher Islands has several annually recurring polynyas and flaw leads. Latent heat fluxes that are driven by upwelling occur along the edges of large polynyas and this upwelling increases the upward flux of nutrients (Dunbar 1981). This contrasts with ice-covered surrounding waters where strong stratification will usually prevent deep mixing (Dmitrenko et al. 2008). In the summer months, Hudson Bay is typically characterized by vertical stratification that impedes the renewal of nutrients in the surface layer and upwelling (Kuzyk and Candlish 2019). However, the Belcher Islands area is an exception due to the presence of cold water upwelling around the islands a unique opportunity for increased nutrient availability during summer months (Galbraith and Larouche 2011).

Water Temperature and Salinity

Water temperature and salinity profiles within Hudson Bay change seasonally due to fluctuations in water circulation patterns and the hydrological cycle. In Hudson Bay, summer surface water temperatures are greater than 8°C across the northeast near Coats and Mansel islands, and generally less than 6°C along the western coast and southern to southeast areas (Prinsenberg 1986a). During summer months, surface salinity also tends to be less than 28 psu along the coasts and greater than 30 psu towards the center of the bay (Prinsenberg 1986a). During winter, under the sea ice, salinity and temperature distributions are poorly studied (Stewart and Lockhart 2005). However, profiles are likely similar to those in summer but with higher salinities and lower temperatures, including extensive surface dilution by river plumes (Prinsenberg 1986a, 1987; Wang et al. 1994; Ingram and Prinsenberg 1998).

Ice growth and melt cycles contribute to the freshwater budgets of polar estuaries (MacDonald 2000) which control stratification, mixing, and biological production (Granskog et al. 2009). During the fall season, ice begins to form, and salt is rejected, resulting in a layer of cold, dense water at the ice-ocean interface (Prinsenberg 1988). In the summer season, surface water that is entering Hudson Bay is diluted by runoff, therefore low in salinity, and subsequently heated by solar radiation as it circulates around Hudson Bay (Prinsenberg 1986a).

The two domains of water in the QSA have distinct salinity characteristics: water in the interior domain is well mixed with high salinity (higher than anywhere else in the region), while the coastal domain is strongly stratified (Prinsenberg 1986a; Wang et al. 1994; Saucier et al. 2004; Stewart and Lockhart 2005; Granskog et al. 2011; St-Laurent et al. 2011). Exiting James Bay, flowing northwards, is surface water that is higher in temperature and lower in salinity values, as the water moves north it circulates along the eastern shore near the Belcher Islands before eventually leaving Hudson Bay (Prinsenberg 1986b). The area of saline unstratified waters in the northwest sector and the area of fresher stratified waters southeast of the BI were previously characterized as open water domains; however, recent studies have determined that they are also present under sea ice during winter and are therefore considered to be a permanent feature in Hudson Bay (Eastwood et al. 2020). Outside of these two domains, there are also deeper waters around the BI that are isolated from the central bay area because of sills less than 100 m deep causing bottom water salinities to be even higher (32 psu) with temperatures around -1.4°C (Ingram and Prinsenberg 1998). Surface water temperatures around the BI in the summer range from -1°C to a max of 7°C (Figure 9).

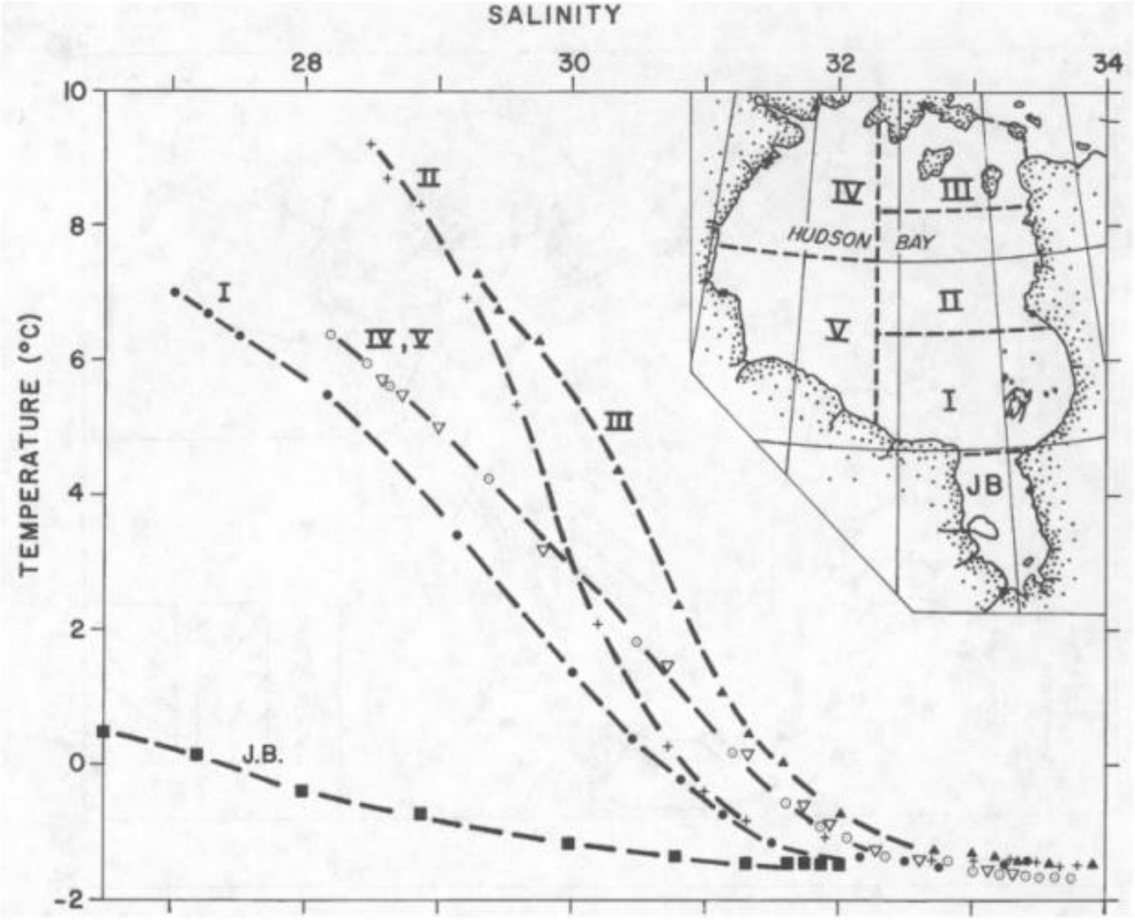


Figure 9. Temperature – Salinity diagram for summer conditions in Hudson Bay. The QSA is located in Area I. Source: Ingram and Prinsenberg (1998).

In the interior domain, summer salinity is around 28 psu (Barber 1967, 1968; Prinsenberg 1986b), and salinity increases throughout the winter (Eastwood et al. 2020). In the northwest part of the islands, the total depth was 128 m with a SSML depth of 51 m, a WSML depth of 73 m, and a WSML salinity of 32.7 psu (Granskog et al. 2011). For the WSML, the less stratified high salinity northwest area of Belcher Islands persists in winter due to brine-driven winter convection that occurs in the absence of winter river inflow (Saucier et al. 2004; Granskog et al. 2011). Around the Belcher Islands there is a small amount of brine production by the local sea-ice growth, however, brine is advected into the area with river water in a 1:1 relationship between the accumulation of river water and brine in surface waters in the winter (Eastwood et al. 2020). During winter salinity ranged from 26–30.5 psu with temperatures from -1.5 to -0.5 °C (Eastwood et al. 2020). During the winter season, Petrusevich et al. (2018) took a series of water temperature and salinity measurements across the Belcher Islands. Towards the southern ends of the islands, temperatures ranged from -1.4 to -1.5 °C with salinity values ranging from 27–29 psu and increasing with depth. On the east side of Tukarak Island, temperature and salinity patterns were similar to the southern stations, while those north of the island recorded higher temperatures (-1.6°C) and higher salinity (29–30 psu). Seasonally, data from summer months at the southern Belcher Islands stations showed a fresher and warmer surface water layer compared to winter. Additionally, as depth increased, temperature increased from slightly less than 0 to above 10°C while salinity values decreased from 30–25 psu.

At the southern end of the QSA, the high salinity concentrations observed in the interior domain meet the less saline waters exiting from James Bay and create a relatively steep surface salinity gradient in the coastal domain (Stewart and Lockhart 2005). Further, in the southern locations of Belcher Islands many “staircase” patterns were exhibited where there were multiple density layers with constant temperature and salinity that are separated by thin interfaces of temperature and salinity that increase with depth (Petrusevich et al. 2018). Some of these transition layers range in thickness from 1–3 m and separate the cold and fresh surface water layer SSML from the warm and saltwater layer WSML underneath (Petrusevich et al. 2018). Salinity data across the winter mixed and summer mixed layers were collected by Granskog et al. (2011) in early to late fall. At the southwest part of the islands, the total depth was 97 m with a SSML depth of 68 m, a WSML depth of 97 m, and a WSML salinity of 32.2 psu (Granskog et al. 2011). WSML depth is equal to the total depth in this specific area because winter convection is likely to reach the bottom (Granskog et al. 2011). At the mouth of GWR, the total depth was 89 m with a SSML depth of 76 m, a WSML depth of 76 m, and a WSML salinity of 31.72 psu (Granskog et al. 2011). Recent studies by Eastwood et al. (2020) and Petrusevich et al. (2018) have shown that the presence of the fresher surface layer persists to a depth of approximately 20 m through winter. Part of this salinity gradient comes from the melting of ice in the spring around GWR plume. The plume is highly stratified under the landfast ice in the upper 10 m of the water column (Ingram and Larouche 1987; Lepage and Ingram 1991). As ice breakup occurs in spring, the salinity gradient is strengthened due to the addition of a 2 m layer of fresh meltwater and runoff between the ice and the more saline seawater (Stewart and Lockhart 2005).

Tides

Tides entering Hudson Bay originate in the Atlantic Ocean and overshadow local tides and tidal influence from the Arctic Ocean (Stewart and Lockhart 2005). These tides are mostly lunar semidiurnal (M_2) and surge into Hudson Bay twice daily through Hudson Strait (Dohler 1968; Drinkwater 1988; Saucier et al. 2004). The tide is in the form of a Kelvin wave that distributes anticlockwise around Hudson Bay: part of it enters via James Bay at the southern end of Hudson Bay while the other part moves along the east coast of Hudson Bay before joining the incoming tide at Hudson Strait (Prinsenberg and Freeman 1986; Wang et al. 1994; Saucier et al. 2004; Chen et al. 2009).

In the Belcher Islands, the maximum tidal reach is 1.2 m (Petrusevich et al. 2018). The internal waves generated in the Belcher Islands are interesting because of the unique shoreline and bottom topography of the area. Further, the Belcher Islands is located near an amphidromic point (located in the east-central part of James Bay), resulting in an M_2 tidal wave that rotates counter-clockwise around the island. Seasonally there is also a sharp phase shift in the surface tidal wave that results in currents being driven through the narrow channels of the Belcher

Islands in the winter, creating small latent heat polynyas and a possible influence on wave development (St-Laurent et al. 2008). Additionally, there is a seasonal displacement of the amphidromic point from ice formation that causes tides to arrive 40 minutes earlier in the winter months in Inukjuak (Stewart and Lockhart 2005).

Analysis of tidal predictions using the Bedford Institute WebTide modelling program indicated that tides within the QSA are strongly semidiurnal, with the M_2 constituent being dominant (**Error! Reference source not found.**). Modeling predicted that the largest tidal amplitudes occur in the southern areas of the Belcher Islands around Tukarak Island, including southern Sainsbury Point and along the southeast and eastern parts of the island. Tidal amplitude decreases to the north, with the lowest amplitude occurring at the northern shore of the Sleeper Islands which is at the northern end of the Belcher Islands. Tidal elevation along the western side of the Belcher Islands (western shore of Kugong Island) was similar to values between Bakers Dozen and King George Islands to the northeast. Along the coast of Québec, tidal amplitude is high, especially near Kuujjuarapik. Tidal amplitude decreases northward along the coast but remains higher than observed at offshore stations in the QSA.

Table 1. Estimated mean tidal elevations (m) in the Qikiqtait Study Area from the Bedford Institute's WebTide Tidal Prediction Model.

Location	Elevation (cm)				
	Semidiurnal			Diurnal	
	M_2	**N_2**	**S_2**	**K_1**	**O_1**
Between Bakers Dozen and King George Islands	32.9	6.4	8.5	2.1	1.0
Sainsbury Point	81.9	13.8	24.6	1.7	0.7
Southern Shore of Flaherty Island	51.6	8.7	13.9	1.4	0.7
Western Shore of Kugong Island	30.2	6.0	9.2	2.2	1.0
Eastern Shore of Tukarak Island	69.7	12.2	20.2	2.0	1.0
Southeast of Tukarak Island	78.5	13.5	22.7	1.7	0.7
Northeast of King George Islands	30.9	5.5	7.0	2.0	0.8
Northern Shore of Sleeper Islands	4.8	1.8	2.6	2.1	0.9
Northeast of Bakers Dozen Islands	46.8	8.3	12.3	2.0	0.8
Northeast of Sleeper Islands	15.1	2.0	3.6	1.9	0.8
Long Island	77.9	12.5	22.5	1.2	0.3
Kuujjuarapik - Whapmagoostui	93.4	15.6	27.4	1.3	0.5
Between Jiaviniup Narsanga and Umiujaq	69.0	12.0	19.2	1.9	0.8

River Discharge and Plume

The Belcher Islands supplies almost no river water to Hudson Bay. Most freshwater in the QSA is found in a coastal boundary current that contains the outflow of fresh water from rivers to the south in James Bay (e.g., La Grande River, LGR; Figure 10) and southeast along the Québec coast (Eastwood et al. 2020). While there is no traditional estuary in the Belcher Islands, the islands lie within and are influenced by one that is produced by these mainland rivers draining into coastal Hudson Bay (Saucier et al. 2004; Eastwood et al. 2020). The moderate to large river systems within the QSA include the Great Whale River (GWR), Boutin River, Nastapoca River and Little Whale River (LWR) (Figure 10).

Figure 10. Map of the Hudson Bay Basin showing the location of rivers with outlets into Hudson Bay or James Bay. The inset shows the overall contributing drainage basin for Hudson Bay shaded in grey. Source: Déry et al. (2011).

The GWR watershed covers an area of 43,200 km^2 with an annual mean discharge of 19.9 km^3 (Déry et al. 2011). The river is a major freshwater inflow for southeastern Hudson Bay with an outlet at Manitounuk Sound (Dery et al. 2005). As with other stream systems in Hudson Bay, the magnitude of freshwater discharge varies across seasons with a minimum discharge occurring in mid-April and a maximum in late May to early June (Ingram et al. 1996). The LGR watershed covers an area of 96,600 km^2 with an annual mean discharge of 80.5 km^3 (Déry et al. 2011) and is located south of the QSA where it drains into James Bay. The Boutin River is north of GWR and its outlet to the east of the Belcher Islands and drains an area of 5,060 km^2 with an annual mean discharge of 0.5 km^3. Further north along the Québec coast are the outlets of Little Whale River and the Nastapoca River. Little Whale River has a drainage area of 11,700 km^2 with an annual mean discharge of 3.7 km^3, while Nastapoca River covers an area of 12,500 km^2 with an annual mean discharge of 8 km^3.

Both GWR and LGR were assessed for their hydroelectric potential. No projects have yet been developed for GWR. However, during the late 1970s and early 1980s, headwater tributaries were diverted into LGR for hydroelectric development, resulting in flow changes (Ingram and Larouche 1987). These diversions significantly shifted the main discharge period of the river system into James Bay from summer to winter, affecting seasonal freshwater input patterns in James Bay and the nearby QSA (Ingram and Larouche 1987; Eastwood et al. 2020).

At the mouth of GWR, an extensive plume forms at all times of the year due to the large ratio of mean freshwater discharge velocity to tidal current (Ingram and Larouche 1987). In winter and spring, because of the continuous landfast sea ice cover that forms offshore most years (Larouche and Galbraith 1989), the extent of the plume is much wider (500–2,000 km^2 in horizontal area) than in open water periods from mid-summer to fall (50 km^2) (Ingram and Larouche 1987; Lepage and Ingram 1991). The extensive ice coverage causes weak circulation that lowers turbulence levels, favouring the expansion of the river plume (Lepage and Ingram 1991). In contrast, in open water conditions, increased tidal action and low frequency phenomena provide kinetic energy that causes intense vertical mixing, which results in the collapsing of the river plume (Lepage and Ingram 1991). LGR also has an extensive plume that can extend as far as 100 km north of the river mouth under the landfast ice (Ingram and Larouche 1987). Prior to the diversion of flow from the Eastmain River into it, LGR discharge was 500 cms but increased to over 4,000 cms after the diversion (Stewart and Lockhart 2005). This diversion increased the reach of LGR plume under the landfast ice and increased midwinter flow resulting in the dilution of nearshore surface waters in southeastern Hudson Bay.

Distribution and Seasonal Ice Patterns

Hudson Bay is ice-covered for eight to nine months annually and is ice-free during the summer (19 June to 19 November) (ECCC 2019; CIS 2021). Most ice in the HBC is annual and although small amounts of multi-year ice (MYI) can occasionally enter into the area via Fury and Hecla Strait, it generally remains in the northeastern part of the bay (CIS 2021). There is typically no MYI in the QSA. Hudson Bay ice formation begins in the northwest corner in late October expanding to the southeast by December (Hochheim and Barber 2014), and in most years expands to cover 95–100% of the surface waters during winter and spring (Ingram and Prinsenberg 1998). Freeze-up from 1991-2020 occurred in early December for SE Hudson Bay, late November for most of the rest of the bay, mid-November for north Hudson Bay around SI and most coastal areas along the west coast and into James Bay, and late October in isolated inlets in the northwest (Figure 11) (CIS 2021). Break-up over the same time period started in early June in isolated pockets in James Bay, northwest Hudson Bay, and at the northern edge of the QSA near the Innuksuac River mouth (Figure 12) (CIS 2021). Much of the shallower areas of the bay saw break-up occur by mid-June, including most of the QSA east of the Belcher Islands. The area west of the Belcher Islands and parts of northern Hudson Bay and James Bay broke-up by early July while the remainder of the bay started to lose ice cover by mid to late July. The average open water season for the Kuujjuarapik/Whapmagoostui area at the Great Whale River estuary from 1996-2016 was 154.7 days (Andrews et al. 2018). Inter-annual variability of sea ice in Hudson Bay is attributed to large-scale atmospheric circulation changes. For example, when strong winter westerly winds from the North Atlantic Oscillation and low west summer episodes of the Southern Oscillation occur, the sea ice grows thicker, and breakup of ice is delayed (Wang et al. 1994).

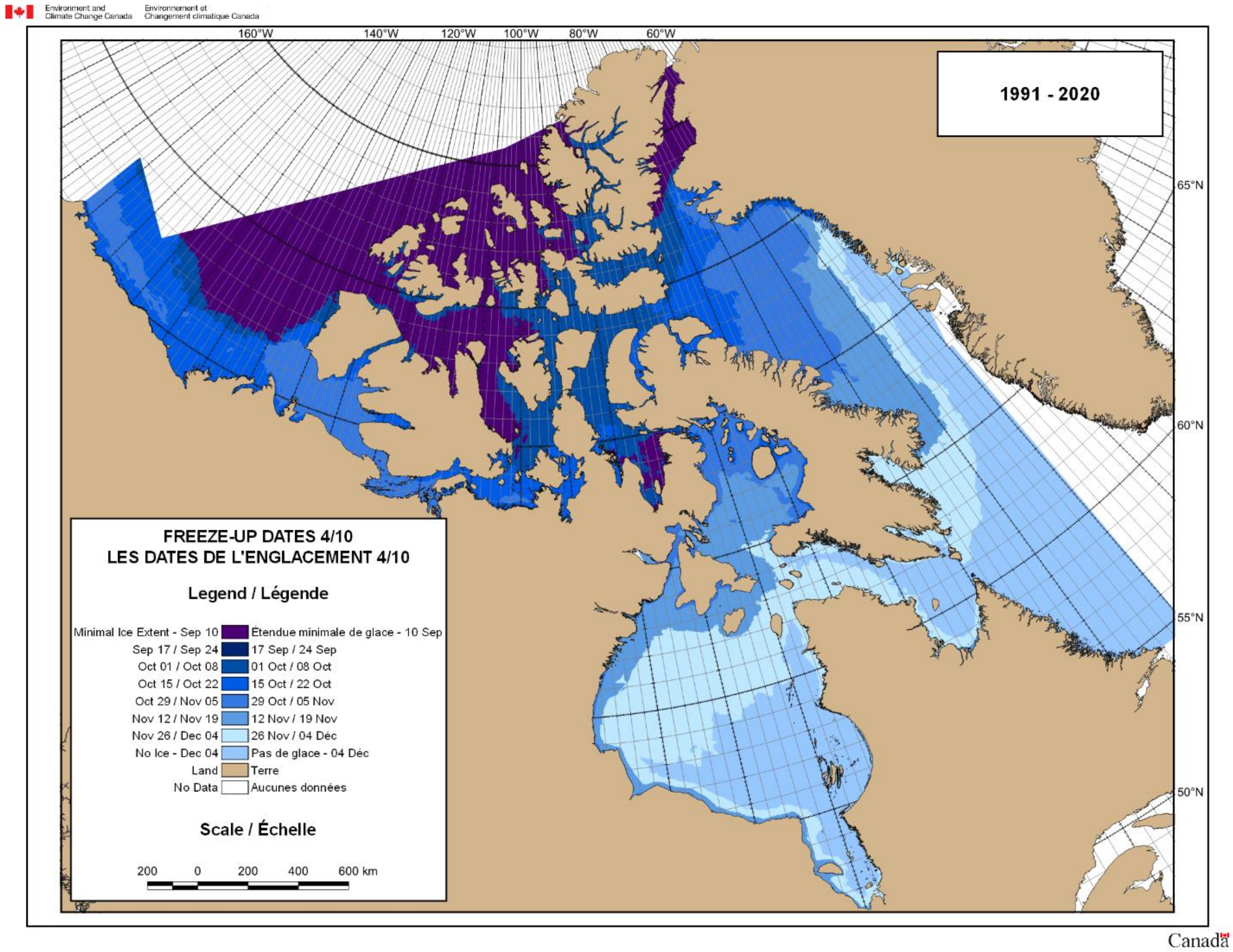


Figure 11. Sea ice freeze-up dates (all ice types) for the Canadian Arctic from 1991-2020. Source: CIS (2021).

Maximum sea ice thickness in the HBC follows a coarse northwest to southwest gradient; 175-215 cm thick in northern Foxe Basin ice ranges and 100-125 cm thick in James Bay (Markham 1981; Ingram and Prinsenberg 1998). Within Hudson Bay itself the prevailing hypothesis was an asymmetrical northwest to southeast gradient of ice thickness (Saucier et al. 2004; Gagnon and Gough 2006). However, these earlier studies were restricted to *in situ* drill-hole measurements through landfast ice at a few coastal locations within Hudson Bay and provided only a coarse overview of conditions. Recent high-resolution ice thickness surveys within Hudson Bay provide a more detailed description of the asymmetry. Using laser and radar altimeter satellite data over a 14-year period (2003-2016), Landy et al. (2017) observed mean spring thicknesses of 1.17 m in northwestern Hudson Bay and 1.54 m in eastern Hudson Bay where the QSA is located. The authors found that strong and positive ice drift vorticity in the bay influenced the observed asymmetrical thickness measurements. Although ice begins to grow rapidly early in winter in northwest Hudson Bay, and ice growth rates were highest in central Hudson Bay by spring, predominantly northwest winds result in pack ice continually moving from these areas to southeastern Hudson Bay where it rafts and ridges (Stewart and Lockhart 2005; Landy et al. 2017). As a result, by early spring, ice is thickest in coastal areas to the south and east and within the Belcher Islands. The average drifting velocity of this pack ice was measured at approximately 0.85 km day^{-1} in southeastern Hudson by Prinsenberg (1988). Landy et al. (2017) reported a mean December-April drift velocity of 0.85 km day^{-1} with an average drift velocity out of western Hudson Bay of - 0.53 km day^{-1} and into central and eastern Hudson Bay of + 0.30 and + 0.53 km day^{-1}, respectively.

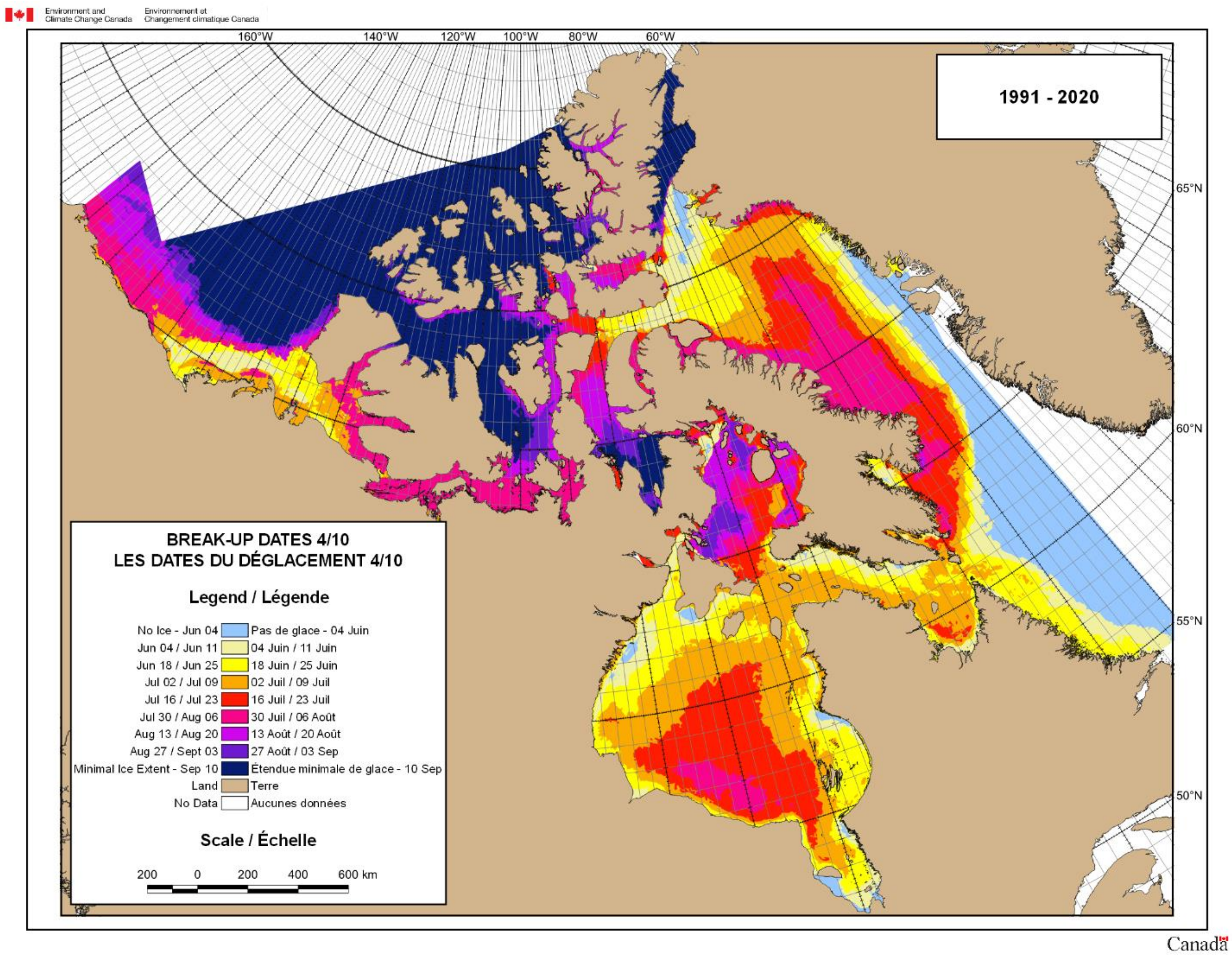


Figure 12. Sea ice break-up dates (all ice types) for Canadian Arctic from 1991-2020. Source: CIS (2021).

The QSA is surrounded by fast ice between February and March with ice formation beginning in mid-December (Environment Canada 2021). In general, sea ice features in the winter months within Belcher Islands include landfast ice coverage across most of the QSA including Omarolluck Sound, Wetalltok Bay, Robertson Bay, Coats Bay, Churchill Sound, Eskimo Harbor, and extending north from Kugong Island to Split Island (Figure 13 and Figure 14). As winter ends and spring returns the fast ice edge south of Belcher Islands begins to break up in June and generally finishes by late June to early July (Environment Canada 2021). During especially cold winters, the entire area from Cape Smith to the Ottawa Islands, to the Belcher Islands to Cape Jones, becomes covered in a consolidated mass of fast ice for a short period (Stewart and Lockhart 2005). This “ice bridge” was documented in February 2015 by Eastwood (2018).

In winter and early spring, ice floes are kept in constant motion by the wind and leads can develop if the winds blow offshore and the area is covered by new and young ice (Stewart and Lockhart 2005). These leads often provide important habitat for Arctic fauna and, along with polynyas present in the Belcher Islands and western Québec, are the only permanent areas of open water in southeast Hudson Bay during the winter season (Smith and Rigby 1981; Barber and Massom 2007). Polynyas in the area are thought to be latent-heat types that remain open throughout the winter (World Meteorological Organization 1970; Smith et al. 1990). These small, recurring latent-heat polynyas form in the QSA due to strong tidal currents that prevent the formation of ice (Stirling and Cleator 1981; Nakashima and Murray 1988), but also because of the shifting pack ice that create these initial openings. These polynyas provide winter habitat for a variety of seabirds and marine mammals (see sections below), and thus are biologically important areas (Gilchrist and Robertson 2000). Within the Belcher Islands, there are at least eight of these polynyas (Figure 15). There are two types of polynyas; those less than 900 m in diameter, and those that are open water adjacent to landfast ice and can extend for several kilometers. The community of Sanikiluaq uses these polynyas to hunt seabirds during winter, however, in the last few decades these polynyas have been more consistently experiencing a rapid freezing over.

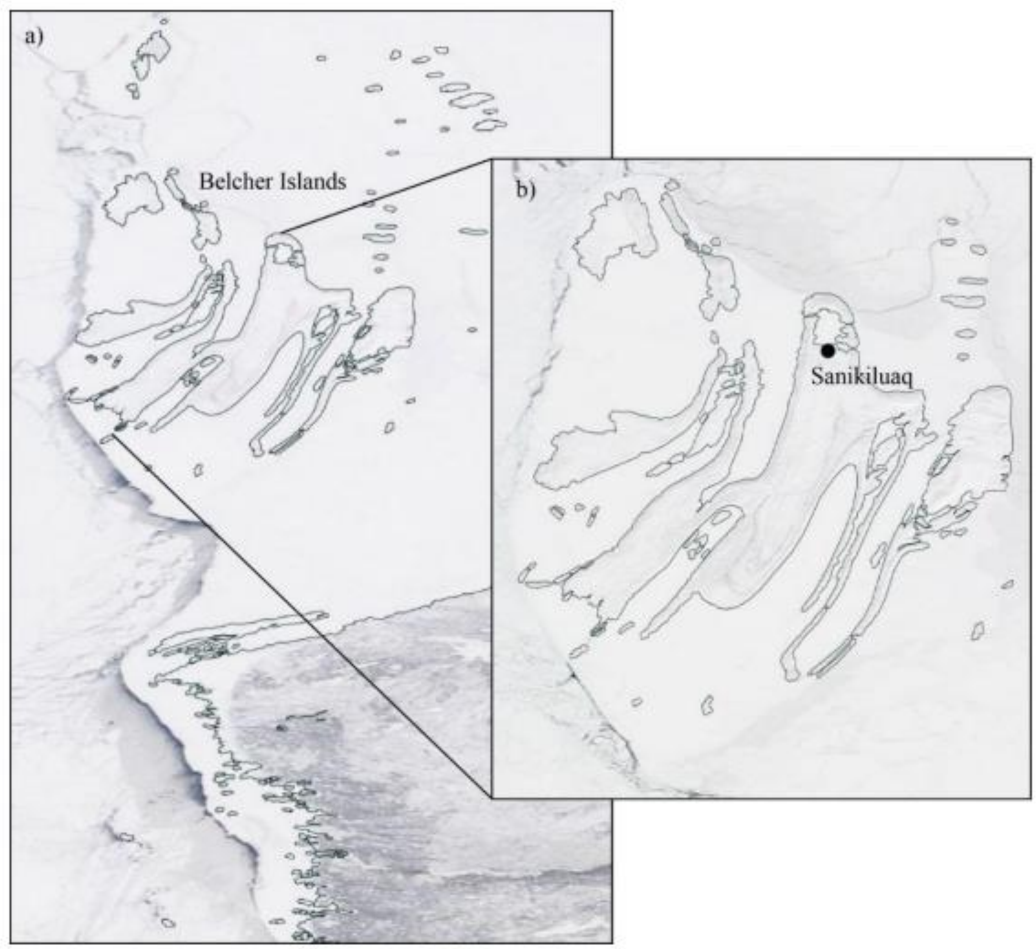


Figure 13. Icescape in February 2015, a) showing the large NNW-SSE oriented flaw lead that extends from northeast James Bay into southeast Hudson Bay west of the Belcher Islands. B) Landfast ice platform that is present around the Belcher Islands. Source: Eastwood (2018).

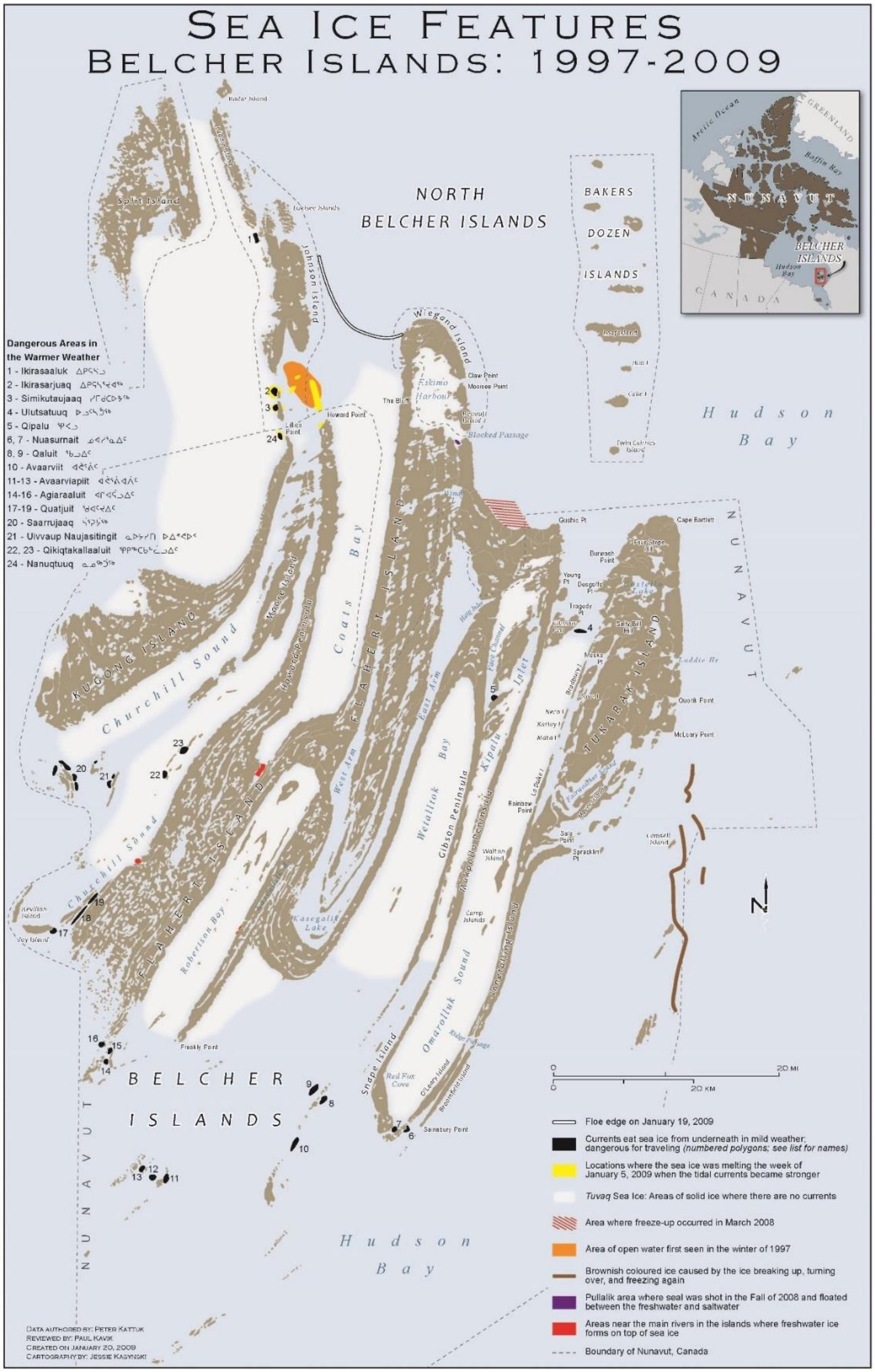


Figure 14. A map of sea-ice features in the Belcher Islands. Source: National Snow and Ice Data Center (2022).

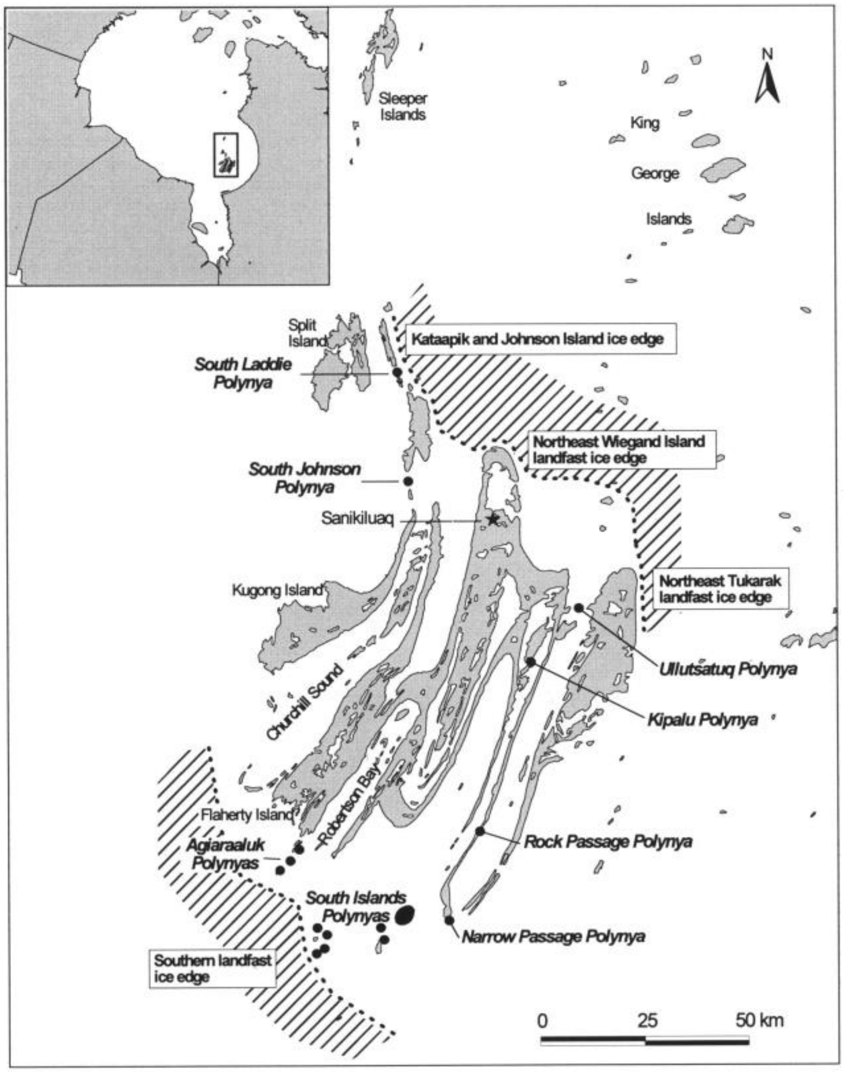


Figure 15. A map of known polynyas in the Belcher Islands Source: Gilchrist and Robertson (2000).

Ocean Acidification and CO_2 flux

Oceans have absorbed as much as 30% of the anthropogenic CO_2 emissions since the industrial revolution, slowing the pace of climate change. However, dissolved CO_2 reacts with water molecules to produce carbonate, bicarbonate, and free hydrogen ions. This oceanic uptake of anthropogenic CO_2 and increasing hydrogen ion concentration has lowered the pH of the world's surface oceans by ~30%, a process which has been named Ocean Acidification. The impacts of ocean acidification on the marine ecosystem are potentially significant, including the dissolution of the calcium carbonate shells of certain key marine organisms, thus reducing their survival and reproductive rates, as well affecting fish populations, microbial populations, and metabolic functions (Niemi et al. 2020, Tai et al. 2019, Das and Mangwani 2015 and references therein). The large inputs of river runoff and sea-ice melt to Hudson Bay make it particularly susceptible to Ocean Acidification, as these waters experience a greater change in pH per unit CO_2 added due to their low buffering capacities (i.e. lower concentrations of ions that take up free H^+ ions). This may be exacerbated by the large terrestrial organic matter inputs that release CO_2 when degraded in nearshore, river-runoff rich waters. A key proxy for ocean acidification is the saturation-state of aragonite (Ω_{AR})– a mineral form of calcium carbonate used to build the shells of certain key marine organisms. When waters have an aragonite-saturation state below 1, aragonite will tend to dissolve, potentially reducing the fertility and fecundity of these organisms. Within the HBC, aragonite saturation states are lowest in southeastern Hudson Bay and James Bay, including the area around the Belcher Islands, ranging from 0.6 to 1.5 (Figure 16, Azetsu-Scott et al. 2014; Burt et al. 2016). However, the impacts on the regional marine ecosystem remain uncertain.

The Arctic Ocean is, on average, a sink for atmospheric CO_2, but coastal regions influenced by river water tend to be weaker sinks, or sources of CO_2, due to the remineralization of terrestrial organic matter supplied by rivers. A recent study showed the waters of SE Hudson Bay were net CO_2 sinks during spring (Ahmed et al. 2021), whereas positive fluxes (net CO_2 outgassing) was observed during fall 2005 (Figure 17, Else et al. 2008), suggesting the region may experience seasonal transitions from CO_2 source to sink. To date, no studies have provided insights into the ocean acidification state or CO_2 flux of the region during the ice-covered season, mid-summer, or potential long-term changes.

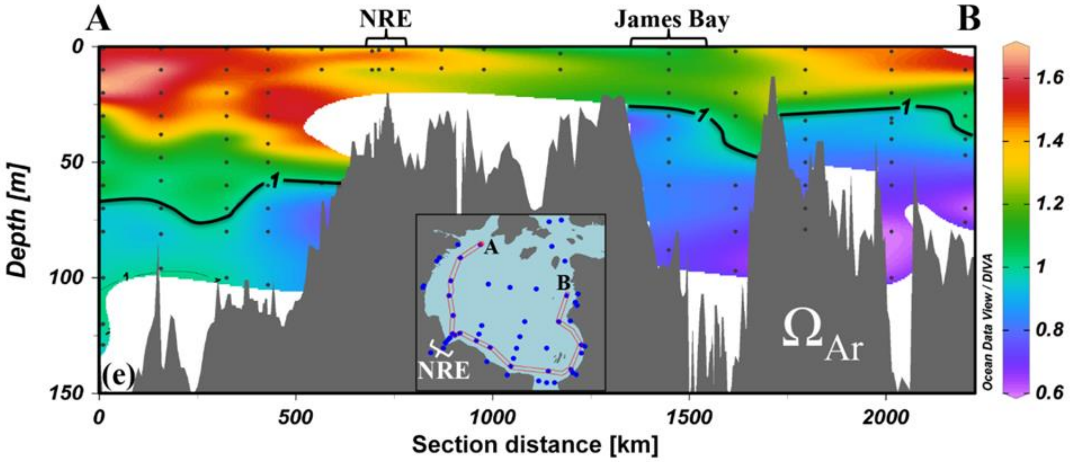


Figure 16. Alongshore distance vs. depth transect showing distribution of aragonite saturation state (Ω_{AR}) in coastal Hudson Bay waters (Burt et al. 2016).

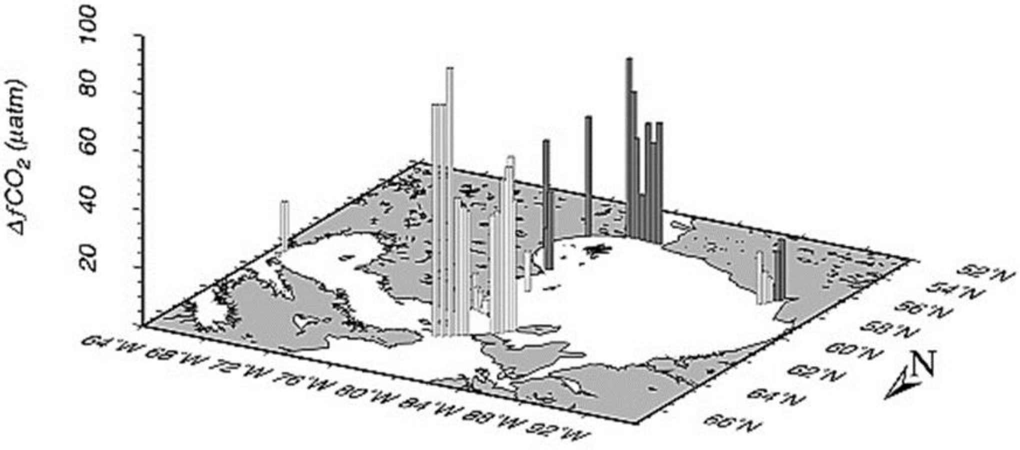


Figure 17. Carbon-dioxide sea-air flux estimates from Hudson Bay during Fall, 2005 (Else et al. 2008).

CLIMATE CHANGES AND PROJECTIONS

Climate change brings about a suite of effects, including changes in air and water temperatures, precipitation, weather patterns, and ice coverage. Significant changes in weather patterns have already occurred across the Belcher Islands. Residents of Sanikiluaq observed that the weather patterns are less predictable, and it has become more difficult for them to rely on their knowledge (McDonald et al. 1997). Another major influence of climate change will be changes in weather patterns, and the frequency of extreme weather events such as storm surges and heat waves. Increased precipitation and changes to ice coverage such as a decreasing ice-covered period will influence water mass characteristics and circulation. Increased precipitation over land, and inland melting will lead to changes in river output, which will affect water chemistry. Changing air temperatures associated with climate change are influencing ocean and freshwater salinity values. In 2015–2016, drinking water quality issues in Sanikiluaq were investigated and it was found that the increased salinity of their drinking water was due to permafrost thaw and the gradual release of salt water into their drinking source from warming temperatures (Lamhonwah et al. 2017; Elliott et al. 2022).

Increase in Air Temperature

Seasonal air temperatures in the region have risen in the past several decades and are continuing to rise. Across Hudson Bay, in the past 40 years, there has been an increase of 1.5–3°C during the winter, spring, and summer months and an increase in air temperature of 4–5°C during fall (Kuzyk and Candlish 2019). Further, elders have reported that winters are getting shorter, and summers are getting longer (McDonald et al. 1997). Temperature rise has been variable across Hudson Bay. Analysis from 1979–2018 shows that average temperatures are warmer in southwest Hudson Bay and colder in the north, with the exception of the fall season (October to December) where warmer temperatures remain over James Bay and south-central Hudson Bay (Kuzyk and Candlish 2019) (Figure 18).

Multiple projections on future air temperatures predict temperatures to continue rising. Steiner et al. (2013) combined data from CRCM4 and the Intergovernmental Panel on Climate Change (IPCC) and compared data from 1961–1990 to modeling for 2012–2061. They projected an increase of 1°C per decade over that time period (Steiner et al. 2013). Further, they confirmed that both models project that the most rapid warming will occur in the winter months of January, February, and March (Steiner et al. 2013). Table 2, generated by Kuzyk and Candlish (2019), shows the average projected changes from 2040 to 2064 in the Greater Hudson Bay Marine Region, including eastern Hudson Bay. Eastern Hudson Bay annual air temperature is expected to increase by 2.1–4.6°C over this period, with an especially high winter average increase ranging from 3.2–8.3°C (Kuzyk and Candlish 2019). The QSA would show similar increases under this scenario (Table 2).

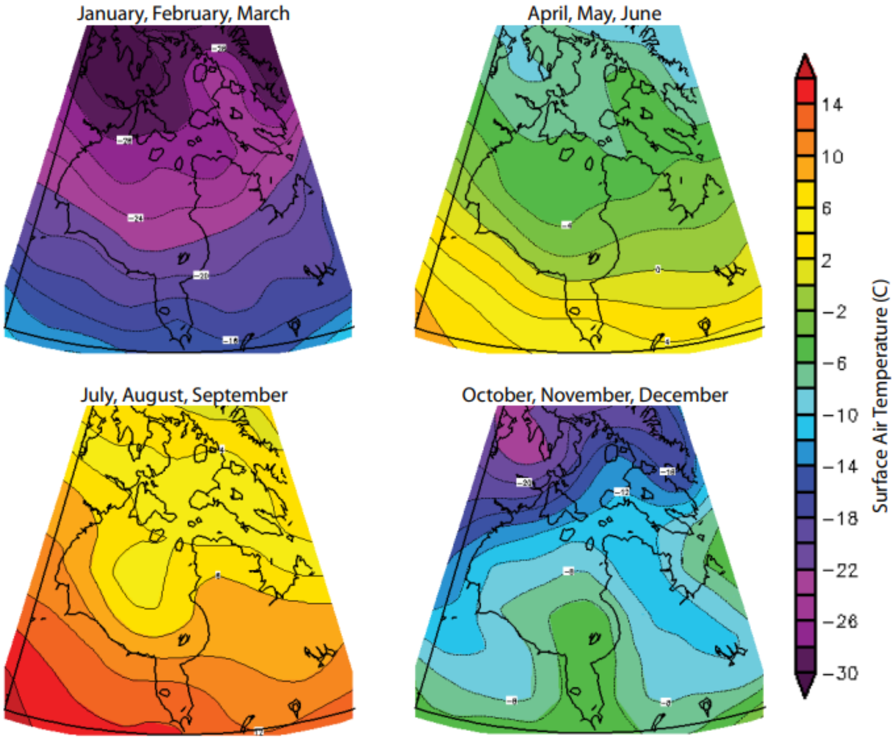
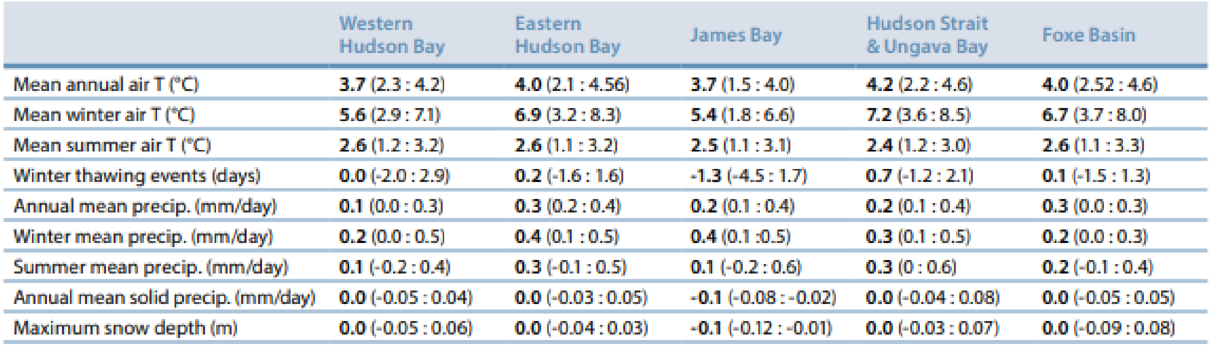


Figure 18. Average seasonal surface air temperatures for the Hudson Bay Region between 1979 and 2018 according to NCEP reanalysis data. The seasons are defined as follows: Winter – January, February, and March; Spring – April, May, and June; Summer – July, August, and September; and Fall – October, November, and December. Source: Kuzyk and Candlish (2019).

Table 2. A summary of spatially averaged projected changes in the Greater Hudson Bay Marine Region. The values indicate the median (spatially averaged) projected changes for the period 2040 to 2064. The changes are computed using seven RCM simulation runs from the CORDEX experiment for the reference period 1980–2004. The bolded values represent the spatially averaged median value and in brackets are the lower and upper bounds. Winter is defined as December, January, February and summer is defined as June, July and August. Source: Kuzyk and Candlish (2019).



	Western Hudson Bay	Eastern Hudson Bay	James Bay	Hudson Strait & Ungava Bay	Foxe Basin
Mean annual air T (°C)	**3.7** (2.3 : 4.2)	**4.0** (2.1 : 4.56)	**3.7** (1.5 : 4.0)	**4.2** (2.2 : 4.6)	**4.0** (2.52 : 4.6)
Mean winter air T (°C)	**5.6** (2.9 : 7.1)	**6.9** (3.2 : 8.3)	**5.4** (1.8 : 6.6)	**7.2** (3.6 : 8.5)	**6.7** (3.7 : 8.0)
Mean summer air T (°C)	**2.6** (1.2 : 3.2)	**2.6** (1.1 : 3.2)	**2.5** (1.1 : 3.1)	**2.4** (1.2 : 3.0)	**2.6** (1.1 : 3.3)
Winter thawing events (days)	**0.0** (-2.0 : 2.9)	**0.2** (-1.6 : 1.6)	**-1.3** (-4.5 : 1.7)	**0.7** (-1.2 : 2.1)	**0.1** (-1.5 : 1.3)
Annual mean precip. (mm/day)	**0.1** (0.0 : 0.3)	**0.3** (0.2 : 0.4)	**0.2** (0.1 : 0.4)	**0.2** (0.1 : 0.4)	**0.3** (0.0 : 0.3)
Winter mean precip. (mm/day)	**0.2** (0.0 : 0.5)	**0.4** (0.1 : 0.5)	**0.4** (0.1 :0.5)	**0.3** (0.1 : 0.5)	**0.2** (0.0 : 0.3)
Summer mean precip. (mm/day)	**0.1** (-0.2 : 0.4)	**0.3** (-0.1 : 0.5)	**0.1** (-0.2 : 0.6)	**0.3** (0 : 0.6)	**0.2** (-0.1 : 0.4)
Annual mean solid precip. (mm/day)	**0.0** (-0.05 : 0.04)	**0.0** (-0.03 : 0.05)	**-0.1** (-0.08 : -0.02)	**0.0** (-0.04 : 0.08)	**0.0** (-0.05 : 0.05)
Maximum snow depth (m)	**0.0** (-0.05 : 0.06)	**0.0** (-0.04 : 0.03)	**-0.1** (-0.12 : -0.01)	**0.0** (-0.03 : 0.07)	**0.0** (-0.09 : 0.08)

Increase in Water Temperature

Changes in water temperature in the QSA have not been well documented, however, the Arctic Ocean has been warming for several decades (Steele et al. 2008; Timmermans et al. 2018), and it is presumed that this trend would also apply to Hudson Bay. Increases in ocean temperature can be caused by, and through feedback loops, contribute to, increased heat absorption, changes in depth of light penetration, and changes in water currents. Increased summer ocean temperature may be sufficient to reduce the thickness and duration of seasonal ice cover in the following winter. Warmer water also has a lower capacity to hold CO_2, potentially reducing the CO_2 uptake potential of the region.

Change in Precipitation/River Output

River flow and discharge have also changed in Hudson Bay over the last few decades and are predicted to continue shifting. Annual streamflow into Hudson Bay has consistently been above historical average since 2000 (Déry et al. 2011). A number of studies argue that these increases in river discharge are following the global rise in surface air temperatures (Peterson et al. 2002; McClelland et al. 2006). Increases in air temperature allow for more moisture loading into the atmosphere which leads to increased net precipitation fluxes in the Arctic (Déry et al. 2011). Therefore, warming of the pan-Arctic is expected to intensify the hydrological cycle thus resulting in increased river discharge.

Steiner et al. (2013) projected an increase in precipitation of 0.05–0.06 mm day^{-1} decade^{-1} when comparing 1961–1990 to 2012–2061. Similarly, Diaconescu et al. (2017) predict a regional increase of 0–0.4 mm day^{-1} when comparing 1980–2004 and 2040–2064, with the largest trends occurring in eastern Hudson Bay near the Belcher Islands. In eastern Hudson Bay, annual mean precipitation is expected to increase by an annual average of 0.2–0.4 mm/day (Table 2). Stadnyk et al. (2019) project increasing runoff in all seasons up to 2070, with largest increases during winter, spring, and fall seasons (Figure 19). Increased precipitation will increase river discharge from the major river systems that empty into the QSA, lowering salinity and increasing the size of river plumes.

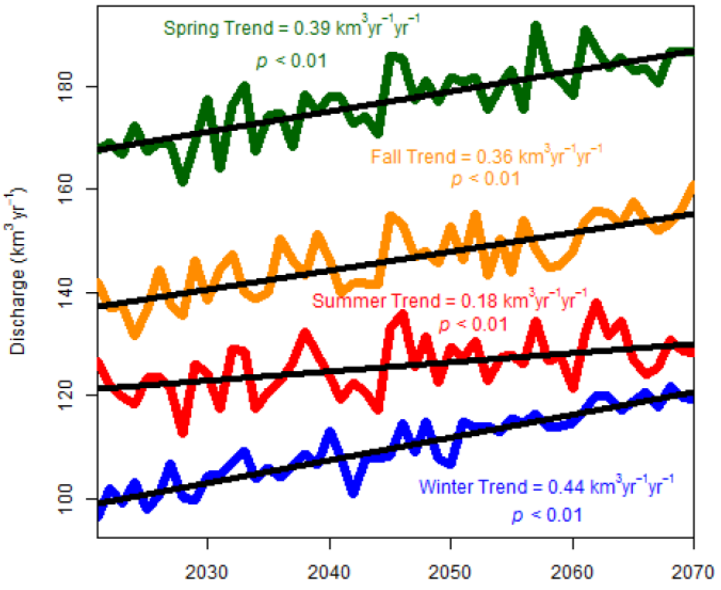


Figure 19. Seasonal trend analysis and significance of discharge for 21 gauged HBDB rivers for (a) observed, historical (1964-2013) period and (b) simulated, future (2021-2070) period where reservoirs are calibrated using default HYPE regulation. Reproduced from Stadnyk et al. (2019)

Increased freshwater inputs into the bay may affect the abundance and distribution of benthic invertebrates, particularly taxa that are less tolerant of low salinities (Pierrejean et al. 2019, 2020). A change in the benthic community structure and function could have a cascading effect on the higher trophic levels that prey on them (see sections on fish, marine mammals, and seabirds for further details).

Increased river outputs would negatively affect seasonal ice thickness and distribution creating a feedback loop. Increase river output would also increase water temperature and sediment loading. While summer sediment loading may decrease light penetration (Gabel et al. 2017), winter sediment loading may speed spring ice-melt. Increasing river runoff could also exacerbate Ocean Acidification in the region, as waters with higher river runoff content exhibit lower pH and are more soluble to calcium carbonate shells of marine organisms. River runoff also tends to be higher in dissolved CO_2, potentially reducing/increasing the CO_2 uptake/outgassing potential of the region.

Changes in Weather Patterns

A major influence on changes to water circulation within the bay is likely to be changes in wind patterns. Wind velocity values are generally growing stronger across Hudson Bay (Kuzyk and Candlish 2019). Using data from the Canadian Centre for Climate Modelling and Analysis (CRCM4), Steiner et al. (2013) projected that there will be a continuation of the increase in annual mean wind speeds throughout Hudson Bay from 1961 to 2100. Although, an average increase in wind velocities across Hudson Bay will influence circulation patterns, it is unclear how different areas will be affected. Upwelling and wind-driven mixing is expected to increase in coastal areas like the QSA due to the greater incidence of upwelling-favorable winds and the loss of the sea-ice cover that usually shelters the surface waters (Gosselin et al. 2015).

An increase in the frequency and intensity of storms and other extreme weather events is expected to occur in the Arctic (AMAP 2017) because of climate change. Wind velocity values are generally growing stronger across Hudson Bay (Kuzyk and Candlish 2019). Using data from the Canadian Centre for Climate Modelling and Analysis (CRCM4), Steiner et al. (2013) projected that there will be a continuation of the increase in annual mean wind speeds throughout Hudson Bay first noted in 1961 to 2100. Although, an average increase in wind velocities across Hudson Bay will influence circulation patterns, it is unclear how different areas will be affected. For example, the community of Kuujjuarapik, at the outlet of GWR, had the lowest monthly average wind speeds recorded during open water seasons from 2001–2011 (Andrews et al. 2016).

Extreme weather events, including thunderstorms, have increased over some parts of the Arctic (Hartmann et al. 2013; Hansen et al. 2014) and are likely to increase further in the future. A northward migration of tradition summer storm patterns has been noted by some models, (Collins et al. 2013; AMAP 2017), but data are not available on a local scale.

Increases in storm events can create feedback loops by reducing ice cover and raising water temperature. Reduced ice cover and warmer open water result in an increased frequency of storms that draw in moisture and track along coastlines (Pope et al. 2017). There is also evidence of increased coastal erosion in areas exposed to prevailing winds and storm surges, particularly along sandy coastlines and areas with melting permafrost bluffs (Barnhart et al. 2014). This may have little effect on the exposed bedrock of the Belcher Islands but may increase erosion and water turbidity along sandy coastlines such as Kuujjuarapik. Storm surges inland may also further contribute to sediment loading from inland rivers.

Changes in Sea Ice

Climate-driven changes to sea ice in Hudson Bay have occurred in recent decades and are predicted to continue under current greenhouse gas emission scenarios. Studies have shown that surface air temperatures (Etkin 1991; Comiso 2003; Hochheim et al. 2010; Hochheim and

Barber 2014) and the duration of the ice-free period (Gagnon and Gough 2005b; Hochheim and Barber 2014; Kowal et al. 2015) have increased significantly since the 1970s/1980s. These changes are concurrent with decreases in sea ice extent (Parkinson and Cavalieri 2008; Hochheim et al. 2010; Tivy et al. 2011) and snow depth (Ferguson et al. 2005). Falkingham et al. (2002) identified a decrease of 40% in sea ice coverage in the Hudson Bay region during summer from 1969-2001. Hochheim and Barber (2014) examined changes in fall and spring sea ice extents (1980-2010) in the HBC in relation to seasonal surface air temperatures and found that every 1°C increase in temperature resulted in a 14% decrease in sea ice extent. The import of MYI into the northern areas of the HBC has also decreased in frequency due to changes in sea ice in the Canadian Arctic Archipelago (Smith and Barber 2007).

Overall the timing of ice formation and break-up of sea icer in Hudson Bay is also changing, resulting in an increase in duration of the open water period (Gagnon and Gough 2005b; Stirling and Parkinson 2006; Scott and Marshall 2010; Hochheim and Barber 2014; Kowal et al. 2015; Andrews et al. 2018). Increased southwesterly winds in spring and corresponding surface temperature increase are thought to be at least partially responsible for an earlier ice break-up in Hudson Bay in recent decades (Scott and Marshall 2010). A study of a long-term dataset for the HBC, showed that every 1°C increase in temperature from 1980-2010 resulted in a delay in freeze-up of 0.7-0.9 weeks (Hochheim and Barber 2014). Similarly, Kowal et al. (2015) noted a significant trend of ice break-up in Hudson Bay occurring 0.50 days yr^{-1} earlier and freeze-up 0.46 days yr^{-1} later from 1971-2011. Similar values were noted for a 1980-2014 dataset (Andrews et al. 2017, 2018). In general, over the past 30 years, the open water season in Hudson Bay has increased by between 3 and 5 weeks (Kuzyk and Candlish 2019) with areas in the northwest and coastal waters of the southeast experiencing the greatest change (Hochheim and Barber 2014; Andrews et al. 2018). However, changes to sea ice extent and its phenology varies regionally within Hudson Bay, as freeze-up occurs earlier in the fall and a delayed break-up occurs in spring in the eastern side of Hudson Bay and James Bay resulting in a longer fast-ice season at a rate of 8 days per decade since 2000 (Gupta et al. 2022).

Future climate models suggest these current trends in sea ice characteristics of the Hudson Bay region are likely to continue (Gagnon and Gough 2005a; Joly et al. 2011; Andrews et al. 2016). Using the same historical dataset as Hochheim and Barber (2014) and assuming a similar rate of change into the future, Andrews et al. (2016) predicted further increases in the open-water season length of 2.1 weeks by 2030 and 4.1 weeks by 2050 in Hudson Bay. Using the Canadian Regional Climate Model 4, Joly et al. (2011) projected freeze-up will occur 25 days later and break-up 24 days earlier from 2041-2070 when compared to 1961-1990. This model also predicts significantly lower sea ice volume with an ice thickness decline of 20–60%. Within the bay, the greatest changes to sea ice concentration and thickness are expected to occur in the QSA and James Bay areas. The large decline in these areas can be explained by a reduction in both thermodynamic and dynamic growth of sea ice. There will likely be a reduction in the rate of pressure ridge formation and an overall thinning of the mean sea ice cover in the QSA.

Changes within the QSA have also been noted by residents of Sanikiluaq. For example, elders from Sanikiluaq explained that there used to be a delay in the spring melt, with freezing conditions overnight to slow the melt down, however, the spring melt is much faster now and disrupts community activities (McDonald et al. 1997). One elder described how spring ice-fishing camps in the past would persist for 2–3 weeks (Community Environmental Monitoring Systems Workshop 2008). However, in more recent years, they could only stay out on the ice for about a week, because of rapid melting occurring much earlier in spring. Others have expressed that ice used to form around the island in late October, but now the formation doesn’t occur until mid-late December (Nunavut Tunngavik Inc.

2001). In addition, they have observed that there has been unprecedented rapid freezing of the biologically important flaw leads and polynyas in the Belcher Islands (McDonald et al. 1997). Reports from residents of Sanikiluaq have also indicated that ice isn’t thick enough or strong enough to travel on safely with thickness that used to be six feet thick but now averages three feet or less (Nunavut Tunngavik Inc. 2001).

Given the importance of the combination of ice features present in the QSA to local biota and how they are relatively unique for the Hudson Bay area (i.e., thick ice ridging, many recurring polynyas), more detailed analyses of current ice conditions specific to the QSA are necessary to fully understand impacts from potential future trends.

LOWER TROPHIC LEVELS

Most of the existing studies on the lower trophic levels at the base of Arctic marine food webs within the HBC have been conducted at the north end of the system (e.g., northern Foxe Basin and Hudson Strait). Relatively few studies have examined lower trophic levels in the QSA. Most of these studies are focused on the estuarine areas of large river mouths in Québec along the southeastern boundary of the QSA and in polynyas near the Belcher Islands (Pierrejean et al. 2020; Nozais et al. 2021).

Phytoplankton and Ice Algae Primary Production

Due to limited data on prokaryotic components of the food web, particularly in the QSA, the following discussion on primary production will focus on eukaryotes (algae and phytoplankton). Microbial eukaryote communities within Hudson Bay are genetically distinct from those in other regions of the Canadian Arctic (Lovejoy 2014). There is little species overlap between marine and freshwater habitats, with differences in salinity the main factor creating distinct coastal and offshore assemblages in areas with significant freshwater inputs, such as Hudson Bay (Jacquemot et al. 2021; Nozais et al. 2021). On an even finer scale, Jacquemot et al. (2021) identified unique communities within the estuarine transition zones and offshore of each of three large rivers along the Hudson Bay coast using rRNA sequencing. Offshore from the GWR within the QSA, heterotrophic taxa and small photosynthetic protists were dominant as compared with diatoms offshore from the Nelson River. In the GWR estuary, the herbivorous ciliate *Mesodinium rubrum* were dominant while in the Churchill River estuary *Urotricha* spp. and Didiniidae spp. were most common. These data demonstrate the highly variable nature of planktonic community structure and the need for more detailed surveys throughout the QSA

Ice algae and phytoplankton directly and indirectly provide important energy inputs to higher trophic levels in the Arctic marine food web. There is an estimated minimum of 1,229 taxa in the Canadian Arctic, though fewer than half that number (586 taxa) may be present in Hudson Bay (Archambault et al. 2010). The dominant phytoplankton groups in Hudson Bay are diatoms (261 taxa) and dinoflagellates (150 taxa). Groups that include many ice algal species (e.g., Bacillariophycae and Bacillariophyta) appear to have reduced diversity within Hudson Bay compared to other areas in the Arctic. Nitrogen availability was thought to be the determining factor affecting phytoplankton diversity and distribution in this part of the QSA. Table A 1 (appendix) provides a list of phytoplankton and ice algae taxa identified in Hudson Bay and the QSA during the few biological surveys conducted since the 1960s, representing a minimum level of diversity in the region.

The factors affecting ice algal growth in the Arctic vary seasonally (Lavoie et al. 2005; Leu et al. 2015). Ice algae growth is light limited early in the season and then transitions to nutrient limitation as the bloom progresses.. Light availability for ice algae is influenced by precipitation (primarily snow) during the ice covered period. In addition, the amount and type of light reaching the water below the sea ice during spring is dependent on snow cover conditions (Mundy et al. 2005; Perovich et al. 2007; Campbell et al. 2015). Additionally, within Hudson Bay, seasonal ice melt and river runoff combine to create vertical stratification with low surface nutrients which limits phytoplankton growth (Kuzyk and Candlish 2019). However, the Belcher Islands area is an exception to this general bay-wide trend, where cold water observed during the summer months indicates the presence of upwelling and, therefore, greater nutrient availability for primary production (Kuzyk and Candlish 2019). Coastal areas near large river estuaries also have increased nutrient supply, which can intensify local primary production.

A review of studies of sea ice algae in southeastern Hudson Bay near the GWR from the 1980s and early 1990s identified seasonal trends for the region (Nozais et al. 2021). Algae colonized the undersurface of the ice and ice-water interface in April and May, usually dominated by pennate diatoms with taxa diversity increasing with distance from the river mouth. Biomass was highest in areas with lowest ice growth rates (and probably lower grazing rates). At the beginning of the bloom season, algal biomass was highest in areas with the thinnest snow cover where irradiance to the under ice surface was highest; however, by the end of the season, when overall irradiance peaked and was no longer not a limiting factor, biomass was highest under the thickest snow cover. Annual ice algal production at the time of these surveys was estimated at 6.5 g C m^{-2} (Gosselin et al. 1990). These ice algal blooms support a variety of grazing ice-associated invertebrates with an estimated 50% of the production becoming available to pelagic herbivores as it sloughs from the ice and settles/is exported to the benthos (Nozais et al. 2021).

Under ice phytoplankton blooms have become recognized as important features throughout the Arctic and Sub-Arctic, particularly in areas with thinner and/or seasonal ice cover (Ardyna and Arrigo 2020; Ardyna et al. 2020). They represent a key source of primary production that can bridge the gap between peak ice algal and open water phytoplankton blooms, and may prevent the outgassing of CO_2 that builds up from net heterotrophy in under-ice waters during winter (Else et al. 2019; Duke et al. 2021). Under ice blooms of phytoplankton were reported from the GWR plume in the 1980s, composed mainly of centric diatoms (*Chaetoceros karianus*) and pennate diatoms (*Navicula* spp.) (Nozais et al. 2021). These blooms in the GWR plume seem to originate from ice algae seeding the water column as the ice begins to melt, followed by development of other centric diatoms not originating from the ice.

Although recent data are lacking, spatial differences in phytoplankton diversity within the QSA have been noted in the past. A study in the 1970s identified greater diversity and mean abundance of phytoplankton at the mouth of the GWR and in adjacent Manitounuk Sound than in waters farther offshore towards the Belcher Islands (Legendre and Simard 1979; Nozais et al. 2021).

Researchers can better understand phytoplankton dynamics and their ecological roles by assessing light absorption. Temporal and spatial variation in phytoplankton light absorption was measured for the HBC in fall 2005 and compared with other Arctic regions (Brunelle et al. 2012). The study concluded that the large freshwater inflows in southern and eastern Hudson Bay transported dissolved organic matter that contributed up to 80% of all light absorption in Hudson Bay, which was more than in any other Arctic region. Factors affecting the differences observed in the various sampled regions were light limitation, nutrient availability, community composition and cell sizes driven by physical processes (Brunelle et al. 2012). Measurements for this study included four sites within the QSA (Figure 20); one west of the Belcher Islands and three along the coast of Québec (GWR, LWR, and near the community of Inukjuak). The site west of the Belcher Islands had a lower phytoplankton light absorption coefficient and lower proportion of picophytoplankton than most other sites within Hudson Bay, outside of James Bay (Brunelle et al. 2012). The sites along the Québec coast had higher light absorption and picophytoplankton proportions than the Belcher Islands, but still lower than most other sites in the bay.

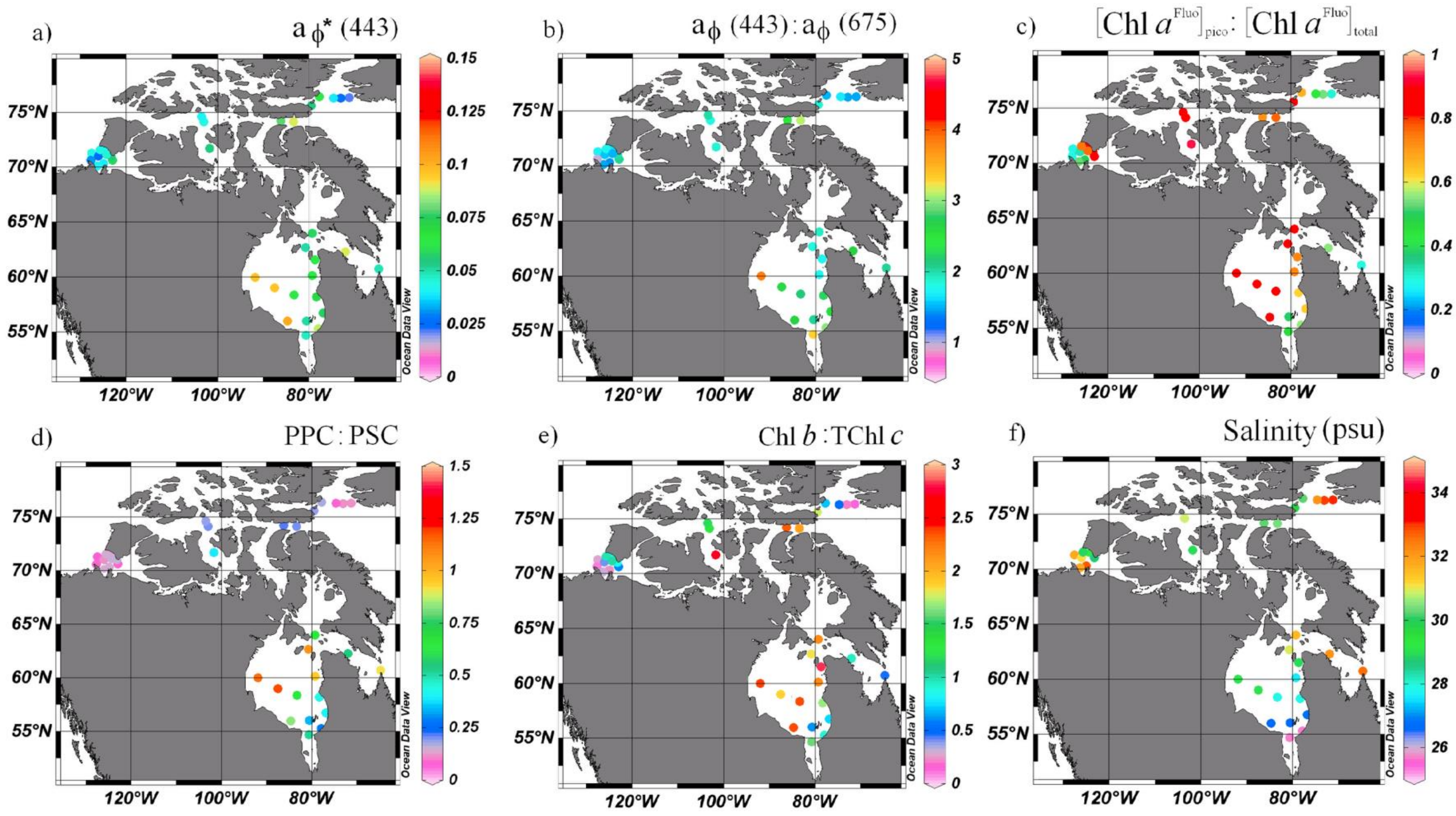


Figure 20. Spatial variations of the (a) total Chl a-specific phytoplankton light absorption coefficient aϕ(443), (b) blue-tored ratio aϕ (443):aϕ (675), (c) relative proportion of picophytoplankton, (d) ratio of photoprotective carotenoids (PPC) and photosynthetic carotenoids (PSC), (e) ratio of Chl b and TChl c and (f) salinity in surface waters (i.e., ≥50% of surface irradiance) of the Canadian Arctic during fall. Source: Brunelle et al. (2012).*

Direct measurements and modeling studies of planktonic primary productivity in Hudson Bay have all concluded that the bay is oligotrophic with low annual primary production ranging from 10-80 g C m^2 yr^{-1} (Kuzyk et al. 2010, 2011; Ferland et al. 2011; Lalande and Fortier 2011; Lapoussiere et al. 2011, 2013; Sibert et al. 2011; Bélanger et al. 2013; Kuzyk and Candlish 2019). A review of several small regional studies that include productivity measurements within the QSA noted some contradictory findings (Kuzyk and Candlish 2019). Although some areas within the QSA (i.e., the Belcher Islands) may have elevated primary production, there is evidence to suggest other areas have relatively low production when compared with the greater HBC, particularly near some of the river outflows. Different methodologies have also produced different results. For example, some studies showed late summer phytoplankton production and export in the 1990s and 2000s were generally low to moderate in the GWR marine system when compared with other areas of Hudson Bay (Lapoussière et al. 2013; Nozais et al. 2021). The community was dominated by small flagellates at the time of the survey. Additionally, a 3-D ecosystem-model showed that annual primary productivity within the QSA was among the lowest within Hudson Bay (Sibert et al. 2011). In contrast, relatively high surface chlorophyll measurements have been recorded from around the Belcher Islands and along the SE coast of Hudson Bay at the outflow of the GWR (Anderson and Roff 1980; Kenchington et al. 2011; Kuzyk and Candlish 2019). The QSA region also has the coldest summer sea-surface temperatures south of Southampton Island, suggesting strong vertical mixing that can likely sustain high primary productivity (DFO 2011; Galbraith and Larouche 2011). Similarly, satellite-based modeling has indicated that the area between the Belcher Islands and the southeast coast of the QSA has some of the highest phytoplankton primary productivity in the entire bay (Bélanger et al. 2013; Kuzyk and Candlish 2019). Kuzyk and Candlish (2019) have suggested that additional detailed studies with seasonal *in situ* measurements is needed to better describe primary productivity within the QSA.

Impacts of climate change on primary productivity have been observed throughout the Arctic in recent decades (Arrigo et al. 2008; Frey et al. 2011; Bélanger et al. 2013; Ardyna et al. 2014; Lewis et al. 2020) and are predicted to continue as sea ice declines, allowing for greater light penetration and more widespread under-ice blooms (Arrigo et al. 2012; Tremblay et al. 2012). Increases in under ice bloom frequency and magnitude could potentially shift much of the productivity away from the ice edges where seabirds and marine mammals feed with potential consequences to Arctic marine food webs (Barber et al. 2015). While initial increases in primary production have been associated with this loss of sea ice, subsequent increases are thought to be sustained by nutrient influxes at higher latitudes (Lewis et al. 2020) but have not been quantified in southeastern Hudson Bay. Within Hudson Bay, predicted increases in river runoff, particularly in watersheds along the Québec coast of the QSA, would increase the export of nutrients and organic matter into the bay and increase stratification offshore (Kuzyk and Candlish 2019). Vertical nutrient supply processes decrease due to predicted reduced ice formation and decreased winter convection, the proportion of riverine supply may influence greater planktonic productivity in coastal areas such as in the QSA, as long as water clarity doesn’t decline markedly, while offshore production decreases. Peak productivity is also expected to shift to earlier in the year due to and earlier sea ice melt, which could impact coupling between algae blooms and grazing zooplankton. Sea ice loss may also lead to an increase in wind-driven upwelling from extreme weather events in the QSA. There have already been some small increases in primary productivity reported within the QSA from 1998-2010 (Kuzyk and Candlish 2019).

Marine Macrophytes

Limited information exists on the distribution and diversity of marine macrophytes in the QSA. An estimated minimum of 210 macrophyte taxa occur in the Arctic, which is lower than the diversity reported from the Atlantic and Pacific coasts of Canada (Archambault et al. 2010). Most of the recent direct observations of marine macrophytes within the QSA were made by resource users in Sanikiluaq (Government of Nunavut 2010). Hollow-stemmed Kelp (*Saccharina latissima*), Edible Kelp (*Alaria esculenta*), and Sea Colander (*Agarum clathratum*) were all noted in coastal areas around the islands. These three taxa are reported to be particularly common along the north coasts of the main islands in the archipelago and throughout the Baker's Dozen and Sleeper Islands, often in areas with strong currents. With continued climate change and under Representative Concentration Pathway (RCP) 8.5, the predicted suitable habitat of Hollow-stemmed Kelp will decline by the year 2100, while the predicted suitable habitat of Sea Colander will increase (Goldsmit et al. 2021; Figure 21). Dulse (*Palmaria* sp.), Sea Lungwort (*Champia* sp.), and Spiny Sour Weed (*Desmarestia aculeata*) have been observed less frequently in isolated areas along the north coast of Flaherty Island and south coast of Wiegand Island (Government of Nunavut 2010). Table A 1 (appendix)provides a list of marine macrophyte taxa identified in Hudson Bay and the QSA from biological surveys and IQ, representing a minimum level of diversity in the region.

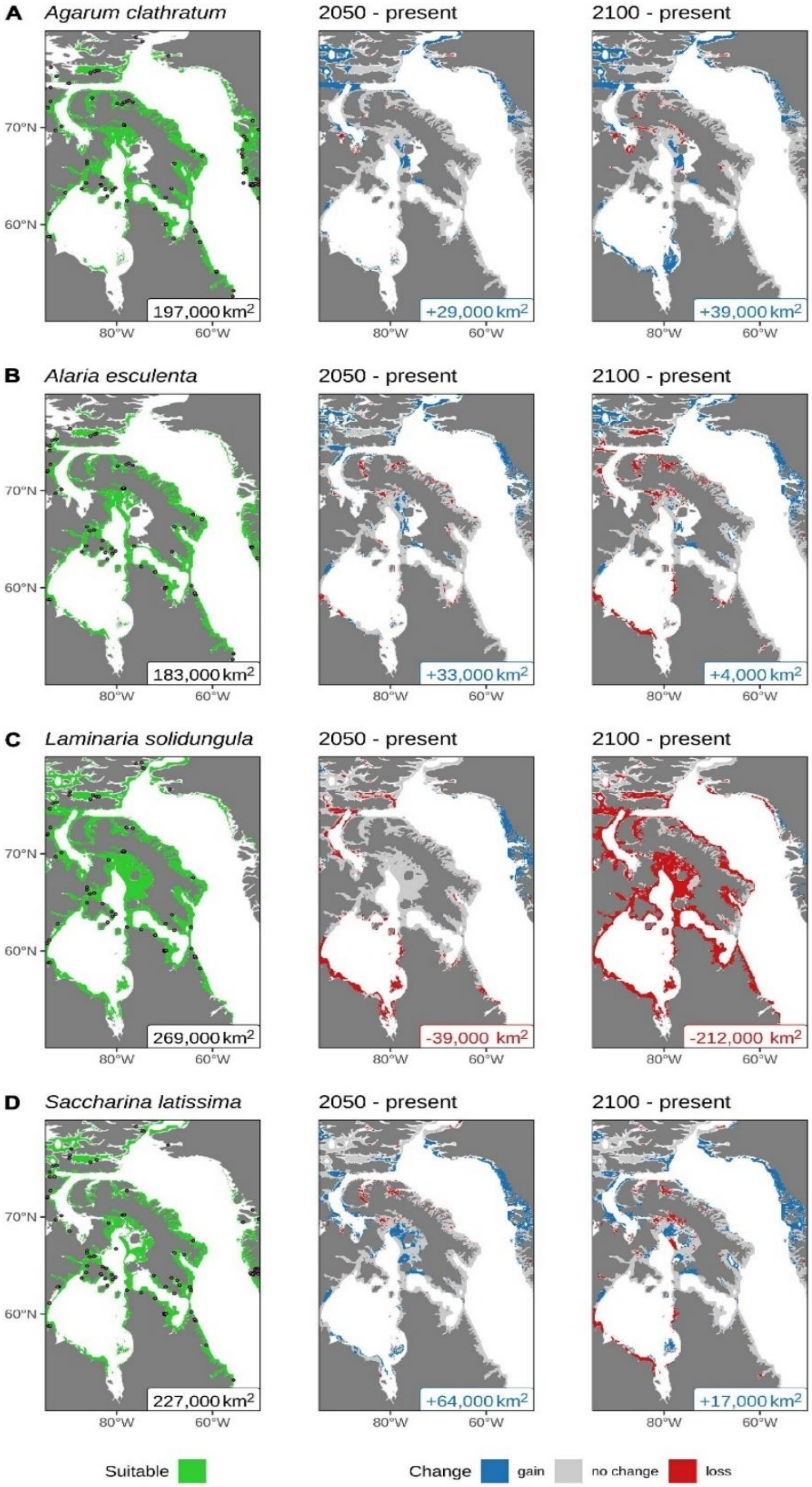


Figure 21. Predicted suitable habitat for four kelp species under Representative Concentration Pathway 8.5 until 2100 across the Eastern Canadian Arctic and West Greenland. Source: Goldsmith et al. (2021)

Krause-Jensen et al. (2020) examined trends in pan-Arctic marine vegetation in a changing climate. Overall, the review identified large increases (45%) in brown macroalgal distribution, especially in subtidal zones, since the 1940s with polar migration rates of 18-23 km/decade. The authors suggest the brown macroalgal expansion has been stimulated by decreased coastal sea ice cover and warming water. In the Eastern Canadian Arctic, the distribution, abundance, species composition, and diversity of kelp forests and seaweed communities are influenced by sea ice cover and concentration, sea temperature and salinity, and nutrient availability (Goldsmit et al. 2021, Filbee-Dexter et al. 2022) opening the possibility to increased macroalgal productivity and compositional changes in the future. With continued warming and diminishment of sea ice cover, habitat suitability for kelps and other habitat-forming seaweeds is expected to increase in the QSA and Belcher Islands EBSA by mid- and end-century, although predicted responses are species-specific (Goldsmit et al. 2021, Wilson et al. 2019). Extirpations at the southern range edge are projected to decrease the extent of Arctic endemic species (e.g., *Laminaria solidungula*) in the area, while more favourable conditions and poleward expansions are predicted for more widely distributed cryotolerant species (e.g., *A. clathratum, S. latissima*) and cryophobic temperate species (e.g., *Chondrus crispus*) (Wilson et al. 2019, Goldsmit et al. 2021, Bringloe et al. 2022).

In contrast to macroalgae, eelgrass in Hudson and James Bays is one of the few macrophyte taxa showing a decrease in distribution since the 1940s (Krause-Jensen et al. 2020). A particularly large, sudden decline occurred in 1998 along the eastern Hudson Bay and James Bay coastlines (Lalumière and Lemieux 2002). Low eelgrass cover, shoot density and above-ground biomass, and shorter shoots have persisted at most sites since the decline was initially observed (Leblanc et al. 2022). The decline and continued poor health of much of the remaining eelgrass was attributed mainly to increased turbidity, decreased salinity, and warming, making the plants more susceptible to wasting disease from protists (*Labyrinthula zosterae*) (Lalumière and Lemieux 2002; Kuzyk and Candlish 2019; Krause-Jensen et al. 2020). However, there is minimal evidence for the widespread occurrence of wasting disease and analysis of long-term monitoring data identified warm water temperatures, earlier ice break-up, and increased freshwater discharge as likely drivers of continued loss of eelgrass meadows in the region (Leblanc et al. 2022). While range-wide species distribution modeling indicates that subarctic eelgrass meadows may benefit from ongoing climate change with increased presence projected in the QSA (Wilson and Lotze 2019), the lack of recovery along eastern Hudson Bay and James Bay contradicts this expectation. More recent genomic offset predictions that account for local adaptation and decreased genetic diversity of James Bay eelgrass populations highlight that these subarctic meadows may be more vulnerable to climate change and benefit from stronger protection measures (Jeffery et al. 2023, Preprint).

There is also a risk of introduction of non-indigenous species to the HBC. The area has been identified as a suitable receiving environment for species introductions via biofouling on ships and ballast water discharge (Stewart and Howland 2009). Hudson Bay, particularly coastal areas near ports, have been identified as high risk for introductions (Goldsmit et al. 2019; Goldsmit et al. 2020; Goldsmit et al. 2021). Macroalgae from the east and west coasts of the North Atlantic Ocean are thought to be one of the taxonomic groups with the highest overall risk of introduction, based on a combination of higher likelihood of invasion into Hudson Bay and greater potential impacts relative to other taxa (Goldsmit et al. 2021). Three of the 14 highest risk invaders, the encrusting bryozoan *Membranipora membranacea,* the green macroalga *Codium fragile* ssp. *fragile*, and the Green Crab *Carcius maenas* are known to have profound effects on the structure and function of macrophyte habitats (kelp and eelgrass) in other regions (e.g., Scheibling and Gagnon 2006, 2009, Howard et al. 2019). As the climate changes, and the volume of ship traffic into the HBC increases, the potential for introduction of non-indigenous species and pathogens also increases (Goldsmit et al. 2021).

Zooplankton

Despite being important links between primary producers and higher trophic levels, studies of zooplankton and ice-associated invertebrate communities in the QSA are limited. Most of the existing surveys in the Arctic or in the Hudson Bay complex have been conducted in Foxe Basin (Grainger 1959, 1962, 1965; Harvey et al. 2001) and the Canadian Arctic Archipelago (Buchanan et al. 1977; Darnis et al. 2012; Estrada et al. 2012; Harwood et al. 2017) and not in southeastern Hudson Bay. Table A 2 (appendix) provides a list of zooplankton and ice algae fauna identified in Hudson Bay and the QSA, representing a minimum level of diversity in the region.

Like other lower trophic levels, marine zooplankton occurrence, abundance, and ecology are not well understood in Hudson Bay. Survey results have suggested that the HBC supports less than half the number of species identified in northern Arctic waters (Archambault et al. 2010) and that biomass in the bay averages four times lower than in adjacent (Hudson Strait and Foxe Basin) waters (Estrada et al. 2012). This difference could be due to the higher stratification of Hudson Bay waters compared to other areas across the Canadian Arctic (Harvey et al. 2001; Estrada et al. 2012). Taxa that are characteristic of Hudson Bay include *Microcalanus* spp., *Oithona similis*, *Triconia borealis, Aeginopsis laurentii*, *Parasagitta elegans*, *Fritillaria* sp., and larvae of cnidaria, chaetognatha, and pteropoda (Estrada et al. 2012). Pelagic ecosystem modeling of zooplankton biomass also predicted low total biomass for Hudson Bay with microzooplankton (20-200 µm) more abundant in the coastal areas of southeast Hudson Bay whereas mesozooplankton (200-2000 µm) accounted for two thirds of the total secondary production throughout the bay (Sibert et al. 2011).

There are well-defined regional differences within Hudson Bay. For example, smaller zooplankton are more abundant in the east and south, resulting in lower biomass than west and north Hudson Bay and Hudson Strait (Estrada et al. 2012; Kuzyk and Candlish 2019). While typical lipid-rich Arctic species like *Calanus glacialis*, *C. hyperboreus*, and *Pseudocalanus* sp. are abundant in the north and central regions, they are uncommon in coastal areas in the south and east. Instead, *Acartia longiremis* (a species tolerant of a wide range of environmental conditions) is abundant within these coastal areas of the QSA (Harvey et al. 2001; Kuzyk and Candlish 2019). Non-copepod zooplankton diversity is similar to other Arctic regions, though *Parasagitta elegans*, a predator of copepods, is relatively common along the SE coast of the QSA (Lapoussière et al. 2009). Variation in zooplankton biomass and community assemblages will be linked indirectly to local environmental dynamics that influence water column structure and mixing processes, as they directly influence phytoplankton phenology and community assemblages.

Zooplankton surveys within the salinity gradient of the GWR plume have identified copepods as the most numerous and diverse taxa with four species, *O. similis*, *T. borealis*, *Pseudocalanus* spp. and *Microcalanus pygmaeus,* most abundant (Rochet and Grainger 1988; Drolet et al. 1991; Ponton and Fortier 1992). Seasonally, maximum copepod egg and nauplii abundance was highest in late May and June, coinciding with peak ice algal biomass in the deeper saline water layer before the summer phytoplankton bloom. Several species of copepods (e.g., *C. glacialis*, *P. minutus*, and *Metridia longa*) have been observed grazing on ice algae in early spring which allows their reproduction to occur with the summer phytoplankton bloom, optimizing feeding conditions for their offspring. These copepod eggs and nauplii are also an important food source for larval fish that emerge during spring.

Studies specifically focused on ice-associated invertebrate fauna in Hudson Bay are even less common than those for pelagic zooplankton. Some similarities can be expected with other areas of the Arctic that have primarily seasonal ice cover. Common taxa in nearby regions include calanoid, harpacticoid and cyclopoid copepods, hyperiid amphipods, *Onisimus glacialis*, *Apherusa glacialis*, and *Gammarus wilkitzkii* (Grainger 1959, 1962; Atkinson and Wacasey 1989; Pomerleau et al. 2011). A survey in the 1980s, within the GWR outflow, identified an ice-associated copepod composition that included primarily *O. similis* and *Tisbe furcata* over the plume and *Harpacticus superflexus*, *T. furcata* and *Halectinosoma* sp. outside the plume (Grainger 1988; Nozais et al. 2021). Nematodes, rotifers, ciliates, and copepods (in that order) were the most abundant taxa in ice over and outside the plume. Salinity and availability of ice algae were correlated with ice fauna biomass, and interannual variability in plume extent could result in large variability in ice fauna composition, distribution and biomass.

Information on zooplankton and ice-associated fauna within Hudson Bay and the QSA is insufficient to accurately predict trends with climate change. Studies that span multiple seasons and years are needed to assess zooplankton variability and change relative to environmental drivers and ecosystem impacts. The predicted changes to primary production from increased freshwater inputs, stratification and reductions in seasonal ice cover and timing of the melt in the bay (described above) will likely affect the ice fauna and zooplankton community composition within the QSA, especially in coastal areas to the southeast. For example, ocean acidification can impact the shell dissolution of pteropods, a key indicator species for change, and in turn have negative consequences on their abundance, growth and ecosystem linkages to mid- and high-trophic level species in the food web (Niemi et al. 2021). Also, there may be a shift toward increased proportions of microzooplankton and taxa more tolerant of lower salinities and warmer surface water. Recently, large numbers of the jellyfish *Aglanthe digitale*, were captured 15 km from the mouth of the GWR at 100 m depth, earlier in the year than the usual seasonal descent (Lalande and Fortier 2011; Kuzyk and Candlish 2019). This observation may be an indicator of biological changes in southeast Hudson Bay associated with warming surface waters. Climate change can also increase the risk of non-indigenous species introductions into Hudson Bay. Coastal areas near ports in the bay have been identified as particularly high risk for introductions (Goldsmit et al. 2019, 2020, 2021). From these ports, invasive species could spread to other coastal areas. Macrozooplankton from the east and west coasts of the North Atlantic Ocean have been identified as one of the taxonomic groups with the highest overall risk of introduction into the bay (Goldsmit et al. 2021).

Benthic Community

Quantitative data on benthic invertebrate communities within the boundaries of the QSA are limited. General patterns of diversity and abundance and knowledge of benthic ecosystem processes in the HBC and other parts of the Canadian Arctic may provide useful context. Benthic invertebrate diversity, distribution and community composition in the Arctic are influenced by a number of variables, including salinity, temperature, depth, substrate, sea ice cover, primary productivity, and prey availability (Cusson et al. 2007; Roy et al. 2014; Pierrejean et al. 2020). Changes in sea ice cover is one of the variables in particular that can influence the efficiency of pelagic-benthic coupling and primary production (Renaud et al. 2007; Boetius et al. 2013; Roy et al. 2015), which has implications for energy and nutrient cycling as reductions in sea ice cover continue. Initial comparisons of overall diversity of marine benthic taxa in Canada’s three oceans suggested the Canadian Arctic harboured approximately 1,000–1,300 taxa: exceeding Pacific coastal and at least matching Atlantic coastal diversity within Canada (Archambault et al. 2010; Darnis et al. 2012; Snelgrove et al. 2012). The most recent compilation that included new data from the under-sampled Arctic and Pacific and epifaunal taxa, which were not included in previous assessments, increased the number in the Arctic to 1552 taxa (Wei et al. 2020). Of the three oceans, the Arctic showed the highest benthic diversity for common and dominant taxa and closely following the Pacific in terms of total diversity (Wei et al. 2020). Table A 3 (appendix)provides a list of benthic invertebrates identified in the QSA during historical and recent surveys, representing a minimum level of diversity in the region.

Available data on benthic diversity and production proxies support the proposed boundaries of the various EBSAs within Hudson Bay (Kenchington et al. 2011). High pigment concentrations and organic carbon content in surficial sediments northwest of the Belcher Islands may indicate high benthic diversity and productivity (Kenchington et al. 2011). An assessment of Hudson Bay diversity using data collected by Atkinson and Wacasey (1989) from 1953-1965, concluded the bay had among the lowest diversity (167 taxa) of all Arctic regions (Cusson et al. 2007). Despite low species richness, Cusson et al. (2007) also found high beta diversity (i.e., species turnover) in Hudson Bay, which may reflect the diversity of available habitat types in the region. However, these data were collected primarily from nearshore areas and were not representative of all available habitat types in the bay and were therefore considered to be underestimates (Piepenburg et al. 2011). Furthermore, based on low taxonomic breadth relative to sampling effort, certain taxa, namely mollusks, arthropods, and echinoderms may have been under-sampled in previous surveys relative to other taxa (e.g., annelids) (Piepenburg et al. 2011). Within the QSA, there were a handful of surveys in the 1970s and 1980s in the GWR plume that identified relatively few species mostly consisting of bivalves, arthropods and echinoderms (Nozais et al. 2021). For example, Legendre (1977) reported the occurrence of 38 species of macroinvertebrates (mainly represented by Bivalvia and Polychaeta) at deep stations within Manitounuk Sound. Atkinson and Wacasey (1989) identified 18 macroinvertebrate species (most of them belonging to Arthropoda and Echinodermata) at another station located within Manitounuk Sound at 90 m depth.

Based on the amount of energy available for growth and reproduction, Kostylev et al. (2015) modeled, using a variety of environmental parameters, a preliminary map of benthic scope for growth for Arctic Canada that included Hudson Bay (Figure 22). The bay showed an average to low overall scope for growth with the highest values in its coastal areas and near the Belcher Islands. However, new research combining data from both historical and recent surveys has identified 380 total benthic taxa from the HBC and concluded that Hudson Bay was, contrary to results from previous studies, at least as productive as other Arctic regions (Pierrejean et al. 2019, 2020). After accounting for recent surveys and correcting for unequal sampling effort across ecoregions, Wei et al. (2020) identified previously unreported hotspots of benthic diversity in the Canadian Arctic including Hudson Bay. Furthermore, the first pan-Arctic predictive model of benthic organic matter remineralization identified hotspots of sediment oxygen demand in James Bay and southeast Hudson Bay (Bourgeois et al. 2017), indicating a high level of benthic functioning in the area of the QSA. However, the estimates of benthic carbon remineralization in this area are based on model interpolation and should be validated with empirical measurements.

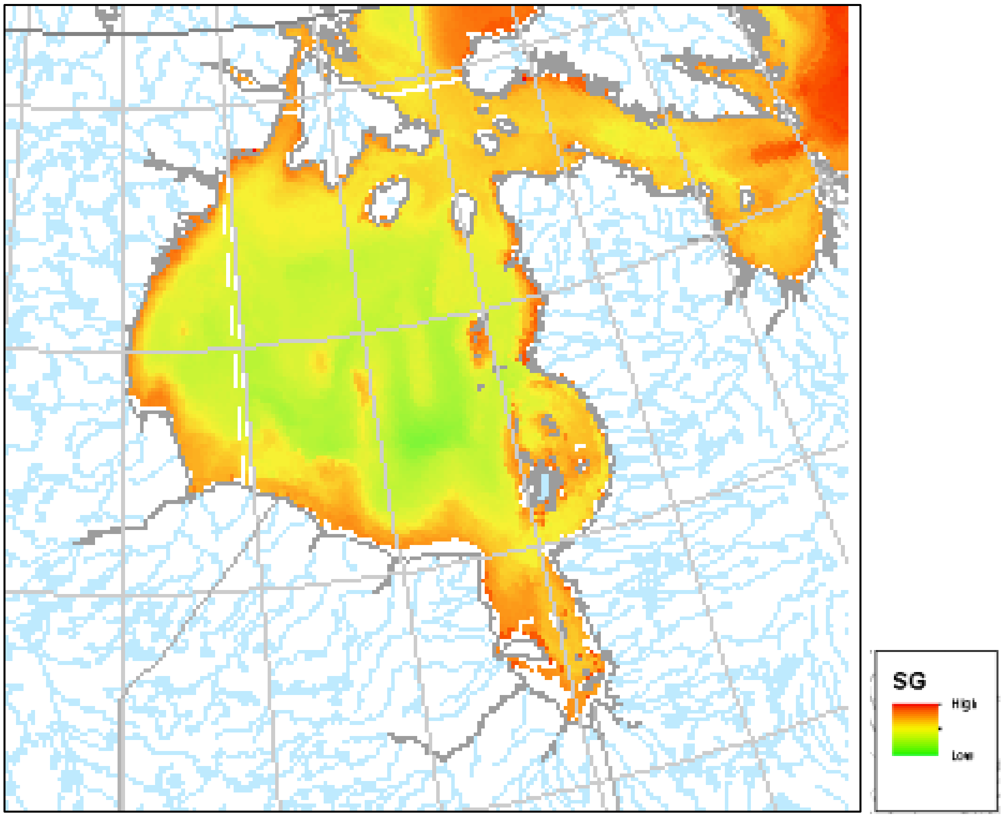


Figure 22. Scope of growth (SG) for the benthic environment in Hudson Bay. Source: Kostylev et al. (2015).

Biological production and benthic community structure and dynamics in the HBC are heavily influenced by river runoff and seasonal sea ice cover (Pierrejean et al. 2019, 2020). Pierrejean et al. (2019) examined epibenthic and infaunal communities in Hudson Bay using historical and recent data that included four sites around the Belcher Islands Archipelago and another five along the southeast and south coastlines of the bay within the QSA. Most sites in the QSA were characterized, along with other sites in southern Hudson Bay as heavily influenced by rivers, mostly sandy/rocky bottom with epifaunal species that are more tolerant of salinity variations such as some arthropods (e.g., *Atylus carinatus* and *Eualus* sp.) and filter feeding bivalves. Infaunal biodiversity was relatively low at QSA sites, similar to most sites in the bay, but much lower diversity than at Hudson Strait sites. Annelida and Mollusca were the most common infaunal phyla within the QSA.

In a second paper comparing HBC epibenthic communities with mean annual primary production, particulate organic carbon in surface water, bottom oceanographic variables and substrate type, Pierrejean et al. (2020) described three distinct communities based on biomass and taxonomic composition. Differences in salinity, substrate composition and primary production largely explained the spatial distribution of these three communities:

1. The first community is defined by coarse substrates in areas along the coast of the bay near river mouths that have low benthic density and community richness but high biomass of filter and suspension feeders;
2. The second community was associated with mixed substrates, usually near polynyas, with high biomass and diversity;

3. The third community was associated with deep water and soft substrate and was composed mainly of deposit feeders and small numerous epibenthic taxa.

Pierrejean et al. (2020) included data from three coastal sites at the north end of the QSA boundary near the community of Imirtavik in Québec, two coastal sites at the south end of the QSA near the outflow of the GWR and the community of Kuujjuarapik in Québec, and one at the polynya west of Split Island near the QSA boundary. The polynya sampling station near the Belcher Islands had among the highest values for biomass, density and taxonomic richness of all sites in the HBC. The coastal site nearest the shore at the north end of the QSA showed high biomass and richness, while the other two at this location showed high density. In contrast, the two sites near the GWR had among the lowest biomass, density and richness values.

Five of the six sites in the QSA were classified as Community 3 types with only the site nearest the north shore classified as Community 1 (Pierrejean et al. 2020). Community 3 types were dominated by Ophiuroidea with moderate proportions of Mollusca and relatively low proportions of Arthropoda. Community 1 had the highest proportions of Echinoidea, Arthropoda, and Mollusca among all three communities. More precisely, Community 1 was characterized by high bottom DO, longer open water periods and coarse substrates with deposit feeders (e.g., *Strongylocentrotus* sp.), filter feeders (Pectinidae bivalves and Balanidae barnacles), and opportunist-predator decapods (Thoridae and Oregoniidae) most common. Community 3 was associated with high primary productivity, low DO, longer ice cover and deeper, softer substrates where deposit and filter-suspension feeding bivalves (Yoldiidae and Astartidae) and opportunist-predator brittle stars (Ophiuridae) were dominant.

Resource users from Sanikiluaq have identified a number of benthic invertebrates from waters around the Belcher Islands and other nearby islands (Government of Nunavut 2010). Mussels (Mytilidae) are found year-round in rocky areas with currents throughout the islands. Iceland Scallops (*Chlamys islandica*), clams, sea cucumbers, cockles and crabs are concentrated mostly in the northern half of the Archipelago. *Gonatus* spp. squids and *Cryptonatica* spp. snails are found around Wiegand Island and shrimp are concentrated offshore of the north coast of Flaherty and Weigand islands and between Johnson and Kugong islands and appear to be particularly common prey for seals during winter (Government of Nunavut 2010). Mussels are among the eight most prominent prey choices for residents of Sanikiluaq and many residents believe that mussels and Arctic Char could be more intensely harvested, though there is uncertainty about commercial viability. A harvest study conducted from 1996-2001 indicated that mussels from the Belcher Islands were collected primarily during the winter and early spring, from November to May (Priest and Usher 2004). The number of monthly mussel harvesters was typically less than ten individuals. The estimated mean annual harvest during the survey period was 22,872 mussels; the highest total for any harvested species. Clams were only rarely harvested with most of the reported catches (917 of 934 clams) from the 1997/1998 season (Priest and Usher 2004).

As with the other biotic components of Hudson Bay, benthic community data are generally insufficient to predict impacts from climate change (Piepenburg et al. 2011; Pierrejean et al. 2019), particularly as baseline studies are ongoing while changes (e.g., increased river runoff) are already occurring within the bay. Freshwater inputs into the bay are currently increasing (Andrews et al. 2018) and expected to continue increasing in the future (Derksen et al. 2019) with some projections suggesting as much as a 50% increase from surrounding drainages (Gagnon and Gough 2005a; Bring et al. 2017). See the Climate Changes and Projections section for a more detailed description of the current and projected future trends in precipitation and freshwater inputs to the bay. Increased freshwater inputs into the bay and shorter duration ice cover could potentially affect the abundance and distribution of benthic invertebrates, particularly taxa that are less tolerant of low salinities (Pierrejean et al. 2019, 2020). Increasing contribution of terrestrial organic matter from freshwater inputs can also decrease the strength of benthic-pelagic coupling (Stasko et al. 2018). Changes in the duration and extent of sea ice cover also has potential implications for benthic and pelagic foodwebs. In the HBC, The rapid sinking of ice algae and assimilation by benthic invertebrates supports complex coastal foodwebs in both benthic and pelagic compartments (Amiraux et al. 2023). Changes in the benthic compartment therefore could have a cascading effect on higher trophic levels (e.g., fish, marine mammals, seabirds) as has been observed in other parts of the HBC and Arctic regions. In Foxe Basin, Yurkowski et al. (2020) observed a 75% decline in the contribution of sea-ice derived carbon in the diet of benthivorous Atlantic Walrus between 1982 and 2016. In the northern Bering Sea, benthic communities (especially clams) have declined as sea ice cover has decreased, which has coincided with changes to benthic-feeding marine mammal distributions (Grebmeier et al. 2006, 2012).

Hudson Bay coastal areas near ports have been identified as particularly high risk for introductions of benthic invertebrate NIS (Goldsmit et al. 2019, 2020, 2021). Crabs (e.g. green crab *C. maenas*, snow crab *C. opilio*, and red king crab *P. camtschaticus*) and molluscs (e.g. common periwinkle *L. littorea*, and soft-shell clam *M. arenaria*) from the east and west coasts of the North Atlantic Ocean have been identified as some of the taxonomic groups with the highest overall risk of introduction into Hudson Bay, in terms of higher likelihood of invasion and greater potential impacts relative to other taxa (Goldsmit et al. 2021). As with other lower trophic level groups, more shipping means greater potential risk of such introductions in the future. Additional data collection and descriptions of existing benthic communities, their importance within the QSA and greater Hudson Bay ecosystems are necessary to better predict all potential impacts from climate change. With changes already occurring, especially to those areas around the periphery of the Arctic, it is imperative that important baseline data be collected now and in the near future.

MARINE AND ANADROMOUS FISHES

There is little published information on the diversity, distribution and abundance of fishes in Hudson Bay, nor on the life histories of several key anadromous species (Kuzyk and Candlish 2019). Remoteness and an historical lack of interest in commercial fisheries are some of the reasons there have been so few studies in recent years, though there is extensive local knowledge of species used for subsistence among Hudson Bay communities. A minimum of 61 marine and anadromous species from 31 families are present in the HBC marine region, with at least 42-44 species of fishes occurring in Hudson Bay (Coad and Reist 2018; Kuzyk and Candlish 2019). Nine of these species are anadromous/diadromous (e.g. *Salvelinus alpinus*). Arctic Cod (*Boreogadus saida*) are a ubiquitous species throughout the Arctic and inhabit southeastern Hudson Bay while some other fish species (i.e. Capelin, *Mallotus villosus,* and shannies, Stichaeidae) are more commonly in the southern and western section of Hudson Bay (Kuzyk and Candlish 2019). Table A 4 (appendix)provides a list of fishes identified in Hudson Bay and the QSA, representing a minimum estimate of fish diversity in the region. Some of the key species within the Belcher island EBSA and QSA include anadromous and resident? Arctic Char (*Salvelinus alpinus*) in the Belcher Islands, Coregonids in river estuaries along the Québec coast (Coregonus spp), and Arctic Cod, Capelin and sand lance (*Ammodytes* spp.) throughout the area. These important species will be discussed in greater detail in subsections below following a brief description of the general fish community.

Salmonidae, Catostomidae and Cottidae were the most speciose and abundant families in the GWR ecosystem surveyed in the 1980s and 1990s (Morin et al. 1980; Kemp et al. 1989; Nozais et al. 2021). Anadromous Coregonines (e.g. Lake Whitefish, Cisco), Brook Trout (*Salvelinus fontinalis*) and sticklebacks (*Gasterosteus aculeatus* and *Pungitius pungitius*) were common in river plumes after ice breakup (Kemp et al. 1989; Hudon 1994). Ichthyoplankton within the plume was even more diverse, with at least 21 species observed, than the adult fauna (Drolet et al. 1991; Ponton et al. 1993; Kuzyk and Candlish 2019) and consisted mainly of Arctic Cod and sand lance larvae as well as from many stichaeid and cottid species. In addition, large numbers (approximately 5 million) of Burbot (*Lota lota*) larvae were predicted to drift into Hudson Bay from the GWR during ice breakup in early spring, based on their abundance in the river (Hudon 1994).

In addition to the key species, a number of other fish species have been observed by local Inuit from Sanikiluaq in marine waters around the Belcher Islands (Government of Nunavut 2010). Greenland Cod (*Gadus ogac*) have been identified from several small bays throughout the Archipelago. Rainbow Smelt (*Osmerus mordax*) have been found throughout the islands. A number of marine sculpin species have been reported from Eskimo Harbour, and lumpfish (Liparidae) were noted from a number of areas, including the Sleeper Islands to the north, and have occasionally been found dead near seal breathing holes (Government of Nunavut 2010). Of these taxa, a small number of sculpin spp. (mean estimate of 350) are harvested annually by resource users from Sanikiluaq (Priest and Usher 2004).

Much of the discussion on climate change impacts to ichthyofauna has focused on a few key species (see subsections below). Generally, projected increases to freshwater input from climate change and expansion of estuarine/brackish habitat are expected to have among the most significant impacts to the fish community of the QSA. Such changes are expected to favour species that preferentially use these habitats (e.g., Rainbow Smelt, Capelin, some stichaeids, and sand lance) over those that prefer more saline waters (e.g., most gadids) (Kuzyk and Candlish 2019).

As with other taxonomic groups, increased shipping and other anthropogenic activities that could potentially accompany climate change, and decreased ice cover mean greater potential risk of harm to fish health and habitat. This includes the introductions of non-indigenous species with potential ecosystem-wide consequences in the future (Halpern et al. 2008; Andrews et al. 2016; Goldsmit et al. 2020, 2021). Some modeling of future fish distributions have identified many north Atlantic and north Pacific species (e.g. Atlantic cod and Atlantic wolffish) extending their ranges across the Canadian Arctic by 2100 (Wisz et al. 2015; Huntingdon et al. 2020) with an estimated northward expansion of up to 40 km annually due to changes in habitat suitability, larval drift, migration patterns, and population growth (Cheung et al. 2008, 2009). Although habitat conditions within Hudson Bay may quickly become more suitable for the introduction/range expansion of sub-Arctic fish species, oceanographic conditions in Hudson Strait may continue to prevent natural migration from the north Atlantic for some time (Stewart and Lockhart 2005).

Additional data collection and descriptions of existing fish communities, their importance to ecological functioning within the QSA and greater Hudson Bay ecosystems are necessary to better predict all potential impacts from climate change. With changes already occurring, especially to those areas around the periphery of the Arctic, it is imperative that important baseline data be collected in the near future. As with other trophic levels, more data on fish populations in the QSA are required to accurately identify potential impacts from climate change.

Arctic Char (*Salvelinus alpinus*)

Arctic Char are a circumpolar species with both anadromous and non-anadromous populations found throughout the Canadian Arctic (Coad and Reist 2018). Anadromous populations are common where there is access from freshwater overwintering lakes to productive coastal marine regions that are critical for summer foraging. They are the most abundant salmonid in the Canadian Arctic and are important to subsistence, commercial and recreational fisheries, and coastal ecosystems where they occur. Char populations within the QSA are near the southernmost extent of the species' range in the Canadian Arctic (see distribution map in Coad and Reist 2018). Genetically, Arctic Char in the Belcher Islands are part of an Arctic lineage that is dominant from the Mackenzie Delta east to Greenland and Québec and south to the Belcher Islands (Moore et al. 2015). This lineage likely originated from a small source population either in a high Arctic refugium during the Last Glacial Maximum or northern Beringia from Alaska and Russia.

Anadromous char are highly opportunistic predators that consume a wide variety of fishes and invertebrates. Prey availability is the most important factor determining the diets of individual populations both spatially and temporally (Dempson et al. 2002). In marine environments, common prey items from populations across the Canadian Arctic in recent years include several species of amphipods (e.g., *Onisimus* spp., *Gammarus* spp., and *Themisto libellula*), *Mysis* spp. shrimp, krill (Euphausiidae), large calanoid copepods (e.g., *Calanus* spp.), and several taxa of adult and juvenile fishes (e.g., Capelin, sand lance, gadids) (Dempson et al. 2002; Rikardsen et al. 2005; Ulrich 2013; Ulrich and Tallman 2021). In summer and during ice-breakup, Arctic char prefer to reside in estuaries and near-shore habitats (Moore et al. 2016). As summer progresses, char diving activity has been observed to increase in the Kitikmeot Sea and it is thought this is in response to diel vertical migration of preferred prey shifting to deeper waters, and in some cases up to 100m depth (Harris et al. 2020). Also, it is during this limited foraging time in summer that Arctic char stocks can mix extensively (Harris et al. 2022). Arctic char also move to further offshore to cooler, deeper waters in summer to stay within their thermal optimum temperature (Harris et al. 2020). While in freshwater, common prey items of char include aquatic insects (especially Chironomidae), copepods, and small fish (Rikardsen et al. 2005; Gallagher and Dick 2010).

Arctic Char appear to be rare or absent from most of the large watersheds along the Nunavik coast in the Belcher Island EBSA near the QSA (Kemp et al. 1989; Nozais et al. 2021). Only in the northernmost (e.g., Innuksuac River) watersheds along this Québec stretch near the QSA coastline do they appear to be more than just vagrants based on catches within the estuaries of these rivers. Char abundance in watersheds of eastern Hudson Bay increases further north of the QSA. The greatest concentration of char within the Belcher Island EBSA and QSA are anadromous and found among the Belcher Islands (Figure 23) (Government of Nunavut 2010; Kuzyk and Candlish 2019). However, to date, there have been no detailed scientific studies on the biology of these populations and their importance to the marine ecosystem of the QSA.

Arctic Char have consistently been one of the most important harvested animals for residents of Sanikiluaq (Wein et al. 1998; Government of Nunavut 2010). Anadromous char are found throughout the main Archipelago and north to the Sleeper Islands in coastal marine and freshwater habitats. They are harvested year-round with some fishers noting there are fewer and/or smaller char than historically. Spawning locations have been identified in Kasegalik Lake on Flaherty Island (Government of Nunavut 2010). They have historically been fished at a minimum of 34 sites, usually from anadromous stocks (Freeman 1982). A harvest study conducted from 1996-2001 indicated that char were captured year round in the Belcher Islands (Priest and Usher 2004). Monthly catch estimates were typically highest during the open water period with totals occasionally exceeding 2,000 fish. Estimated mean annual harvest over the survey period was 9,769 fish. Arctic Char were the second most harvested species (by total catch) by Sanikiluaq residents but involved the greatest number of hunters. There has been some interest in development of a potential commercial fishery, however, the consensus from resource users is that commercial fishing in the Belcher Islands is likely not as viable as in other areas of Nunavut (Government of Nunavut 2010). There has also been some concern that char populations in the islands have already been depleted from historic and current levels of harvest while others have suggested the fish could be more heavily used by the community.

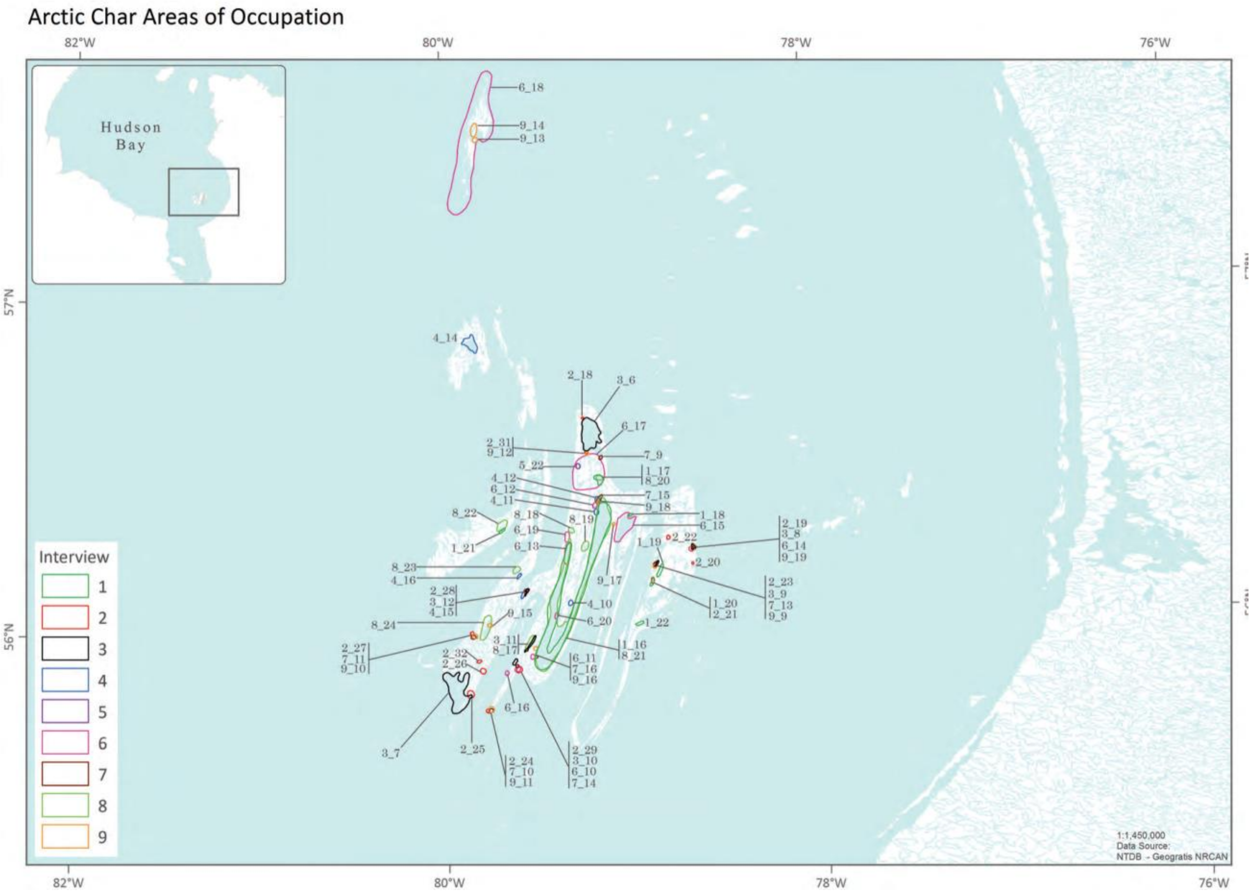


Figure 23. Arctic Char areas of occupation around the Belcher Islands. Source: Government of Nunavut (2010).

The effects of climate change can pose a significant effect on a cold-water species such as Arctic Char in terms of altering the migration phenology, species interactions and physiological impacts in association with warming temperatures. Char migrations between freshwater lakes and marine coastal areas may be affected by increased environmental variability from climate change (Kuzyk and Candlish 2019). For example, using temperature and precipitation changes projected by two emission scenarios, Finstad and Hein (2012) modeled 22-61% reductions in the prevalence of anadromy in Norwegian populations of char. The predicted changes were due primarily to increases in terrestrial primary production that would, in turn, increase productivity in the lakes and decrease the profitability of long-distance migrations downstream to the ocean. Furthermore, with spring sea ice break-up occurring earlier in the year as a result of climate change, the downstream migration of Arctic char will also occur earlier leading to increased foraging opportunities over the summer before migrating back upstream in the fall to overwinter.

Overall range reductions are also expected under climate change scenarios. Hein et al. (2012) predicted a range reduction of 73% for freshwater Arctic Char in Sweden by 2100 likely due to both increasing water temperature physiological stresses and associated range expansions of predatory Northern Pike (*Esox lucius*). Higher altitude, mountainous areas are expected to provide refugia for the species in Sweden. In northern Norway, abundance of some anadromous char populations has decreased relative to Atlantic Salmon (*Salmo salar*) as summer air temperatures have increased Svenning et al. (2016). Using growth rates, the authors suggested the warmer temperatures were more beneficial to the Atlantic Salmon such that they could outcompete char for resources. In North America, co-occurring populations of Atlantic salmon and Arctic char are limited currently; however, warming temperatures may be facilitating distributional shifts of Atlantic salmon northward (Bilous & Dunmall 2020). Given rising temperatures, it may be possible for Atlantic salmon to establish in new locations in the Canadian Arctic and, due to overlap in life cycles and habitat preferences with Arctic char, interactions between these species may occur in the fresh water (Bilous and Dunmall 2020). With warming temperature and a northern expansion of species, novel parasites or disease could also impact Arctic char populations across the Canadian Arctic.

Populations of char in parts of northern Québec and Labrador are predicted to be reduced as anadromous Atlantic Salmon and Brook Trout (*Salvelinus fontinalis*) expand northwards (Reist et al. 2006). However, the exact effects are largely unknown and would require long-term studies to properly assess, especially for a slow-growing, long-lived fish such as Arctic Char and has implications for both the important subsistence fisheries in the Belcher Islands and also coastal and Freshwater ecosystems. Changes to lower trophic levels can also affect char diets, however, there are no historical baseline data on dietary preferences for the area. Other studies have identified important dietary shifts in Arctic Char populations associated with changes to lower trophic levels. For example, Ulrich and Tallman (2021) assessed stomach content and stable isotope data in Cumberland Sound Arctic Char from 2002-2011 and found that diet shifted from invertebrate-based to Capelin-based in 2011 coinciding with an increase abundance of that species in the area. The data also suggested that the shift to Capelin had increased growth rates of individual char (Ulrich and Tallman 2021).

Given that char within the QSA are generally restricted to habitat within the Belcher Islands themselves and that the area is near the southern extent of the species range, warming could potentially pose an imminent threat to these fish. Although upwelling around the islands keeps the area colder than the rest of Hudson Bay, char freshwater habitats within the islands could warm quicker and affect char spawning and larval survival. Elliott and Elliott (2010) summarized temperature tolerance of three salmonids (Arctic char, Atlantic Salmon and Brown Trout, *Salmo trutta*) and noted that char were the least tolerant of warmer water temperatures at all life stages with survival rates of alevins and parr/smolts negatively affected by sustained temperatures in the low to mid 20s (°C). Eggs are particularly sensitive to warm temperatures with a maximum of 8°C as the upper limit for survival. It is during this egg incubation stage in freshwater where Arctic Char are most vulnerable to warming temperatures. Several recent experimental studies were conducted to monitor cardiac responses of wild char to warm temperatures (Gilbert et al. 2020, 2022; Gilbert and Farrell 2021). Maximum heart rate increased with warming water temperatures with arrhythmia occurring at approximately 21°C (Gilbert et al. 2020). In addition, the char recovery following exhaustive exercise was impaired above 16°C. As the rivers these char use during migration warm, there could be severe impacts on population health and survival. However, there is also evidence that anadromous char maybe better able to adapt to some acute warming if provided with a period of acclimation (Gilbert and Farrell 2021; Gilbert et al. 2022). Char in these acclimation experiments demonstrated rapid compensatory cardiac plasticity that minimized some of the effects of exposure to acute warming at higher temperatures. These data suggest that char might be able to adapt to some of the effects of climate warming under certain circumstances.

Arctic Cod (*Boreogadus saida*)

Circumpolar Arctic Cod are an important component in marine food webs throughout the Canadian Arctic, linking lipid-rich lower trophic levels to higher trophic level piscivores (Bain and Sekerak 1978; Bradstreet 1980; Cobb et al. 2008; Loseto et al. 2009; Majewski and Reist 2015). An estimated 93% of energy transferred from zooplankton to pelagic vertebrates is thought to pass through Arctic Cod in the Canadian Arctic (Welch et al. 1993). Important habitats for Arctic Cod include upwellings, recurrent polynyas, nearshore areas, flaw lead features and ice-edges, all of which can be found in the QSA, likely contributing to the higher abundance of this species noted for eastern Hudson Bay relative to other parts of the bay (Kuzyk and Candlish 2019). Their diet consists mainly of ice-associated copepods and amphipods at the floe edge in spring and among broken ice or open water during summer (Bain et al. 1977; Bain and Sekerak 1978; Hop et al. 1997).

Arctic Cod have been observed by resource users from Sanikiluaq in marine waters around the Belcher Islands, particularly in small bays throughout the Archipelago (Government of Nunavut 2010). A harvest study from 1996-2001 reported estimated annual mean harvests of cod (e.g. both Arctic cod and Greenland cod) at 1,574 fish (Priest and Usher 2004).

Increased freshwater input and expansion of estuarine/brackish habitat due to predicted climate change impacts is likely to negatively affect Arctic Cod within the QSA (Kuzyk and Candlish 2019). Furthermore, reduced ice cover extent and duration due to warming surface water temperatures and corresponding reductions in ice-associated lipid-rich copepods may also have a long-term negative impact on cod, particularly in areas along the fringes of the Arctic, such as Hudson Bay.

In a survey of the ichthyoplankton fauna of fresh and brackish waters of the GWR plume, Ponton et al. (1993) captured larval Arctic Cod in higher salinities than most other species. Ponton and Fortier (1992) noted that larval Arctic Cod were particularly abundant at the pycnocline immediately beneath the plume where feeding conditions (e.g., lower turbidity and more optimal light levels) were ideal. Their peak abundance coincided with ice break-up and increasing quantities of copepod eggs and nauplii, upon which they fed almost exclusively (Ponton and Fortier 1992). Feeding success and larval survival depend on how closely temporally synchronized larval cod and copepod production are and how thick the river plume is, which affects irradiance and primary production (Gilbert et al. 1992; Fortier et al. 1996; Kuzyk

There is already some evidence of changes with respect to the life history of Arctic Cod occurring in the bay. Although larval fish diversity and abundance of fishes during surveys can vary considerably by season due to high larval mortality rates and timing of reproduction for each species, there has been some evidence of a shift in abundance within Hudson Bay. Larval Arctic Cod have gone from being the most abundant larval fish species throughout Hudson Bay in the late 1980s (Ponton et al. 1993) to the fourth-most abundant (behind what species now) in 2005 and 2010 surveys (Kuzyk and Candlish 2019). Ecosystem modeling has also predicted declines in this important species. Florko et al. (2021) modeled the abundance of Arctic Cod in Hudson Bay from 1950-2100 using low- and high-greenhouse gas emission scenarios. The authors found negligible change under the low-emission scenario, but a projected cod decline of 50% under the high-emission scenario concurrent with an increase in abundance of sub-Arctic forage species such as Capelin and sand lance. A study in Darnley Bay, Northwest Territories, demonstrated that juvenile sympatric Arctic Cod and Capelin have very similar diets, suggesting that range expansion and increased abundance of the latter could lead to increased interspecific competition (McNicholl 2016). The potential effects of such a species shift are largely unknown, as are the impacts associated with the distribution of their predators that rely on forage fishes during the summer season.

The eastern Hudson Bay/Belcher Island area appears to be somewhat of a refuge for the Arctic cod within the bay. Although their numbers decreased proportionally since the 1980s relative to other species (e.g., stichaeids), the decline was not as steep as in other parts of the bay and Arctic Cod remained the most abundant larval fish in 2005 and 2010 surveys in the QSA (Ponton et al. 1993; Kuzyk and Candlish 2019). These data suggest that the QSA may represent important habitat for the remaining cod populations within Hudson Bay in the future. There is limited scientific information on the other life stages of Arctic cod, like adults, in the QSA and is an area for future research.

The changing cod abundance and distribution within the Hudson Bay could have ecosystem-wide implications. Replacement of the more energy-rich cod with species that favour the new conditions could, in turn, affect populations of higher trophic level piscivores that have historically relied on cod as a main dietary component. The diets of piscivorous birds and mammals have reflected these changes in the ichthyofauna. Hudson Bay populations of Ringed Seals (*Pusa hispida hispida*) (Chambellant et al. 2013), Beluga (Breton-Honeyman et al. 2016) and Thick-billed Murres (*Uria lomvia*) (Gaston et al. 2003) transitioned from historically cod-dominated diets to greater quantities of Capelin in the 2000s. However, it is unknown what, if any, effects these dietary shifts may have on higher trophic levels in the QSA. More data on Hudson Bay cod populations, particularly in the QSA, are required to monitor current and potential future impacts from climate change.

Capelin (*Mallotus villosus*) and Sand Lance (*Ammodytes* spp.)

Capelin is a pelagic forage fish species found throughout the sub-Arctic and Arctic (Coad and Reist 2018). It can be particularly abundant in the fringe areas of the Arctic such as southern Hudson Bay, and is very abundant off the coast of Newfoundland and Labrador. There are two species of sand lance in the Arctic, *A. dubius* and *A. hexapterus*, and both are found in Hudson Bay. They can burrow in the sand or hide in crevices in sea ice and can form huge schools (1,800 million fish) in some areas (Coad and Reist 2018). Both taxa are important forage fish for piscivores, particularly in more sub-Arctic regions such as southern Hudson Bay.

Ichthyoplankton surveys of the GWR plume identified sand lance as the second-most abundant pelagic taxon after Arctic Cod with smaller numbers of Capelin also present (Drolet et al. 1991; Ponton et al. 1993; Kuzyk and Candlish 2019). Capelin were most abundant in intermediate salinities (range PSU) of the plume while sand lance were abundant in the highest salinities alongside Arctic Cod (Ponton et al. 1993). Similar to cod, sand lance were particularly abundant at the pycnocline immediately beneath the plume where optimal feeding conditions existed and their peak abundance coincided with ice break-up and increasing quantities of their main prey; copepod eggs and nauplii (Ponton and Fortier 1992). Feeding success and larval survival depends on how closely synchronized larval fish and copepod production are, and how thick the river plume is, which affects irradiance and primary production (Fortier et al. 1996; Kuzyk and Candlish 2019).

Capelin have been found throughout the islands with a spawning area identified on the west coast of Tukarak Island. Seals have been noted to feed on Capelin in a number of these areas during spawning events (Government of Nunavut 2010). Sand lance were not identified by harvesters interviewed for the survey. Neither taxon is harvested in significant numbers within the QSA.

Increased freshwater input from climate change and expansion of estuarine/brackish habitat is expected to favour species that use these habitats, including Capelin and sand lance (Kuzyk and Candlish 2019). Warmer water temperatures,reduced ice cover, and a resulting decline in associated lipid-rich copepods may have a long-term negative impact on Arctic Cod, particularly in areas like Hudson Bay. Replacement of cod with these other pelagic forage fishes, that are better adapted to warmer conditions could influence the foraging ecology of higher trophic level species. Along with an observed bay-wide decrease in the abundance of larval Arctic Cod from the 1980s to the 2000s, Capelin have become more abundant than all other species combined (Ponton et al. 1993; Kuzyk and Candlish 2019). The change has not been as dramatic within the QSA, where cod larvae appeared to be declining but remained the most abundant over that time period. Ringed Seals, Beluga, and Thick-billed Murres have all shifted from a historically cod-dominated diet to a greater reliance on Capelin and/or sand lance(Gaston et al. 2003; Chambellant et al. 2013; Breton-Honeyman et al. 2016).

Coregonines (*Coregonus* spp.)

Coregonines are an important component of estuarine fish communities along the Hudson Bay coast and are alsoimportant for subsistence fisheries in the coastal regions of eastern Hudson Bay within the QSA (Kuzyk and Candlish 2019). Diet of these anadromous coregonines has not been well-studied in the Hudson Bay area, though stable isotope analyses have shown that they rely mainly on marine-derived nutrient sources when in estuaries (DeJong 2017).

Generally, adult Cisco are more abundant than Lake Whitefish in James Bay and some of the more southern estuaries of Hudson Bay (e.g., Little Whale River), while the latter are the dominant coregonine in estuaries farther to the north along the Hudson Bay coast (Kemp et al. 1989). Immature Cisco were found to be nearly absent from Hudson Bay estuaries following spring ice breakup while immature Lake Whitefish were one of the most common species (Kemp et al. 1989). Sampling of fish larvae in the GWR plume showed that both species are restricted to fresh and brackish water and are not found at higher salinities (Ponton et al. 1993).

Effects of climate change on coregonine populations in the QSA and adjacent areas is unknown. Wrona et al. (2006) predict that euryhaline and anadromous species, including coregonines, are likely to increase in abundance in estuarine habitats and potentially compete for resources with marine species using the same areas. However, there may be adverse effects on early life stages. An experimental study of different incubation temperatures on the embryonic development of several coregonines (including Cisco) indicated that survival, incubation period, length-at-hatch, and critical thermal maximum were negatively related to incubation temperature while yolk-sac volume and growth rates were positively related (Stewart et al. 2021, 2022). The magnitude of the responses varied by species and location, suggesting some level of plasticity and ability to cope with warming temperatures among coregonines. These data indicate that similar studies on populations within the QSA are necessary to accurately assess any potential effects of warming temperatures.

MARINE MAMMALS

Six species of marine mammal are known to regularly use habitat within the QSA: Atlantic Walrus, Bearded Seal (*Erignathus barbatus*), Beluga, Harbour Seal (*Phoca vitulina concolor*), Polar Bear, and Ringed Seal. All of these mammal species use the QSA year-round, however only Polar Bear and Ringed Seal are associated with the landfast ice, and only Polar Bears spend part of their time inland. The other species are restricted to polynyas, and open leads during the winter months. Killer Whale (*Orcinus orca*) is becoming a more frequent visitor to the area in the summer and, as such, is considered in detail below as well.

Bowhead Whale (*Balaena mysticetus)* , Harp Seal (*Pagophilus groenlandicus*), and Narwhal (*Monodon monoceros*) are occasional visitors to the area, and infrequent sightings of all three have been made by researchers working in southern Hudson Bay. Similar observations have also been noted by resource users from Sanikiluaq and Kuujjuarapik (Manning 1976; Government of Nunavut 2010), However the bulk of this report will focus on species whose traditional ranges overlap the QSA and those expected to potentially increase in abundance in the near future.

The Foxe Basin/Hudson Bay population of Bowhead Whale is listed as Threatened (COSEWIC 2005). Their current population size is unknown. Bowhead Whale numbers were historically depleted due to intensive whaling activity in the 19th century. Though rarely observed south of 60 degrees latitude, and more common along the western versus the eastern shores of Hudson Bay, Bowhead Whales are occasionally observed in the QSA according to several undated observations, and one was observed as recently as July 2022 near Churchill, Manitoba.

Harp Seals migrate through Baffin Bay and Davis Straight and rarely enter Hudson Bay (DFO 2014). However, they are occasionally observed in the summer months in the QSA by local resource users (Government of Nunavut 2010). The Canadian population of Harp Seals is healthy and abundant, and is listed as Not at Risk (DFO 2014).

Narwhal have a summer range similar to Bowhead Whale, and winter in Hudson Strait (DFO 1998). A single observation of Narwhal was recorded in the QSA. The young whale was harvested in December in the 1990s by a hunter who found it stranded in a polynya in a bay on Flaherty Island (Government of Nunavut 2010). Narwhal was listed as Special Concern in 2004 (COSEWIC 2004).

Atlantic Walrus (*Odobenus rosmarus rosmarus*)

Walruses belong to the Family Odobenidae. They are a large tusked marine pinniped that grows to up to 2,000 kg. Their range spans the northern Pacific and Atlantic Oceanswalruses can be divided into two major groups, the Pacific Walrus (129,000 – 283,000 individuals; MacCracken et al. 2017), most of whom breed in the Bering Sea, and the Atlantic Walrus, numbering approximately 40,000 individuals(Keighley et al. 2022; Figure 24).

In 2017, the Atlantic Walrus population was reassessed and split into three subpopulations (Figure 25) (COSEWIC 2017):

- High Arctic population (DU1)
- Central-Low Arctic population (DU2)
- Nova Scotia-Newfoundland-Gulf of St. Lawrence population (DU3)

The delineation of these three populations was based on tagging data (DFO 2010b), however there is ample evidence of movement between these populations (Born et al. 2001; Andersen et al. 2009, 2014).

The QSA falls within the range of the Central/Low Arctic population, which is estimated to consist of approximately 18,900 individuals and is listed as Special Concern (COSEWIC 2017). The Central-Low Arctic population is further broken down into sub-populations. The low Arctic sub- population occupies northern James Bay and the eastern Hudson Bay, which overlaps the QSA. An aerial survey of the low arctic sub-population conducted in 2014 yielded an estimate of 196 individuals, with 99 individuals observed on the Sleeper Islands (Hammill et al. 2016). Previous estimates were not robust enough to provide a population trend for the Walrus population within the QSA however, the population is thought to be in decline (COSEWIC 2017). Another aerial survey was performed in summer 2022 and analysis is ongoing.

During summer, Walruses are less common on the Belcher Islands than on the Sleeper Islands and Kidney Island (Manning 1976; Government of Nunavut 2010) where they haul out in large numbers at terrestrial sites called uglit. In the winter, they are more commonly observed along floe-edges or in polynyas (Gilchrist and Robertson 2000). Proposed borders for the QSA were adjusted southward, in part, to encompass important Walrus over-wintering habitat (DFO 2011).

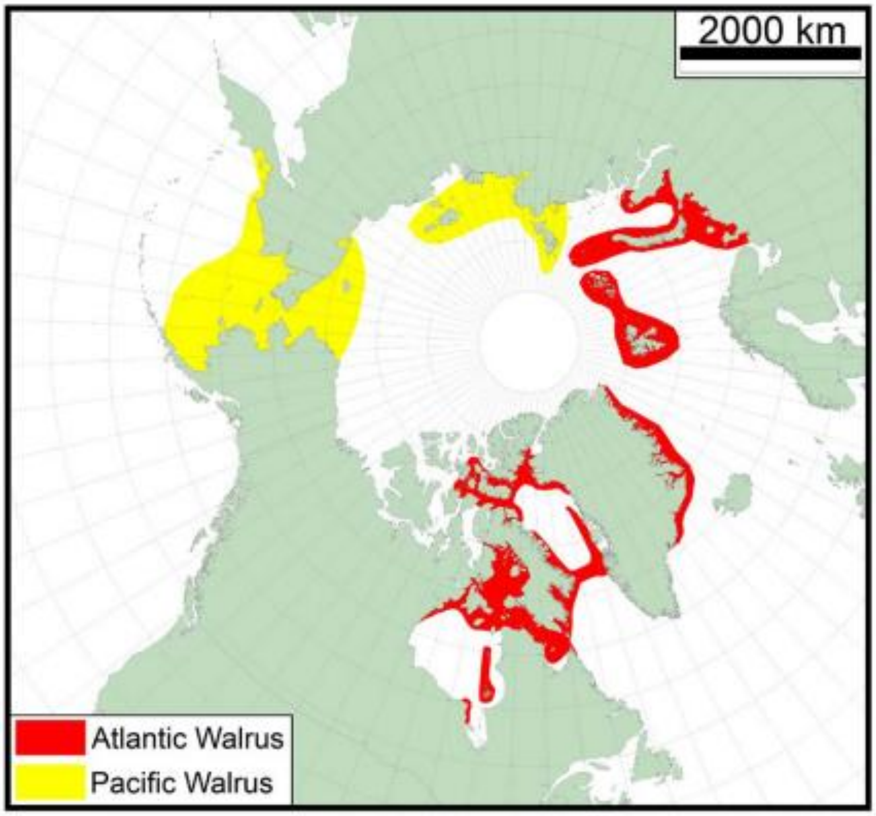


Figure 24. Range of Pacific and Atlantic Walrus. Source: COSEWIC (2017).

Walruses feed on benthic marine invertebrates, especially molluscs, buthave also been recorded consuming fish, pinnipeds and birds (Mallory et al. 2004; Sheffield and Grebmeier 2009).Many Atlantic walruses (i.e. uglit) have been identified during surveys, or from traditional knowledge (DFO 2011). These haul outs appear to be selected on the basis of proximity to food, and degree of human disturbance to which walruses are extremely sensitive (DFO 2011; COSEWIC 2017). Data suggest that ice floes are preferable over terrestrial uglit, but their preference may shift towards terrestrial haul outs as climate change affects ice timing and extent in Hudson Bay (DFO 2011; Kovacs et al. 2015; Higdon 2016).

Walruses are highly social and colonial, and breeding involves noisy displays similar to lekking behaviour in birds (Sjare and Stirling 1996) and these areas are sensitive to disturbance from humans or predators (COSEWIC 2020). Females produce a single pup, every two to three years between the ages of 7 and 35 (COSEWIC 2017). The active gestation period is approximately 11 months that follows a 4-5 month period of delayed implantation (Fay 1982). Walruses live for approximately 35 years, with a generation time of 21 years.

Walruses are susceptible to predation, disturbance and climate change (COSEWIC 2017). Young Walruses are vulnerable to attack by polar bears, but adults have no natural predators

(Calvert and Stirling, 1990). Walruses are traditionally hunted by residents of Sanikiluaq on the Belcher Islands but are less important than other prey such as char, seals, and eider ducks (Manning 1976; Government of Nunavut 2010; Polynya Consulting Group 2021).

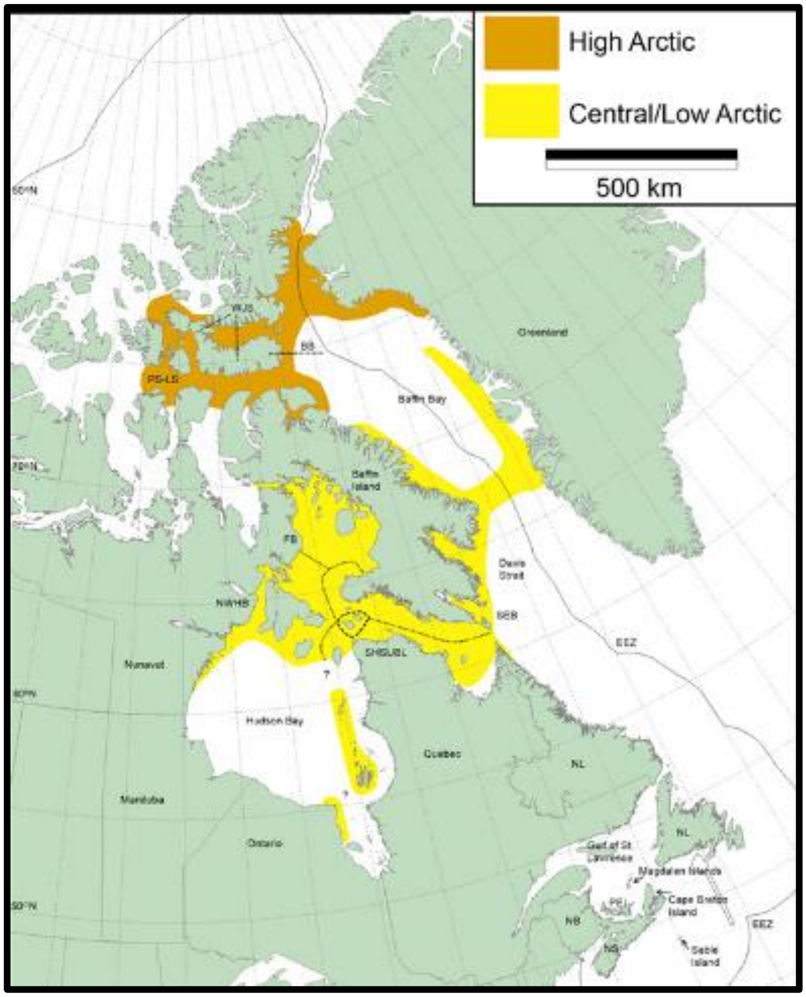


Figure 25. Two of the three Atlantic Walrus sub-populations. Source: COSEWIC (2017).

Harvest estimates for the south and east Hudson Bay Walrus stock are based on reported takes by hunters. The take varies from year to year and appears to be opportunistic. From 2000 to 2014, the reported harvest was under five individuals per year with the exception of 2002, 2003 and 2008, where the harvest was 15, 7 and 8 respectively (Hammill et al. 2016). However, due to the susceptibility of Walruses to disturbance, in Canada, NAMMCO (2006) estimates up to 30% incidental mortality in addition to the harvest number.

The current sustainability of Walrus hunting in the QSA is unknown, however there are regulations in place to manage hunting and trade in Walrus products (Government of Canada 2010), and the Nunavut Wildlife Management Board manages harvesting within Nunavut, with some communities establishing catch quotas (COSEWIC 2017). Other studies to determine hunting sustainability are ongoing (Hammill et al. 2016). The sustainable removal target is estimated to be 2 to 6 individuals annually (Hammill et al. 2016).

The degree of disturbance caused by shipping in the QSA is currently unknown, but the effects of disturbance on uglit are well-documented. Disturbance of an uglit can lead to stampedes and high mortality, especially of females and young, and may lead to site abandonment if frequent (COSEWIC 2017). While parks and other designated areas of protection do little to curb disturbance to Walruses, the Nunavut Land Use Plan requires a marine set-back distance of 1 to 6 km from uglit, depending on the size of vessel, and prohibits aircraft below 1,500 m within 5 km of an uglit (Nunavut Planning Commission 2021).

The effect of climate change on walruses is uncertain, however shifts in habitat use toward more terrestrial uglit is expected (Kovacs et al. 2015; Higdon 2016). For example, the timing of migration of Nunavik Atlantic walrus now occurs one month earlier as a result of changing sea ice dynamics in the area (Martinez-Levasseur et al. 2022). Climate change is also altering the composition of the benthic community, the food source of Walruses (Jones et al. 2021). It is already known that Walruses and their prey adapt differently to reductions in sea ice depending on their latitude (Yurkowski et al. 2020). It may be that climate change effects and human disturbance have a cumulative effect (COSEWIC 2017).

Bearded Seal (*Erignathus barbatus*)

Bearded Seals are a large marine pinniped, a true seal, belonging to the Family Phocidae. They are easily identified by their large body size (2-2.5 m), small head, and conspicuous vibrissae that resemble a beard when dry (Kovacs 2008). They range throughout the circumpolar Arctic and sub-Arctic (Figure 26), generally around pack ice (Lunn et al. 1997; Kovacs 2016) , but also in shallow coastal waters such as present in the QSA (Gilchrist and Robertson 2000). Bearded seals are wide-spread and abundant, stable, and are not currently considered to be at risk (Kovacs 2016).

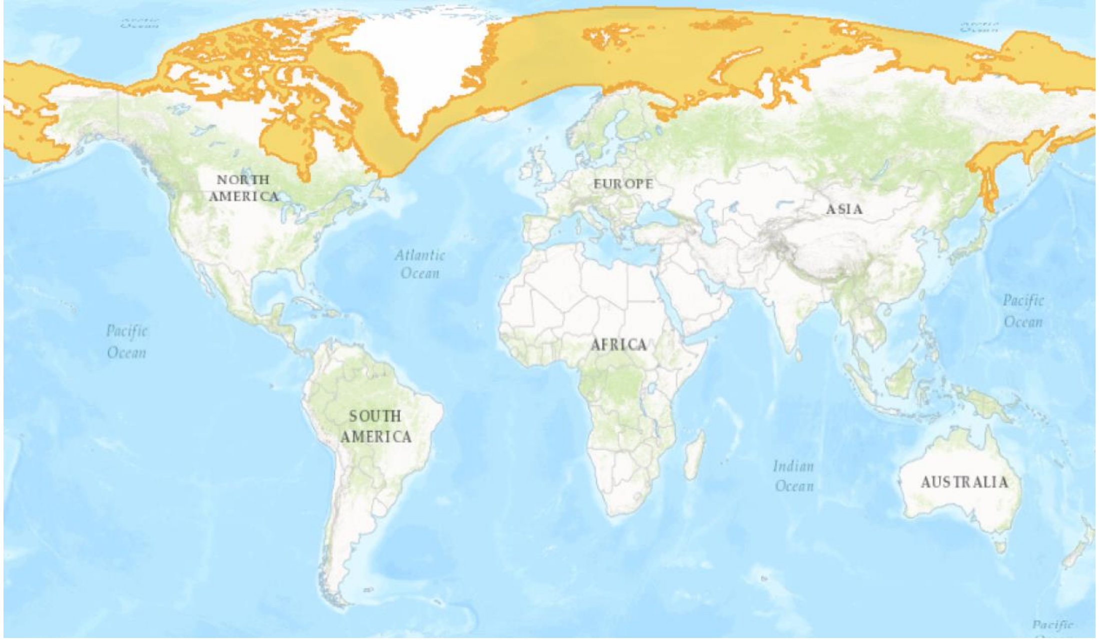


Figure 26. Bearded Seal range in the circumpolar Arctic. Source: Kovacs (2016).

Bearded Seals are sometimes divided into two sub-populations: *E. b. barbatus* in the Atlantic, and *E. b. nauticus* in the Pacific, however, this delineation is subject to some debate (Cameron et al. 2010). The QSA falls within the range of the Atlantic population, believed to consist of approximately 188,000 individuals, however these estimates are highly uncertain (Cameron et al. 2010). Consecutive surveys in western Hudson Bay in 1994 and 1995, for example, yielded population estimates of 12,290 and 1,980 respectively, with very little indication of the reason for the disparity (Lunn et al. 1997). Bearded Seal populations in the QSA are estimated at 13,000 individuals (Government of Nunavut 2010).

Bearded Seals over-winter in polynyas of eastern Hudson Bay near the Sleeper and Belcher Islands Archipelago (Figure 27); and their continued presence in the QSA in summer months suggests they also breed and rear their young there (McLaren 1958; Lunn et al. 1997; Government of Nunavut 2010). Bearded Seals are also common in Manitounuk Sound and the GWR estuary (Nozais et al. 2021). Hudson Bay, Foxe Basin and Hudson Strait (including Ungava Bay), evidently support the highest numbers of Bearded Seals in the Canadian Arctic (Smith 1981; Stirling and Cleator 1981).

Bearded Seals haul out on sea ice during the winter months, taking advantage of mid-afternoon sunshine to rest near breathing holes (Lunn et al. 1997; Cameron et al. 2010; Kovacs 2016). Hauling out on the ice is also important during the moulting season, which peaks in May or June, during which time the seals are more reluctant to enter the water (Kovacs 2016).

They also give birth to their young on the ice in late spring after 240 days gestation, with a single pup born annually to breeding females (Cameron et al. 2010). Females become sexually mature around four years of age (Kovacs 2016), and live to approximately 25 years (NOAA Fisheries). Late spring sea ice allows mothers to have a platform for whelping and raising their young whilst having easy access to the water for feeding (Kovacs et al. 1996; Cameron et al. 2010).

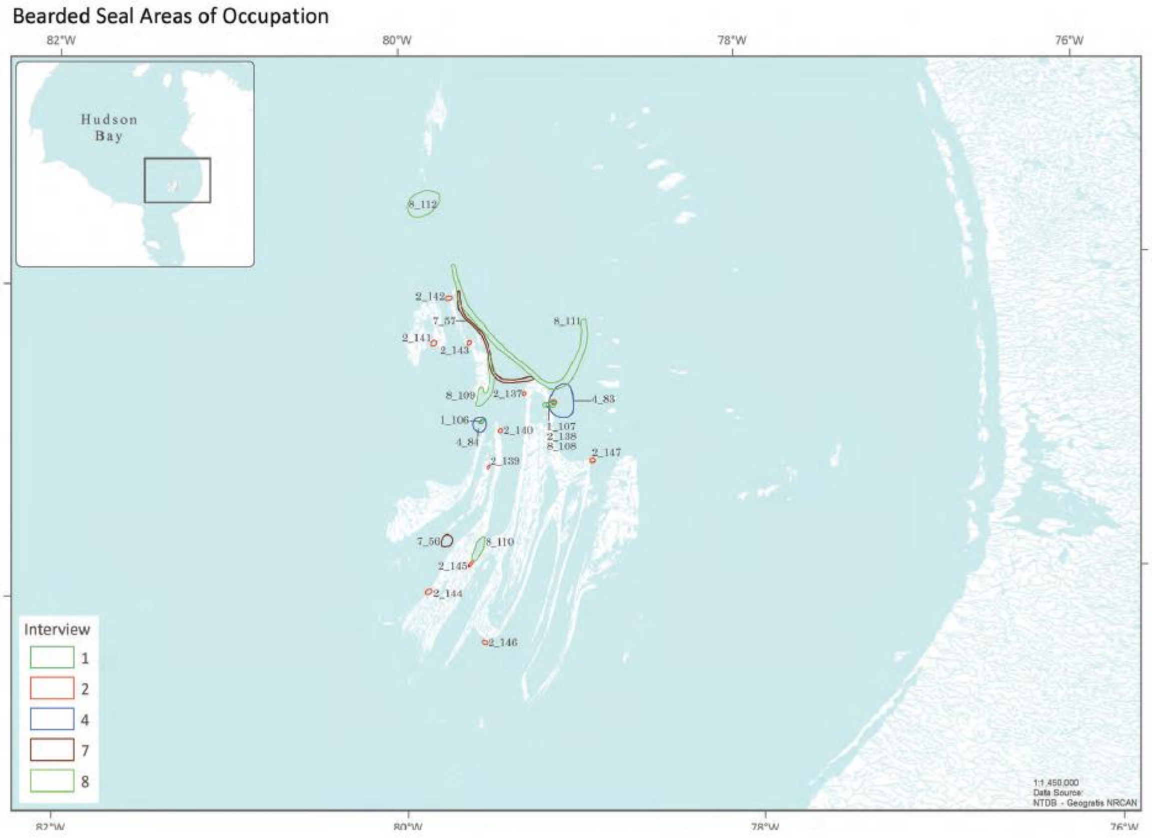


Figure 27. Bearded Seal use of the QSA. Source: Government of Nunavut (2010).

Bearded Seals are a generalist predator that feeds on a variety of prey items that they obtain during foraging dives (Cameron et al. 2010) in coastal, shallow habitats (>100m depth)

(Mansfield 1963; Lowry et al. 1980). Their diet ranges from fish to crabs and other crustaceans and varies by season and location (Finley and Evans 1983; Bourdages et al. 2020). The polynyas that form in the vicinity of the Belcher Islands Archipelago are important habitat for winter foraging for Bearded Seals (Stirling and Cleator 1981). Unlike Ringed Seals, Bearded Seals need access to open leads or polynyas for breathing as their claws are not sufficient to keep breathing holes open.

Bearded Seals are an important food source for the people of Sanikiluaq (Wein et al. 1996; McDonald et al. 1997; Government of Nunavut 2010). The harvest of Bearded Seals in Canada is managed cooperatively by the Fisheries and Oceans Canada and regional resource boards, however the annual harvest is not known and no quotas are in place (Cameron et al. 2010). Subsistence hunting for Bearded Seals is not believed prevalent enough to have population level effects (Kovacs 2016; NOAA Fisheries) However, since hunting pressure is often concentrated around polynyas, which limit population distribution in the winter months, it is believed that hunting pressure could cause localized areas of population depletion (Stirling and Cleator 1981; Riewe 1991; Kovacs 2016)

The largest potential threat to Bearded Seals is likely the effects of climate change, since these species are so dependent on sea ice for breeding and rearing of their young. The period of ice cover on Hudson Bay has already been reduced by several weeks (see Section on Changes in Sea Ice for more details) (Kovacs and Michel 2011), which has been noted by Indigenous hunters to affect their hunting success (Kovacs 2016). Climate change is also altering the composition of the benthic community, the major portion of the food source of Bearded Seals (Jones et al 2021). If ice cover in Hudson Bay diminishes further, with cascading effects on benthic invertebrate and fish communities, impacts to Bearded Seal population biology and distribution may occur (Kovacs et al. 2012).

Beluga (*Delphinapterus leucas*)

The Beluga is one of two members of the Monodontidae. They are toothed whales that are characterized by their white colour and lack of a dorsal fin. They grow to an average size of 3-5 meters and live in large communal groups called pods (O’Corry-Crowe 2018; COSEWIC 2020). The global population is estimated to be approximately 200,000 and their distribution is the circumpolar Arctic and sub-Arctic (Sale 2006). The population in Canada is estimated at 78,000 to 90,000 individuals (COSEWIC 2020).

Belugas in Canada have been separated into eight distinct populations: the Eastern High Arctic - Baffin Bay, Cumberland Sound, St. Lawrence Estuary, Ungava Bay, Western Hudson Bay, James Bay, and Eastern Hudson Bay populations (COSEWIC 2020). All of these populations undergo seasonal migrations (DFO 2011) (Figure 28). These populations fall into 8 designatable units (DU) for management (COSEWIC 2016).

- DU1: Eastern Beaufort Sea (EBS)
- DU2: Eastern High Arctic - Baffin Bay (EHA-BB)
- DU3: Cumberland Sound (CS)
- DU4: Ungava Bay (UB)
- DU5: Western Hudson Bay (WHB) (or Western-Northern-Southern Hudson Bay)
- DU6: Eastern Hudson Bay (EHB)
- DU7: St. Lawrence Estuary (SLE)
- DU8: James Bay (JB)

The EHB Beluga population is recommended by COSEWIC for listing as Threatened, but has not yet been added to Schedule 1 of the *Species at Risk Act;* therefore, the measures to protect and recover do not yet apply to this population (COSEWIC 2020). This population decreased by half during the mid-1970s due to overhunting, but has been considered 'stable' since 1985 (Hammill et al. 2017). Belugas found near the Belcher Islands were considered part of the EHB population until recently. New genetic evidence suggests Belugas in the Belcher Islands (BEL) form their own population (DFO 2022). This population shares some genetic haplotypes and the same summer distribution as EHB Belugas, making it impossible to distinguish animals belonging to the two populations either in the harvest or during the aerial abundance surveys. The Belcher Islands population has not yet been assessed by COSEWIC and for management purposes is still grouped with EHB Belugas (DFO 2022). The combined EHB and BEL populations are currently estimated at approximately 2,300 whales (Gosselin et al. 2017; DFO 2022).

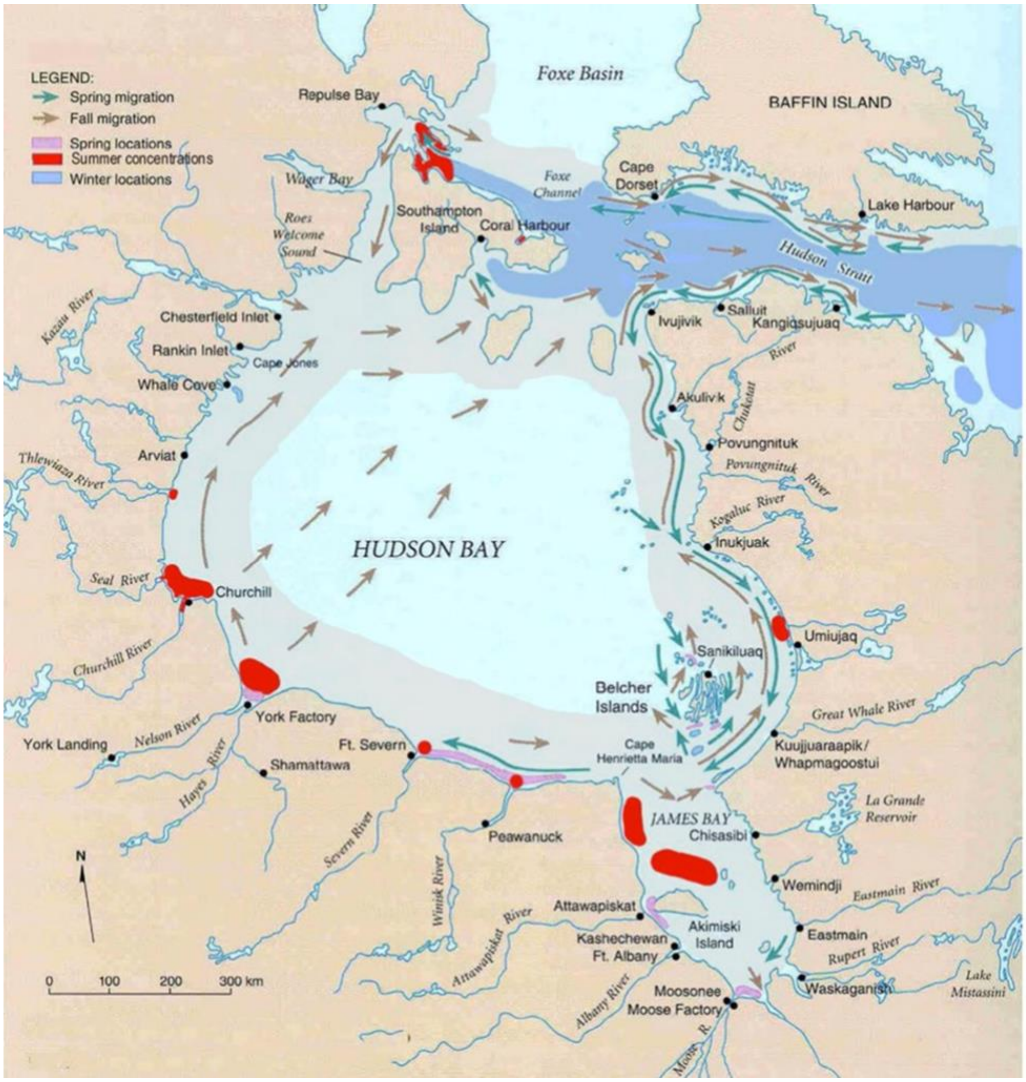


Figure 28. Beluga whale migration patterns within Hudson Bay. Source: Loewen et al. (2020).

The main forage species for Belugas is Capelin; however, Arctic Cod, other fish and invertebrates are also frequent prey items (Kelley et al. 2010; Breton-Honeyman et al. 2016). Belugas migrate and travel in pods, which consist of matriarchal family groups which dive and surface repeatedly in search of prey (Bailleul et al. 2012). Seasonality of prey items is known to influence Beluga fat reserves and body condition (Bailleul et al. 2012; Breton-Honeyman et al. 2016); therefore Belugas can be susceptible to changes in their environment and changing resource availability and abundance (Bailleul et al. 2012).

Belugas spend the summer months in coastal shallows or deep open water, foraging and raising their young (Figure 29). In July and August, the EHB Belugas make frequent commutes between the estuaries and offshore, presumably for foraging trips (Bailleul et al. 2012). Their preferred habitat in the summer is shallow coastal waters, where they predominantly dive to the thermocline (approximately 40 m). Estuaries, such as those along the eastern Hudson Bay coast, provide important moulting habitat due to the decreased salinity of the water and rocky riverbeds, which provide abrasion to aid the moulting process (Smith et al., 2017). Estuaries also provide a safe place to raise young, because the shallow water protects them from predators (Labun and Debicki 2018). As a result, the Beluga calving areas around the Belcher Islands have been designated as a Valued Ecosystem Component (Nunavut Planning Commission 2021).

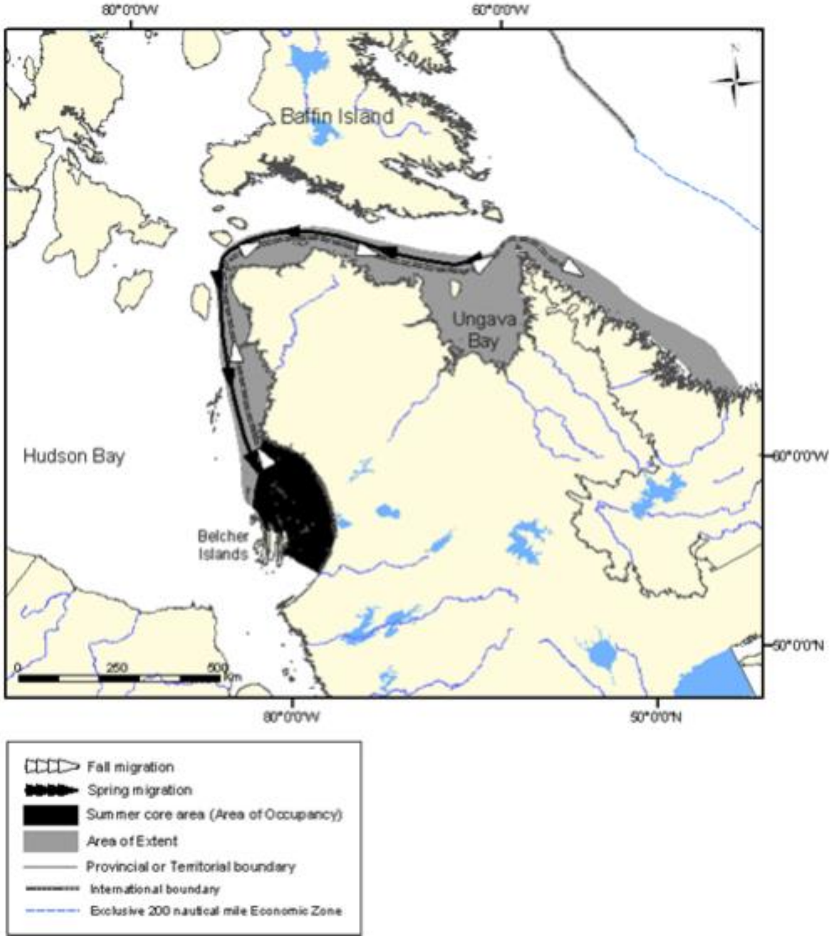


Figure 29. EHB Beluga population range. Source: COSEWIC (2020).

Belugas are the namesake of the Great Whale River estuary (GWR), indicating the importance of this estuary for breeding and rearing calves. However, their presence there during the summer season has diminished in recent years (Nozais et al. 2021), possibly due to an increase in shipping traffic (McDonald et al. 1997).

Female Belugas reach sexual maturity between six and fourteen years of age and give birth to a single calf approximately every three years due to a prolonged lactation period (COSEWIC 2020). Belugas may live for up to 60 years (Stewart et al. 2007). Based on the age at maturity and estimated life span, the Beluga has a generation time of 28.6 years (COSEWIC 2020).

By fall (early September), the frequent foraging commutes between estuary and offshore cease and Belugas gather north of the Belcher Islands. Here they switch to foraging via demersal dives to an average depth of 50 m, spending as much as 80% of their time conducting foraging dives. This behaviour continues until the fall migration commences between late September and late November (Bailleul et al. 2012). During migration, the majority of these whales follow the Hudson Bay coast, an average of 15 km from shore, and travel hundreds of kilometers north from the Belcher Islands Archipelago in September and October, through Hudson Straight to the northern coast of Labrador for the winter (Figure 29), returning in late June (Hobbs et al 2020). However, local knowledge asserts there is overwintering habitat for Beluga within the QSA due to polynyas and currents around the islands creating open water (Gilchrist and Robertson 2000; COSEWIC 2020). In winter months, Belugas are frequently observed in open water to the southwest of the Belcher Islands Archipelago, as well as throughout the archipelago wherever open water is found (Figure 30) (Government of Nunavut 2010). As a result, the southern border of the QSA was extended southward to incorporate this critical feeding habitat (DFO 2011).

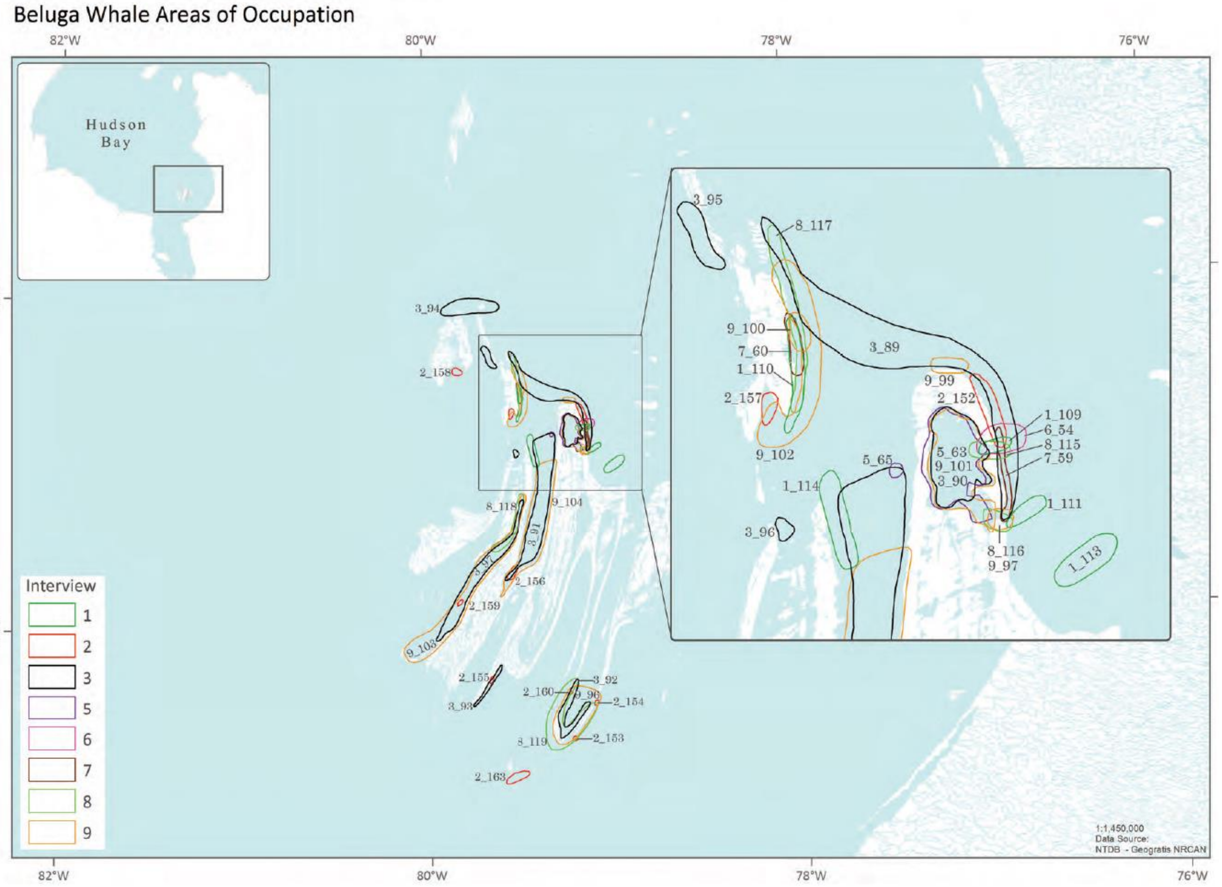


Figure 30. Beluga Use of the QSA. Source: Government of Nunavut (2010).

During the winter months, the Beluga is particularly susceptible to savssats, or creation of ice dams that prevent belugas from leaving a fjord or estuary, or trap them in a polynya where they are limited to a small area that they can keep open for breathing. As a consequence, they because vulnerable to predation by Polar Bears and hunting pressure (Gilchrist and Robertson 2000).

Hunting pressure is believed to be the cause of historical reductions of Beluga abundance. More recently, an average of 95 Beluga were removed annually from the BEL-EHB populations between 2016-2021 by Nunavik hunters. An estimated 139 BEL-EHB Beluga were harvested in 2020-2021 (DFO 2022).

Harvest levels of 0 and 20 Beluga annually would meet management objectives of ensuring a 50% probability that the populations will be at or above 3,400 animals after 5 and 10 years, respectively (DFO 2022). .

In addition to hunting, disturbance from shipping and other human activities is believed to be a source of pressure for the EHB and BEL populations. For example, Beluga movements and seasonal migration have been altered at Kuujjuarapik, on the east side of the QSA, likely due to shipping activity (McDonald et al. 1997; COSEWIC 2020). As shipping traffic has increased, the number of whales seen in the GWR estuary has diminished.

The effects of climate change on Belugas are less studied and understood. It is known that climate change has led to a decrease in the abundance of Arctic Cod in Hudson Bay, and a corresponding increase in Capelin (See Climate Changes and Projections Section for more details) that has resulted in changes to Beluga diet (Kelley et al. 2010; Breton-Honeyman et al. 2016; Yurkowski et al. 2017; Florko et al. 2021). However, it is currently unknown what effects these changes may be having on Belugas in Hudson Bay. Longer ice-off periods due to a warming climate may reduce the formation of savssats and therefore ice-strandings of Belugas (COSEWIC 2020); however, ice reductions could also lead to greater Killer Whale presence, and increased predation (Higdon and Ferguson 2009; Kuzyk et al. 2008).

Harbour Seal (*Phoca vitulina concolor*)

Harbour Seals are small pinnipeds, of the Family Phocidae, which grow to 70-100 kg and favour shallow coastal waters. Harbour Seal range throughout the northern hemisphere, along the east and west coasts of North America, the eastern Canadian Arctic, and the west coast of Europe (Figure 31) (COSEWIC 2008a).

There are no estimates of global population, but the Canadian population is estimated to be over 10,000, based on anecdotal evidence and isolated surveys (COSEWIC 2008a). In Canada, Harbour Seals are split into two subpopulations. *P.v. vitulina* in the north Atlantic Ocean, and a small landlocked freshwater population, *P.v. mellonae* in Québec. In 2007, *P.v. mellonae* was listed as Endangered, whereas *P.v. vitulina* was considered Not at Risk. In 2004, the population of Harbour Seals (*P.v. vitulina*) in the entire Hudson Bay was estimated at greater than 100 individuals (Derocher et al. 2004), with an unknown proportion of these residing within the QSA. However, Harbour Seal populations have been rising in Hudson Bay, likely due to the decrease in sea ice and in 2016 were estimated at >142 in the Churchill River estuary alone (Florko et al. 2018) and they may become more common in the QSA over time.

Within the QSA, Harbour seals has been observed along the eastern shoreline of the Sleeper Islands in June and August, and in polynyas east of Flaherty Island year-round, with historical reports of a freshwater population that lived in Kasegalik Lake on Flaherty Island. The freshwater population has reportedly since been hunted out to preserve the lake’s Arctic Char reserves (Figure 32) (Government of Nunavut 2010).

In general, Harbour Seals conduct dives of 3 to 100 m depth to feed on a widely varied diet of benthic invertebrates and marine fish. Their most frequent prey items generally correspond to the currently most abundant fish species (Tollit et al. 1997). The stomach contents of east coast Harbour Seals revealed 32 species of fish and 18 species of invertebrate, with Winter flounder (*Pseudopleuronectes americanus*), Arctic Cod, Shorthorn Sculpin (*Myoxocephalus scorpius*) and Atlantic Cod (*Gadus morhua*) the most common prey species (Sjare et al. 2002; Thiemann et al. 2008). Harbour Seal diet in Hudson Bay has not been extensively studied (Tollit et al. 1998; COSEWIC 2008a). The stomach contents of one Harbour Seal in Western Hudson Bay indicated forays upriver to feed on freshwater fish species (Beck et al. 1970). An examination of seal stomachs from the since extirpated population at Kasegalik Lake confirmed a diet comprising both freshwater and marine species (Smith et al. 1996)

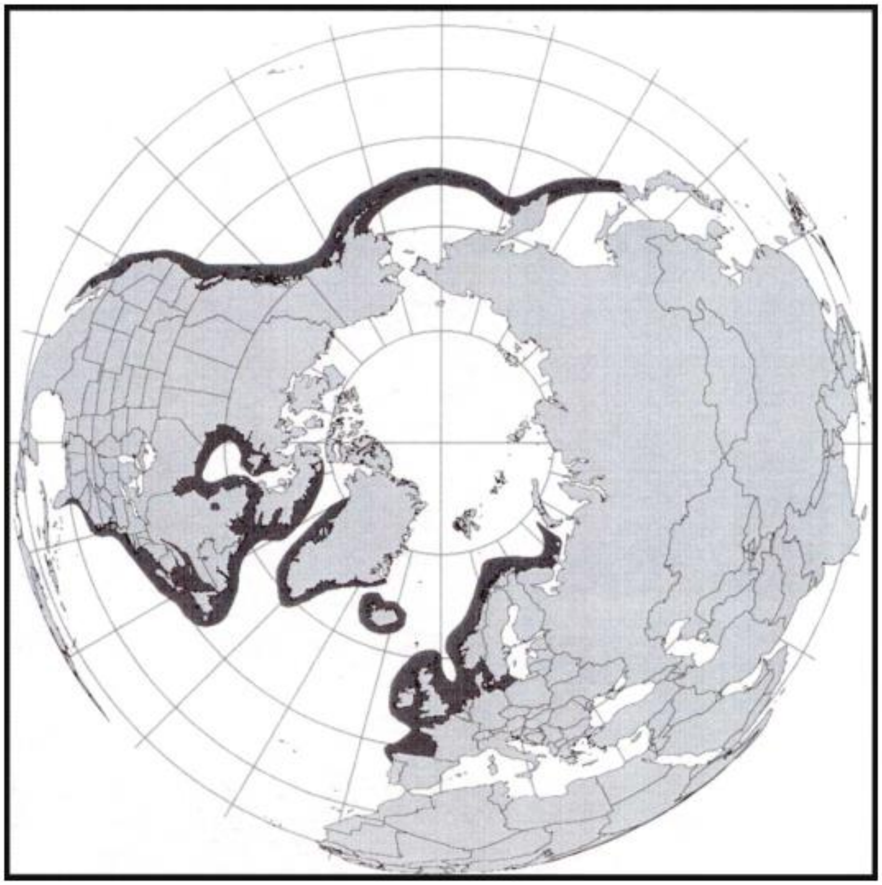


Figure 31. Global range of Harbour Seal. Source: COSEWIC (2007).

While most seal species present in Hudson Bay give birth on sea ice, Harbour Seals do not, possibly to avoid predation, or because their flippers are not adapted to carving breathing holes through ice (COSEWIC 2008a). Instead, Harbour Seals give birth on land, showing high site-fidelity to their haul out sites. Females reach sexual maturity around the age of four, giving birth to one pup annually (Härkönen and Heide-Jørgensen 1990), indicating a generation time of approximately 9 years (COSEWIC 2008a).

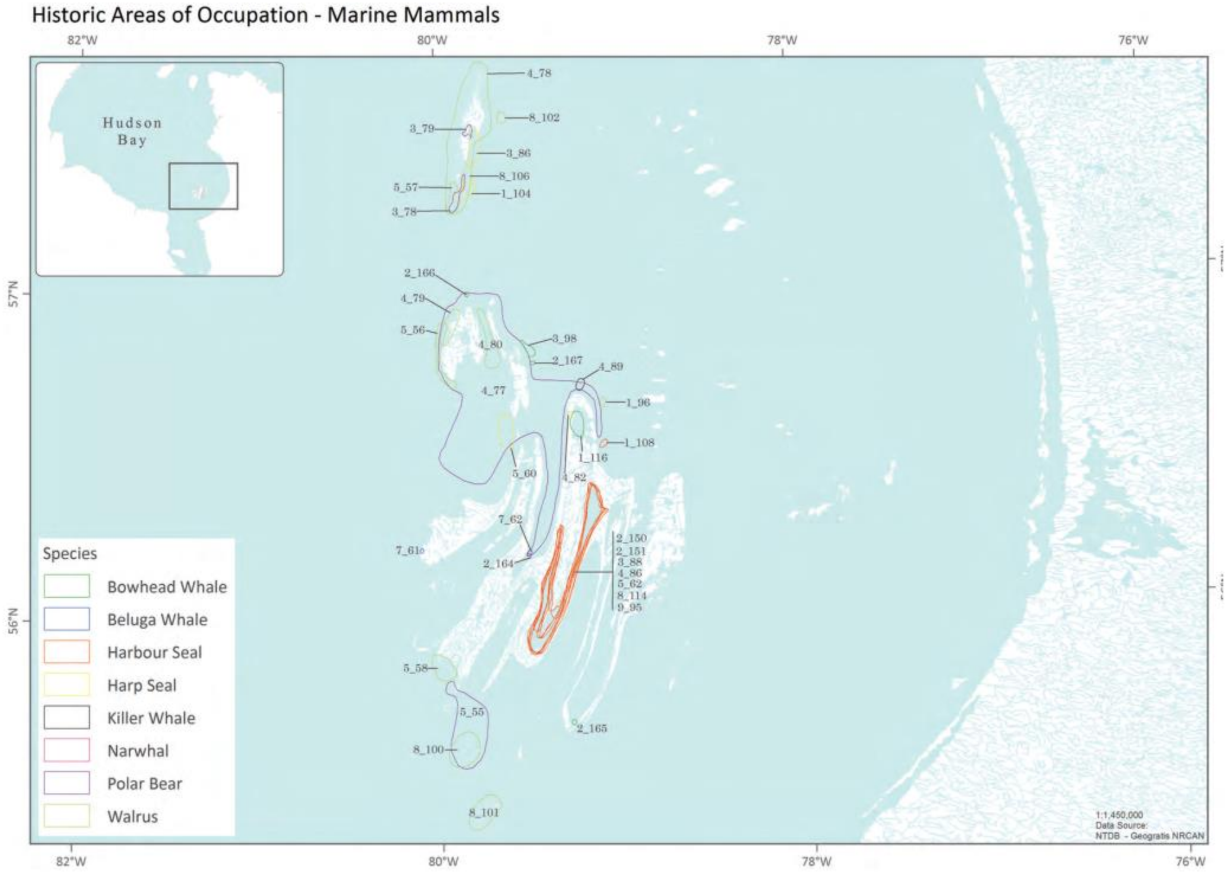


Figure 32. Harbour Seal Use of the QSA. Source: Government of Nunavut (2010).

While hunted consistently in many Nunavut communities, Harbour Seals are less common in eastern Hudson Bay than in the west, and are therefore not a commonly harvested species in the QSA (Priest and Usher 2004).). A number of harbour seals lived on inland waters of the Belcher Islands but were killed off in the 1990s by local hunters (Pers. Comm. Lucassie Arragutainaq, Sanikiluaq Hunter's and Trapper's Association).

Although hunting pressure may not be a significant strain on Harbour Seal populations, there is significant evidence to show disturbance from both large cruise ships and small boats (Robillard et al. 2005; Jansen et al. 2010). Harbour Seals are also sometimes killed as bycatch in the fishing industry (Cairns et al. 2000), or due to conflict with humans over fish resources, as evidenced by the extirpation of the species in Kasegalik Lake. Pollutants and climate change stressors are also known to act concurrently on marine mammals, especially with regard to the bioaccumulation of mercury (Ross et al. 2007). However, since Harbour Seals rely on open water, climate change may create potential habitat (COSEWIC 2008a). Lastly, competition between Grey Seal and Harbor Seal for haul-out sites and food resources is a known stressor on Harbour Seal populations (Bowen et al. 2003; Robillard et al. 2005) and similar competition for prey could occur with Ringed Seals in Hudson Bay.

Killer Whale (*Orcinus orca*)

Orca or Killer Whale traditionally have a circumpolar range in the North Atlantic and Pacific Oceans, but rarely range south of 60 degrees latitude (COSEWIC 2008b; Hidgon et al. 2012). The Northwest Atlantic / Eastern Arctic population is listed as Special Concern (COSEWIC 2008b) and is estimated at around 70 individuals.

The people of Sanikiluaq reported an undated sighting north of the community of Sanikiluaq prior to 2010 (Government of Nunavut 2010). However, in the last decade, observations of Killer Whales are increasing in frequency, likely due to a decline in summer sea ice (Higdon 2007; Higdon et al. 2013). Killer whales typically avoid areas with high sea ice concentration in the Arctic in summer and early fall and migrate to more-temperate areas in the fall (Higdon & Ferguson 2010; Matthews et al. 2011.) Within the QSA, a single Killer Whale was found frozen in the pack ice in northern Hudson Bay 2011. In 2013, a pod of approximately 17 was observed stranded in a lead near Inukjuak, Québec, where it was presumed all perished, and in 2016, four more Killer Whales were observed near Sanikiluaq, where they later starved to death due to last break up of ice (Kemeny 2019; Matthews et al. 2019).

The arrival of Killer Whales in Hudson Bay is a complex issue. As apex predators, their increased frequency in Hudson Bay could have deleterious effects on Beluga and seal populations (Higdon 2007; Labun and Debicki 2018). However, Killer Whales may be at risk themselves, because the ice is still substantial enough to trap them during the winter months, and significant mortalities like those experienced in 2013 and 2016 could have dire impacts on the relatively small Northwest Atlantic / Eastern Arctic population (Matthews et al. 2019).

Polar Bear (*Ursus maritimus*)

This section was written based solely on western science approaches and techniques. There are other knowledge systems, such as Inuit Qaujimajatuqangit (IQ) and Traditional Knowledge (TK) that have a deep understanding of polar bears (NMRWB 2018, Simon 2009, CWS 2009).

Polar Bears are large marine carnivores that range throughout the circumpolar Arctic and sub-Arctic. Polar Bears are sexually dimorphic, with males reaching 350 to 650 kg and females 150 to 300 kg (Derocher et al. 2005). While considered a marine mammal, Polar Bears are more associated with the sea ice than open water and have an annual migration in Hudson Bay between land in summer and sea-ice in fall, winter and spring.

Estimates of the global population are between 20,000 and 26,000, between 19 subpopulations (Figure 33), however there is little conviction in that estimate due to data deficiencies throughout much of their range (COSEWIC 2018). The Canadian population is estimated at 10,448 bears, however survey data from most of the 14 management units (13 subpopulations) in Canada are well over a decade old, and their reliability is uncertain. Polar Bears were listed as Special Concern in 1991 and have been reconfirmed as such as in 2018.

Polar Bear subpopulations are contiguous; however, they can be delineated based on collar tracking movements and genetic markers (Crompton et al. 2014; COSEWIC 2018). Three subpopulations of Polar Bears overlap Hudson Bay, the Foxe Basin (FB), Western Hudson Bay (WH), and Southern Hudson Bay (SH) subpopulations. There is an abundance of genetic mixing among the Hudson Bay subpopulations, as evidenced by low pair-wise F_{ST} values (Crompton et al. 2008; Crompton et al. 2014). However, the populations are different enough in genetics and movement patterns to still constitute three subpopulations, and it has even been suggested that the SH subpopulation could be further divided into James Bay and SH subpopulations (Crompton et al. 2008, 2014). Genetic movement between the subpopulations is expected to decrease as climate related sea ice changes further isolate these groups (Crompton et al. 2008).

The QSA falls entirely within the SH subpopulation of Polar Bears. A survey of the SH subpopulation conducted in September 2016 provided an estimate of 780 individuals. Most bears observed during that survey were near Polar Bear Provincial Park, in Ontario, Akimiski Island in James Bay, and the Belcher Islands Archipelago (Obbard et al. 2018). The SH subpopulation is believed to be in decline (COSEWIC 2018), however the people of Sanikiluaq reported seeing increasing numbers of bears between 2000 and 2010 (Government of Nunavut 2010). This increase in observations may be due to changes in migration patterns rather than an actual increase in population.

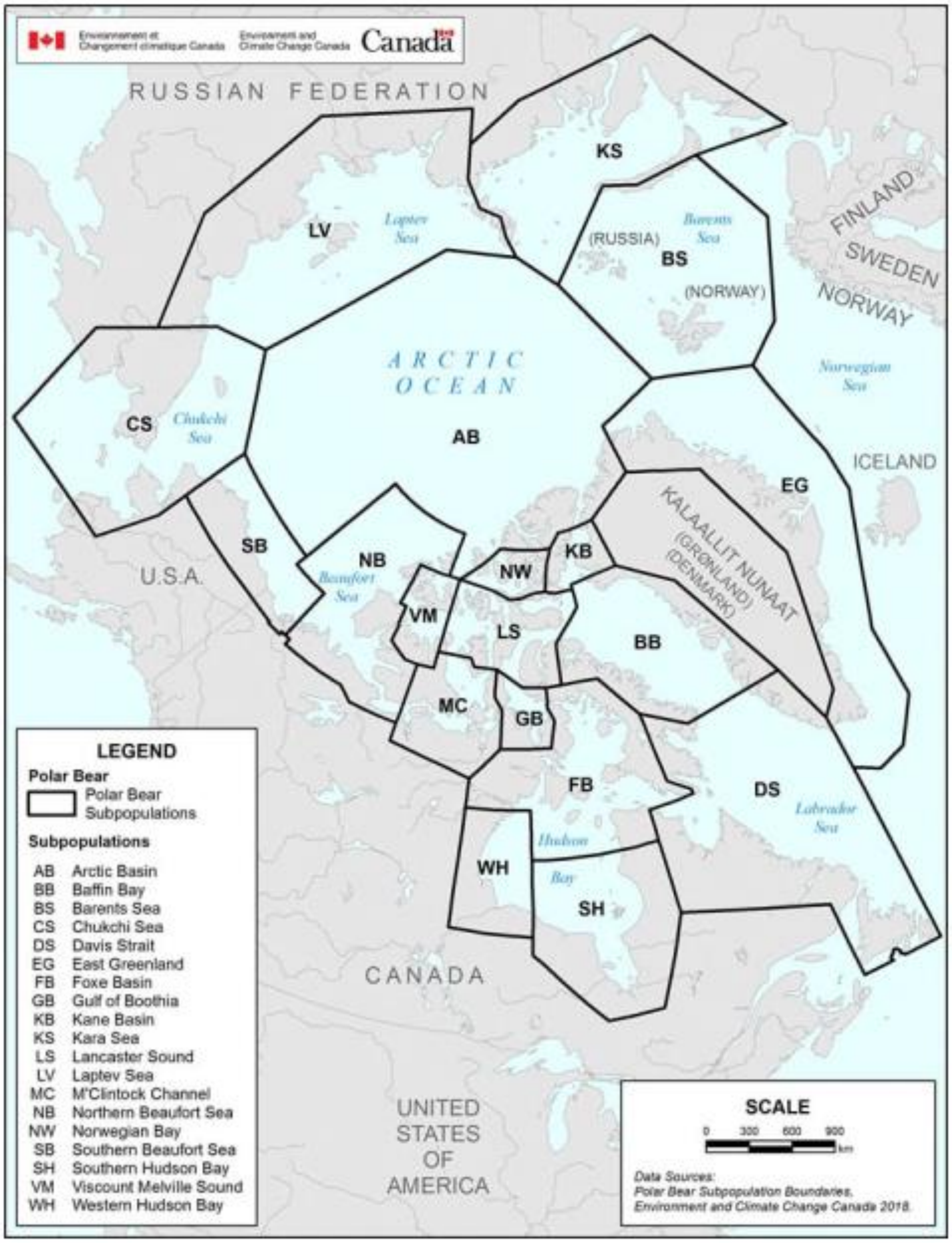


Figure 33 Polar Bear Sub-Populations in the Circumpolar Arctic. Source: COSEWIC (2018).

Aerial and ground surveys in 1976 identified denning areas for the SH subpopulation on Akimiski and Twin Islands in western James Bay, and southwest of Cape Henrietta Maria in Ontario. However, denning was also suspected to occur in the QSA on the southwest Belcher Islands as well as the Nastapoka Island chain and eastern shore of Hudson Bay (Jonkel et al. 1976; Florko et al. 2018). Surveys in 1983 confirmed the fidelity to denning areas on Akimiski and Twin Islands as well as the southern shore of Hudson Bay in what is now part of Polar Bear Provincial Park (Kolenosky and Prevett 1983). Denning on the Belcher Islands Archipelago has never been confirmed (Florko et al. 2018). Observations of Polar Bear on the Belcher Islands are generally confined to December to March, which could coincide with the existence of denning habitat in the area (Figure 34) (Government of Nunavut 2010).

Aerial surveys conducted in September 2016 confirm the observations of residents of Sanikiluaq reporting clusters of Polar Bears on the western shores of the Belcher Islands (Figure 35). The Sleeper Islands are used to a lesser degree (Obbard et al. 2018). The September timing of the surveys maximized the potential for bear observations, but was not necessarily indicative of important summer resting areas, feeding areas, or denning areas because September is a transitional time for Polar Bears in Hudson Bay.

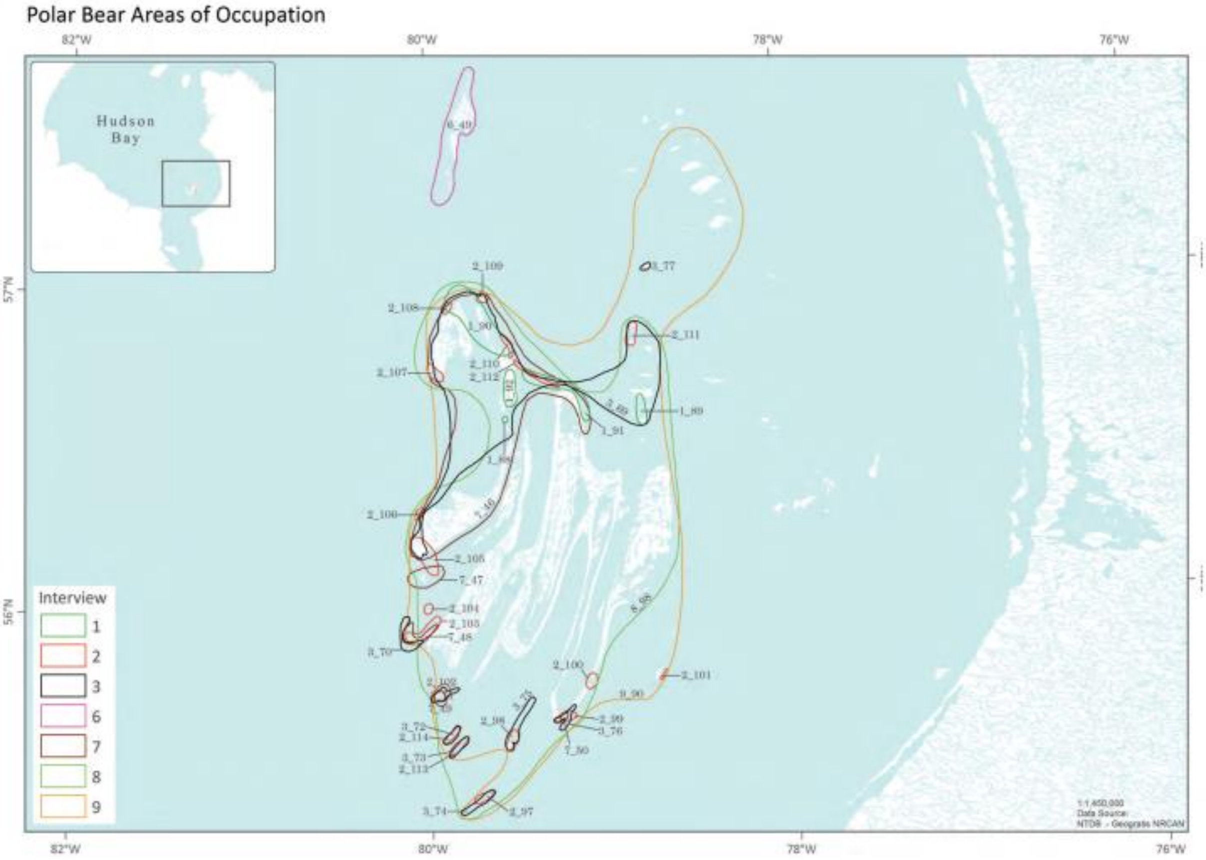


Figure 34 Polar Bear Use of the QSA. Source: Government of Nunavut (2010).

Throughout much of their range, Polar Bears hunt on the ice year-round. However, Hudson Bay has a seasonal ice cycle. During the open water period (July through October), Polar bears in Hudson Bay are on land, conserving energy by travelling very little. They feed opportunistically on eggs, birds, beached whales, Arctic Char, and stranded seals (Lunn and Stirling 1985; Peacock et al. 2010; Gormezano and Rockwell 2013; COSEWIC 2018). A 2012 survey examining scat contents indicated this terrestrial diet has shifted since the 1970s, to include more caribou and geese and their eggs, evidently in response to a rapidly changing climate (Gormezano and Rockwell 2013). This trend is expected to continue as the ice-free duration increases and may be an important component to reducing nutritional stress (Gormezano and Rockwell 2013). When the ice re-forms on the Bay in mid-November, Polar Bears migrate back to the sea ice where they range hundreds of kilometers in search of food (COSEWIC 2018).

In the QSA, this migration generally occurs from the southwest coast northward, towards the centre of the Bay, including the QSA (Kolenosky and Prevett 1983). Early during the ice-on period, collaring data (females only) indicates that the SH subpopulation concentrates north and west of the Belcher Islands, spreading out throughout the bay as the breeding period commences. With the arrival of summer, the females move off the ice southwest towards Polar Bear Provincial Park in Ontario (Middel 2014). Polar Bear use of the eastern coast of Hudson Bay in summer months appears to be minimal, although occasional sightings have been noted near the village of Kuujjuarapik (Nozais et al. 2021). This is likely due to the fact that in the fall, ice will form on the west side of the bay several days or weeks before the east side of the bay, so migrating west rather than east will put them in position for earlier hunting opportunities (Middel 2014).

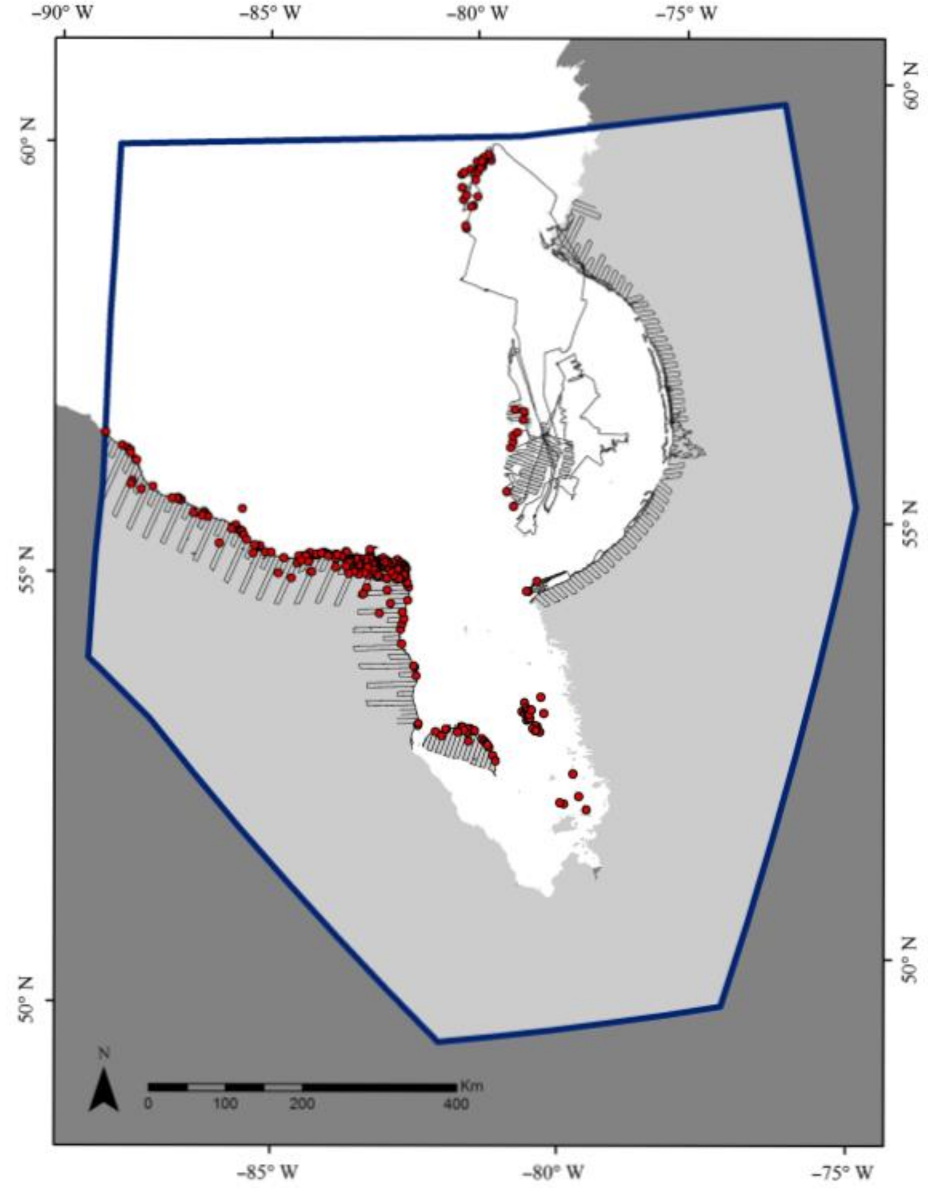


Figure 35 Polar Bear Observations in 2017. Source: Obbard et al. (2018).

Once on the ice, Polar Bears are able to hunt from the ice platform which is crucial to their survival (Courtland 2008; Galicia et al. 2016; COSEWIC 2018). During the on-ice period, bears feed primarily on Ringed Seals but also on Bearded Seals, Walruses and other marine mammals (Thiemann et al. 2007). Polar Bears kill a seal every two to six days, either by waiting by breathing holes or polynyas, or crashing through seal birthing lairs in spring (McKinney et al. 2009; CMS 2017; COSEWIC 2018). Polar Bear hunting activity is generally concentrated at or near polynyas, but also occurs at areas of landfast ice where the ice is sufficiently thin enough to allow Ringed Seals to keep breathing holes open. Polar Bears and Ringed Seals are the only marine mammals associated with both landfast ice and ice floes (Tynan and DeMaster 1997).

Polar Bears travel on and hunt from the landfast ice and ice floes until approximately two weeks after break up (Stirling et al. 1993) at which time they return to shore. The timing and location of this return is subject to weather and current patterns (Stirling and Derocher 2012). The only cohort of bears that do not follow this annual migration are pregnant female Polar Bears.

In the SH subpopulation, pregnant females enter the denning areas in late October or early November (Kolenosky and Prevett 1983; Ramsay and Stirling 1988; Obbard et al. 2018) rather than returning to the ice. In the SH subpopulation, maternity dens are dug into earthen banks on the leeward sides of slopes, often with a roof structure supported by tree roots. The opening of the den is allowed to drift over with snow which provides warmth and protection for newborn cubs (Ramsay and Stirling 1988; Florko et al. 2020). There is a very high degree of fidelity for den site selection and the majority of dens in the SH subpopulation are located less than 60 km inland (Obbard et al. 2018; Florko et al. 2020). Polar bear denning areas are considered critical and limiting habitat and Polar Bear Provincial Park, adjacent to the QSA was created with the purpose of conserving this habitat (COSEWIC 2018).

Females give birth to one or two cubs in December or January after mating in late spring and undergoing a period of delayed implantation. The number of cubs born in a year is dependent on the mother's body condition as she enters the den and can vary widely from year to year based on annual variations in weather patterns and their effects on hunting success (Atwood et al. 2021). Both mother and cubs and emerge and return to the ice between February and April (Kolenosky and Prevett 1983). Female Polar Bears in SH give birth every three years after a period of prolonged lactation. Reproductive success is linked strongly to the body condition and fat reserves of the mother, and therefore changes in seasonal ice patterns and food availability may negatively affect recruitment and population size (Stirling et al. 1999; Derocher et al. 2004; Stirling and Parkinson 2006). Consecutive surveys in the SH in 2011 and 2016 revealed a reduction in the proportion of yearlings from 12% to 5% of the population, whereas the proportion of cubs of the year increased from 16% to 19% in the same time period (Obbard et al. 2018). A repeat of the survey in 2021 indicated both yearlings and cubs of year had again grown in proportion (Northrup unpublished data). Collectively, these data appear to indicate that cubs of the year, while still nursing, are somewhat insulated from population fluctuation, whereas yearling survival is more susceptible to changes in food availability. The data also show that reproductive success is highly variable, but capable of dramatic rebounds in bountiful years (Atwood et al. 2021). After reaching adulthood, survival increases and while body mass fluctuates with the hunting success of the previous year, it does not necessarily translate into mortality. Polar bears live to an average of 20 years with a generation time of 11.5 years (COSEWIC 2018).

Due to climate change, the duration of ice-cover in the QSA has reduced by approximately 3 weeks since the 1970s (See Climate Changes and Projections section for more detail) (Stirling and Derocher 1993, 2012). Because Polar Bear diet is linked intrinsically to sea ice, changes in the timing and extent of sea ice have already begun to contribute to declines in body condition, reproductive success, and survival (Stirling et al. 1999; Derocher et al. 2004; Stirling and

Parkinson 2006). The people of Sanikiluaq report seeing thinner bears in the early 2000s (Government of Nunavut 2010). Polar Bears in the SH subpopulation may either adapt to these changes by relying on other, terrestrial and aquatic food sources, or continue to decline in number (COSEWIC 2018). Even if these bears with access to terrestrial food shift their diet, it is uncertain if these food sources can sustain a Polar Bear's requirements for a lipid rich diet (Gormezano and Rockwell 2013).

Although climate change is the largest current pressure on Polar Bear populations, they also experience hunting pressure by humans. The people of Sanikiluaq report hunting Polar Bears along the east side of Flaherty Island (Government of Nunavut 2010). The annual 5 year mean of Polar Bear mortality in the SH subpopulation due to human activity such as hunting, research or pollutants/toxins was reported at 41.6 in 2017, not including animals that were killed in self-defense. It is believed 43 is a sustainable harvest in the SH population (COSEWIC 2018). Harvest of Polar Bears is permissible, without quota, to members of Treaty 9 residing on the Hudson and James Bay coasts. Harvest reporting is optional, but Polar Bear skins may not be sold.

Water-bourne pollutants, especially heavy metals and chlorinated, brominated, and fluorinated compounds have a tendency to bioaccumulate in the fatty tissues of birds, fish and mammals. As both apex predators and lipivores (fat eaters), Polar Bears are doubly at risk for exposure to these chemicals, which often travel long-distances from industrial areas (Letcher et al. 2010). Thus far, concentrations of persistent organic pollutants, especially organohalogen contaminants in bears in the SH subpopulation remain below levels expected to have deleterious effects. However, these southern populations are potentially most at risk as human activity and therefore pollution levels are increasing in the area (Letcher et al. 2010).

The potential effects of pollutants include reproductive effects, liver and renal histopathology, vitamin deficiencies and effects on growth and development (Verreault et al. 2005). There is also the concern that pollutants will biomagnify in nursing females, compounding the effects on their young (Jenssen et al. 2015). The cumulative effects of climate change and pollutants on bears are currently unknown but are known to compound one another. Changes in current patterns can bring more pollutants to an area and chemical stressors can make animals less able to adapt to temperature changes.

Ringed Seal, Arctic subspecies (*Pusa hispida hispida*)

Ringed Seals are a small pinniped of the Family Phocidae, which grow to 45-110 kg (Sale 2006). Ringed Seals are notable for their small size and light-coloured rings on a dark pelage. They are found everywhere that has seasonal sea ice (NAMMCO [s.d.])

Ringed Seals are the most numerous of all Arctic seals, with a world population estimated at up to 6 million (Sale 2006), approximately 2 million of which are in Canadian waters (COSEWIC 2019). However, these estimates are of low confidence as surveys across the ringed seal range are limited and some areas are lacking information entirely (Laidre et al. 2015). Ringed Seals range throughout the circumpolar Arctic and sub-Arctic, and are split into 5 subspecies, two freshwater, and three marine (Lowry 2016). However, distribution of the three marine subspecies is continuous with no geographical barriers to their movement (NAMMCO [s.d.]), therefore, in Canada, all Ringed Seals are placed within a single DU (COSEWIC 2019).

Historical abundance estimates of Ringed Seal populations in Hudson Bay and James Bay were 455,000 and 61,000 individuals, respectively (Smith 1975). Aerial surveys in Western Hudson Bay in 1995 produced a population estimate of approximately 280,000 individuals (Lunn et al. 1997). To date, no similar studies have been conducted in eastern Hudson Bay. While Arctic Ringed Seals are the most commonly observed pinniped in Hudson Bay, in 2019 they were listed as Special Concern in Canada due to their reliance on seasonal ice cover, which is being negatively impacted by climate change (COSEWIC 2019; Government of Canada 2019).

Within the QSA, Ringed Seals are commonly observed using habitat around polynyas and at the floe edge, as well as open water areas (Manning 1976; Gilchrist and Robertson 2000), and are observed year round throughout the Belcher Islands Archipelago (Figure 36) (Government of Nunavut 2010). Ringed Seals do not undertake seasonal migration because they are well adapted to coping with seasonal ice-cover and landfast ice and rely on it for rearing their young (Reeves 1998). However, during winter months, their movements become restricted to areas with thin enough ice (approximately 2 m or less) to maintain adequate breathing holes (Reeves 1998; Luque et al. 2014).

Ringed Seals conduct forage dives to feed. These forage dives range from 40 to 80 m in depth, with deeper dives occurring during the winter months (Reeves 1998). Prey items for adults include a variety of invertebrates such as crustaceans, amphipods and euphausiids (COSEWIC 2019), however pelagic fish such as Arctic Cod, sand lance and Capelin are the most common prey in the southeastern Hudson Bay (Lowry et al. 1980; Labansen et al. 2007). The diet of Ringed Seals is seasonal, and they feed less often during the spring (March to July) moulting period (Kelly et al. 2010). As a result, the body condition of Ringed Seal varies by season as well (Harwood et al. 2000; Chambellant et al. 2012). As with Belugas, there has been a shift in the diet of Ringed Seals in Hudson Bay since the 1990s, from primarily Arctic Cod to primarily Capelin due to a reversal in the abundance of both species in the bay due to climate change (See Climate Changes and Projections section for more details) (Kelley et al. 2010; Chambellant et al. 2012; Breton-Honeyman et al. 2016; Florko et al. 2021).

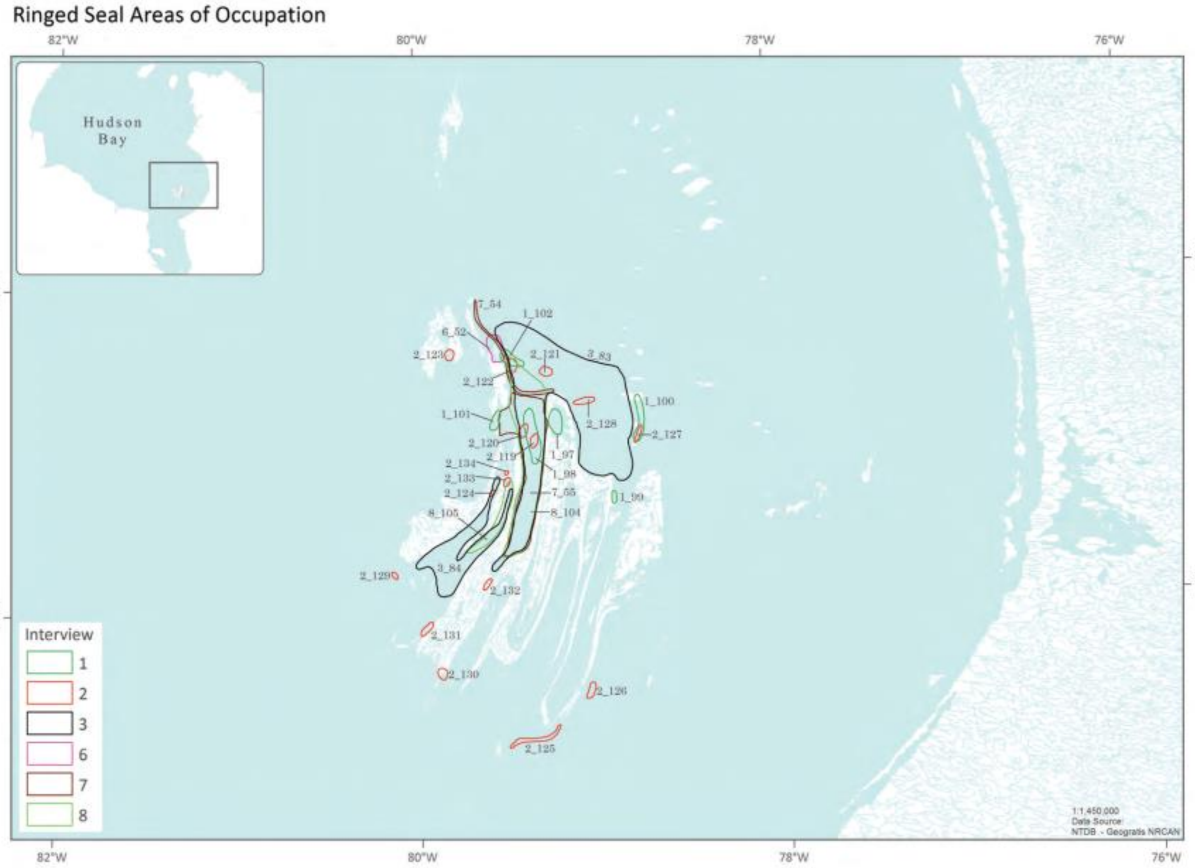


Figure 36. Ringed Seal Use of the QSA. Source: Government of Nunavut (2010).

The life history of Ringed Seals is intrinsically linked to seasonal ice cover. Although mating occurs under the ice in April or May, Ringed Seals are unique in constructing ice- or snow-covered birthing lairs over a breathing hole in which to give birth (Lowry 2016; NAMMCO [s.d.]). These birthing lairs are crucial to the survival of pups, even though Polar Bears are adept at finding and opening these caves (Reeves 1998). Female Ringed Seals typically give birth to their first pup between the ages of 4 and 7 years after a 10 to 11 month gestation (Reeves 1998). In favourable ice conditions, they an interbirth period of 1.3 years (Ferguson et al. 2019), and live for an average of 20 years giving them a generation time of approximately 13 years (Kovacs 2014; COSEWIC 2019).

Ringed Seals face intense hunting pressure from Polar Bears, which consume up to 40 seals per bear per year, translating to 600,000 to 800,000 Ringed Seals being removed from the Canadian population annually due to Polar Bears alone (Kingsley 1990). Ringed seals area also preyed upon by Atlantic Walrus, Killer Whales and other apex predators (COSEWIC 2019). In addition, Ringed Seals are a mainstay of the traditional diet in Sanikiluaq (McDonald et al. 1997). Ringed Seals are hunted by humans during, fall and winter at polynyas and natural cracks in the ice (Gilchrist and Robertson 2000; Government of Nunavut 2010). Although no harvest estimates are available for the QSA, worldwide harvest of Ringed Seals is estimated to be in the tens of thousands annually (Reeves et al. 1998).

While this level of predation has apparently been sustainable for the several decades that Ringed Seal studies have been ongoing, monitoring has also indicated extreme fluctuations in adult populations as well as reproductive success due to variable ice conditions (Chambellant et al. 2012; Young et al. 2015; Ferguson et al. 2017). This link to sea ice during a time when the duration and physical extent of sea ice is decreasing in Hudson Bay through climate change is a threat to Ringed Seal population stability and is the core reason for listing the species as Special Concern (COSEWIC 2019).

Like all marine mammals, Ringed Seals are also susceptible to water-borne pollutants (Wagemann et al. 2000; Fisk et al. 2002; Kucklicka et al. 2002; Sonne-Hansen et al. 2002). The effects of these pollutants on Ringed Seals are not yet understood. The people of Sanikiluaq report harvesting seals with missing patches of fur with increasing frequency, though the cause of this is unknown (Government of Nunavut 2010). However, this loss of fur may be due to stress-related cortisol spikes during “episodic” early-ice breakup, as opposed to pollution levels (Ferguson et al. 2017).

Ringed Seals in Canada are protected under the Marine Mammal Regulations (SOR/93-56) and Seal Protection Regulations (C.R.C., c. 833of the *Fisheries Act* Government of Canada [2010]). As such, residents of Canada are permitted to harvest seals for their personal use, or for the use of their service animals (i.e., sled dogs). There are no restrictions on the sale or trade of Ringed Seal fur. Seal hunting in the QSA (and throughout Nunavut) is managed by the Nunavut Wildlife Management Board (NWMB) in Nunavut, with input from the Department of Fisheries and Oceans, which manages Ringed Seal throughout the rest of Canada (COSEWIC 2019).

WATERBIRDS

At least 70 species of waterbird breed or overwinter within the QSA (Table A 5, appendix), with numerous other species likely to pass through during spring and fall migration as the Belcher Island Archipelago is along the border of the Mississippi and Atlantic Flyways.

The QSA is known to contain abundant important breeding and foraging habitat for many avian species, including seabirds, and waterbirds that use a mix of freshwater and marine habitat. The

Belcher Islands Archipelago is suspected to have a high degree of mixing and high primary productivity due to its cold surface water temperatures mid summer (Galbraith and Larouche 2011). The high primary productivity would make the area very attractive to waterbirds for migration staging as well as breeding and brood-rearing. Numerous estuaries and tidal flats throughout the QSA provide abundant forage opportunities for waterbirds (Sale 2006). The numerous polynyas around the archipelago provide overwintering habitat for non-migratory marine species, especially eiders (Robertson and Gilchrist 1998).

Birds start to arrive back on breeding grounds in late May, and begin to migrate south mid-August, with migration mainly complete by late September (Freeman 1971). Shorebirds and non-breeders leave the area earlier than breeding pairs and young of the year (Sale 2006). The QSA is characterized by huge flocks of Canada Goose, Cackling Goose, and eiders on the archipelago (Freeman 1971). The area is also home to a variety of gulls and shorebirds and large flocks of Snow Goose along the southern and eastern coastline (Rockwell et al. 2009; Nozais et al. 2021). Ducks and swans are present to a lesser extent in the archipelago (Freeman 1971) but are numerous in river estuaries (Nozais et al. 2021; IBA Canada [s.d.]).

Populations of many waterbird species, especially the Hudson Bay population of Common Eiders, are known to be in decline, some by as much as 75% (Robertson and Gilchrist 1998; Birdlife International 2022). As such, many areas have been identified as being of local or regional importance to birds in an attemp to guide conservation efforts. An Important Bird Area (IBA) is an internationally recognized designation which defines a distinct area which supports a specific species or group of birds that is protected by the Species at Risk Act, or in other ways limited in habitat or range. In other cases, an IBA is identified because it encompasses a regionally or locally important breeding or foraging area.

The QSA contains four recognized Important Bird Areas (Figure 37) (IBA Canada [s.d.]).

- NU033 Sleeper Island
- NU031 North Belcher Islands
- NU100 South Flaherty Islands
- NU032 Salikuit Islands

All four of these IBAs are identified for their importance to breeding and foraging Common Eiders (Hudson Bay subspecies) (IBA Canada [s.d.]).

Elliott et al. (2009) recommend that seabird colonies be surrounded by a 60 km buffer due to evidence that habitat use may extend up to 60 km beyond the core breeding habitat. Applying that 60km buffer to IBAs immediately adjacent to the QSA indicates that the following IBAs can be influenced by activities within the QSA:

- QC145 Grand Rivière de la Baleine (GWR)
- QC146 Petite Rivière de la Baleine
- QC147 Rivers of the Lac Guillaume-Delisle Basin
- QC148 Rivière Nastapoka
- ON130 Cape Henrietta Maria
- NU030 Koktac Ricer Archipelago

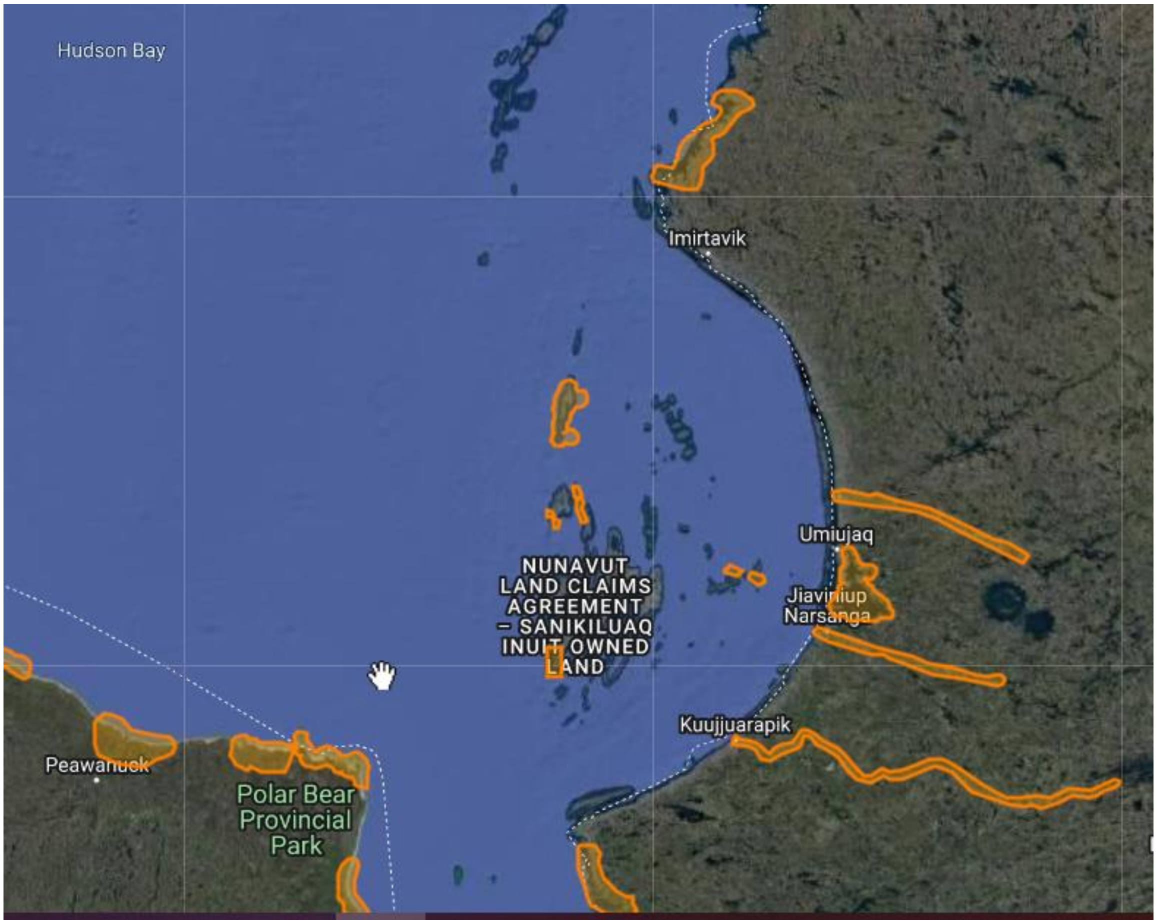


Figure 37 Important Bird Areas in the QSA and adjacent areas highlighted in orange. Source: IBA Canada (s.d.).

QC145 to QC148 are centered around breeding habitat for the eastern population of Harlequin Duck, NU030 is an additional IBA dedicated to Harlequin Duck nesting habitat, and ON130 is considered locally and regionally important breeding and foraging area for all resident sea duck and waterbird populations, especially Lesser Snow Goose (IBA Canada [s.d.]).

In general, ducks and geese are an important local food source for the people of Sanikiluaq (McDonald et al. 1997; Government of Nunavut 2010; Haycock-Chavez 2021), and eider down is an important resource for the production of clothing and craft items (Government of Nunavut 2010)

Common Eider, Hudson Bay Race (*Somateria mollissima sedentaria*)

Common Eider is a large sea duck which lives up to 20 years (The Cornell Lab of Ornithology 2022). Common Eider inhabits coastal habitat across the circumpolar Arctic and as far south as 45 degrees latitude. The Hudson Bay subspecies of Common Eiders (*S.m. sedentaria*), is estimated at 255,000 birds (Sea Duck Joint Venture 2018), and almost exclusively breeds, forages and overwinters within the QSA (Figure 38). During winter surveys in 1998 and 1999, flocks of 200-12,500 individuals were observed foraging along floe edges at Belcher Islands, and smaller flocks were observed feeding in polynyas (Gilchrist and Robertson 2000). In 2010, the wintering population near Sanikiluaq was estimated at 35,000 (Government of Nunavut 2010).

Figure 38. Breeding and overwintering range of Common Eider. Source: The Cornell Lab of Ornithology (2022).

Four IBAs have been delineated where large crèches (flocks) of *S.m. sedentaria* breed and raise young (IBA Canada [s.d.]). The preference for these low-lying, sparsely vegetated rocky islands is likely due to the prevalence of polynyas and floe edge habitat among and around the Belcher Islands, providing open water forage habitat during the winter months (Mallory et al. 2006, 2010). These IBAs align precisely with important harvesting areas for Common Eider identified by the people of Sanikiluaq (Government of Nunavut 2010).

There is some evidence that smaller breeding colonies of *S.m. sedentaria* exist in Hudson Strait, northeast Hudson Bay, northern Hudson Bay and Foxe Basin (Gilliland et al. 2008; Rockwell et al. 2009) and interbreeding between *S.m. sedentaria* and Northern Common Eiders (*S. borealis*) is also thought to occur (Robertson et al. 2001). However, overwintering habitat appears to be concentrated around Belcher Islands (The Cornell Lab of Ornithology 2022).

Common Eider female will lay between 4 and 4.5 eggs/clutch (Robertson et al. 2001) in early summer, with eggs hatching after 24-26 days (The Cornell Lab of Ornithology 2022). Nesting success is dependent on abiotic factors such as delay of the onset of spring, cool weather and storm events (Iles et al. 2013), and biotic factors such as nest predation by Arctic Foxes (*Vulpes lagopus*), Polar Bears, Bald Eagles (*Haliaeetus leucocephalus*) and Herring Gulls (*Larus argentatus*) (Rockwell et al. 2009; Iles et al. 2013). Nest predation is lessened, to an extent, when Common Eider nests near Snow Goose colonies, due to the aggressive nature of the geese against predators. However, there is a tipping point wherein crowding from Snow Goose population growth offsets the protection factor and negatively affects Common Eider nesting success (Iles et al. 2013).

Common Eider forages on marine benthic, near coastal invertebrates, such as mussels (especially blue mussels), echinoderms, and crustaceans, as well as roe of vertebrate fish (Mallory 2006; Mallory et al. 2006; The Cornell Lab of Ornithology 2022). As diving foragers, adult Common Eiders prefer low tide, or slow currents for foraging, meaning they move from place to place throughout the day to find favourable conditions (Mallory et al. 2006; The Cornell Lab of Ornithology 2022).

There is a substantial annual fall harvest of *S.m. sedentaria* in the QSA to provide eider down for the local community (Government of Nunavut 2010; Rothe et al. 2015). While intensive, this harvest appears to be sustainable and locally managed (Gilchrist et al. 2005; Rothe et al. 2015). Instead, nest predation (Rockwell et al. 2009) and unusually cold spells that close polynyas, causing a reduction in open-water habitat (Robertson and Gilchrist 1998), appear to be the main drivers of population decline. There is evidence that in the winter of 1991-1992, cold-weather events led to dramatic die-offs of *S.m. sedentaria* (Robertson and Gilchrist 1998; Gilchrist and Robertson 2000) and if these events become more frequent due to climate change, there could be dire consequences for this sub population (Gilchrist and Robertson 2000; Mallory et al. 2010).

Harlequin Duck (*Histrionicus histrionicus*)

The species is split into two populations, eastern and western. The eastern population breeds in the inland rivers draining into Hudson Bay within the QSA. At the time of last assessment in 2013, COSEWIC designated the eastern population as being of Special Concern based on its small population size and susceptibility to human activities such as oil spills and water pollution (COSEWIC 2013; The Cornell Lab of Ornithology 2022).

The eastern population of *H. histrionicus* can be further separated into two management units based on over-wintering areas: an Eastern North American Wintering Population (EWP) and a Greenland Wintering Population (GWP) (COSEWIC 2013). Harlequin Ducks breeding adjacent to the QSA are believed to over-winter in Greenland (Figure 39) and are therefore part of the GWP population. An estimated 4,600 birds are in the GWP population, but the proportion of these that breed within, or adjacent to, the QSA has not been estimated.

Harlequin Ducks forage on small fish, fish eggs and marine invertebrates during the summer breeding period in the rivers emptying into Hudson Bay, estuaries and tidal flats (COSEWIC 2013). They forage in fast-moving water early in the breeding season, but move upstream into calmer water when the young hatch (COSEWIC 2013; The Cornell Lab of Ornithology 2022). Small islands and sandbars in their foraging streams are preferred habitat for loafing, although boulders and rocks are also used, especially along coastal areas.

Harlequin Ducks have a life span of approximately 15-20 years (The Cornell Lab of Ornithology 2022) based on banding recovery data. Nesting occurs in a variety of substrates: tree hollows, cliff edges and on the ground. They lay 4 to 8 eggs in a leaf, moss, or pebble-lined nest which hatch in 27-29 days (The Cornell Lab of Ornithology 2022). Nesting success is variable from year to year, which can lead to years with very low productivity (Bolduc et al. 2005).

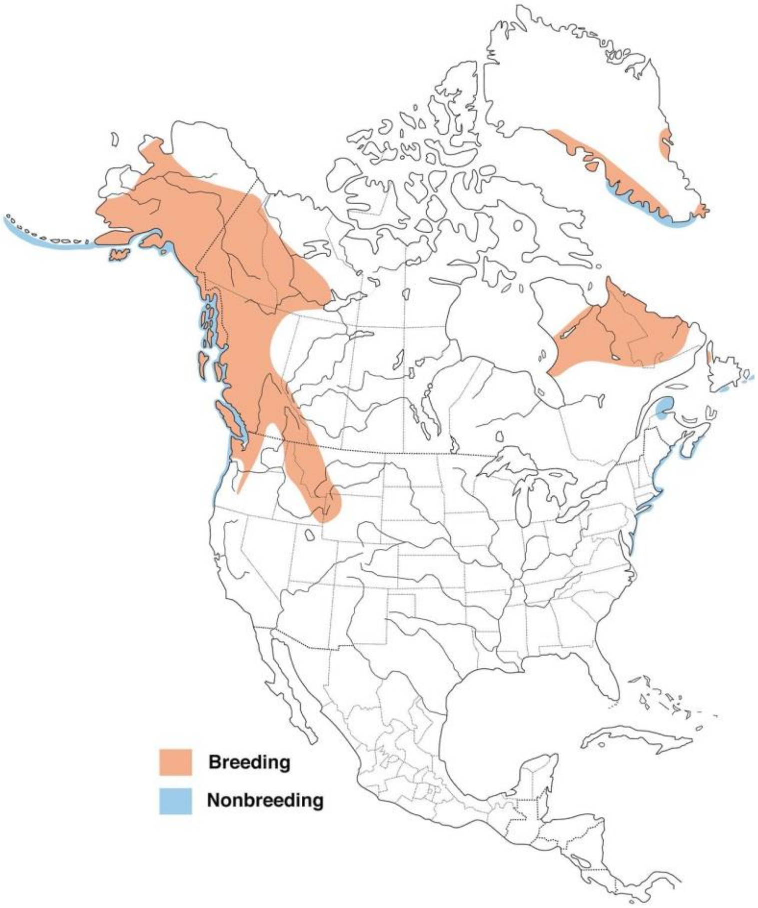


Figure 39. Breeding and Over-wintering Ranges of H. histrionicus. Source: The Cornell Lab of Ornithology (2022).

Populations of Harlequin Ducks were much higher historically, but declined as a result of over-hunting (COSEWIC 2013) or potentially other human activity, such as forestry (Mallory et al. 2003; The Cornell Lab of Ornithology 2022). In fact, the species was believed to be extirpated from its range in Baffin Island until a combination of traditional knowledge and systematic surveys re-confirmed their presence (Mallory et al. 2003)

While data for Belcher Islands are sparse, it is estimated that *H. histrionicus* numbers have been increasing since 1981, at a rate of 5% per year (COSEWIC 2013). This is possibly attributed to the hunting ban imposed for the eastern population since 1990 (COSEWIC 2013). The long lifespan and intermittent productivity of this species are believed to contribute to their slow recovery (Mallory and Fontaine 2004).

ECOLOGICAL AND SUBSISTENCE SIGNIFICANCE

The synthesis of existing information for Hudson Bay, the Belcher Island EBSA and the QSA provided in previous sections of this document provides the basis for identifying ecological and subsistence significance of the various ecosystem components. This ecological and subsistence significance, along with knowledge gaps, and vulnerability/threats (discussed below), will inform the development of conservation objectives as part of the Qikiqtait MPA process. Six ecologically and subsistence significant components were identified in this report, and their associated knowledge gaps and vulnerabilities are discussed in the following section:

1. Polynyas and Strong Upwelling

   There are at least eight mostly small, recurring latent-heat polynyas that form in the QSA due to shifting pack ice and strong tidal currents that prevent the formation of ice. There are two types of polynyas in the QSA; those less than 900 m in diameter, and those that can extend for several kilometres adjacent to landfast ice. These biologically important polynyas are areas of high productivity that provide critical winter habitat for a variety of seabirds and marine mammals. In addition, the community of Sanikiluaq uses these polynyas to hunt seabirds and seals during winter.

   Surface waters within the QSA are among the coldest in Hudson Bay due mainly to strong upwelling. The upwelling can drive latent heat fluxes along the edges of large polynyas and increase the upward flux of nutrients. During summer, most of Hudson Bay is characterized by vertical stratification that impedes the renewal of nutrients in the surface layer and upwelling. However, the cold-water upwelling around the Belcher Islands provides increased nutrient availability during summer that is not occur elsewhere in Hudson Bay. The increased nutrients improve primary productivity within the system and have cascading effects up to higher trophic levels.

2. Large River Plumes and estuaries

   There are significant freshwater inputs into Hudson Bay from a number of large river systems along its coastline. The Belcher Island EBSA and QSA has a north-flowing coastal boundary current that carries outflows of fresh water from major rivers in James Bay (e.g., La Grande River) and those along the Québec coast (e.g., Great Whale River). The size of these plumes can vary seasonally, but influence salinity, light penetration, and the abundance and distribution of marine, brackish and freshwater biota along much of the coastline of the Belcher Island EBSA and the QSA.

3. Benthic Invertebrate Community

   Biological production and benthic community structure and dynamics in the QSA and greater Hudson Bay region are heavily influenced by river runoff and seasonal sea ice cover. Habitat productivity modeling and recent surveys of benthic invertebrates in Hudson Bay have identified areas within the QSA as having diverse, abundant communities with high productivity. In particular, the polynya west of the Belcher Islands and coastal sites at the north end of the Belcher Island EBSA near Inukjuak were shown to have among the highest values for biomass, density and/or taxonomic richness in all of the Hudson Bay Complex. Local resource users in Sanikiluaq have also indicated a productive benthic invertebrate community and have expressed interest in potential commercial fisheries for certain taxa (e.g., scallops, mussels, sea cucumbers, and sea urchins).

4. Hudson Bay Subspecies of Common Eider and Their Prey Species

   This subspecies of Common Eider, estimated at 255,000 birds, breeds, forages and overwinters almost exclusively within the QSA, making them unique to the area. The birds forage along the floe edges and in polynyas among the Belcher Islands in flocks of 200-12,500 individuals. Four IBAs have been identified on low-lying, sparsely vegetated rocky islands where large flocks Hudson Bay Common Eiders breed and raise young. Common Eiders forage on a variety of benthic marine invertebrates, especially blue mussels. The birds are also important to the community of Sanikiluaq where large, sustainably managed fall harvests provide eider down.

5. Migratory Char and other Subsistence Food

   Although largely absent from coastal Québec within the Belcher Island EBSA, Arctic Char are an important species within the Belcher Islands where they have consistently been one of the most important harvested animals for residents of Sanikiluaq. Char are captured year round from marine and freshwater habitats with monthly catch estimates occasionally exceeding 2,000 fish during the open water period. Arctic Char are the most abundant salmonid available for subsistence harvesting and local food security for Sanikiluaq. Migratory Arctic char may also be an important prey species for the resident Beluga population. Other important harvested species include mussels, Eider Duck, several goose species, Greenland cod, Ringed Seal, and Beluga.

6. Resident Marine Mammals and Their Prey Species

   Five marine mammal species, Atlantic Walrus, Bearded Seal, Beluga, Polar Bear, and Ringed Seal are known to use year-round habitats within the QSA. The abundance of biologically productive recurring polynyas and open leads around the Belcher Islands provide important habitat for these species and their prey, allowing them to remain in the area year-round rather than undergo energetically costly seasonal migrations to other areas.

7. Marine Mammal (Beluga and Polar Bear) Seasonal Residence (feeding) and Calving/Denning Areas

   Eastern Hudson Bay Belugas spend the summer months in the QSA moving between coastal shallows or deep open water, foraging and raising their young. Estuaries along the Québec coast also provide important moulting habitat and a safe areas to raise young where the shallow water protects from some predators such as Killer Whales. The Beluga calving areas around the Belcher Islands has been designated as a Valued Ecosystem Component.

   Similarly, there is evidence, though not confirmed, of Southern Hudson Bay Polar Bears potentially denning within the Belcher Islands and along the eastern shore of Hudson Bay. Observations of Polar Bear on the Belcher Islands are generally confined to December to March, which coincides with denning season.

VULNERABILITIES TO THE QIKIQTAIT STUDY AREA AND ADJACENT WATERS

1. Climate change (e.g. reduced extent and duration of sea ice, northward range expansion of southern species, ocean acidification, among many other biotic and abiotic factors)
    - Shifts may occur in species diets (e.g., seabirds, belugas) from shifts in Arctic Cod to Capelin and sand lance distribution and availability. Range expansions of sub-Arctic species will also influence inter-specific interactions (e.g. predation, competition) among species that inhabit the QSA.
    - Introductions of novel parasites and disease on endemic Arctic species in the area.
    - Changes to the timing and magnitude of sea ice algae and phytoplankton blooms could disrupt zooplankton populations with cascading effects to the higher trophic levels.
    - Climate mediated reductions in sea ice and snow are likely to influence Ringed Seal subnivean lair use, Walrus haul-out sites and Polar Bear demography through reduction in suitable habitat, and changes in prey availability resulting in population declines. Reductions in sea ice are likely to increase the use of terrestrial habitats for some species potentially resulting in increased conflicts with humans and other terrestrial species.
    - The changes in ocean properties, atmospheric temperatures and wind patterns could influence the formation, distribution and number of polynyas during winter, potentially leading to constrained available open water habitat for Common Eiders and Belugas becoming ice-entrapped.
2. Vessel Traffic, Resource Development and other anthropogenic activity
    - Increased shipping due to a longer open water period, and from increased mining and other anthropogenic development as has already occurred in northwest and west Hudson Bay can lead to ship grounding, noise pollution, marine mammal strikes, and spills of contaminants.
    - Environmental effects may occur from aquatic invasive species due to ballast water release and vessel bio-fouling from large transport vessels.
    - Disturbance of Walrus haul out sites and important marine mammal summer and winter habitat may be exacerbated due to increased tourism activities, and associated noise from vessel and aircraft-based traffic.
    - Presence of contaminants and their potential synergistic impacts with other anthropogenic impacts to invertebrate, fish and marine mammal physiology.
3. Commercial Fisheries and Subsistence Activities
    - There may be increased interest in potential commercial fisheries for several fish and benthic invertebrate species found within the QSA, though feasibility is currently unknown but is being investigated.
    - Important harvest species for subsistence may become more susceptible to population reductions if other stressors (e.g., climate change and ocean acidification) are affecting overall abundance and health of these species.

KNOWLEDGE GAPS AND DATA DEFICIENCIES

- Lack of contemporary data describing diet, core habitat use and population trends for marine mammal species;
- Lack of life history knowledge and population assessments for Arctic Char in the QSA;
- Lack of recent information on subsistence harvest totals for Arctic char and other species;
- Insufficient data on marine fish ecology and life histories in the QSA, particularly in recent decades;
- Insufficient data on benthic marine invertebrate community composition, diversity and productivity across the QSA;
- An assessment of the productive capacity of the QSA is needed as it is the first step towards an evaluation of fisheries potential;
- Characterization of primary productivity, such as magnitude and phenology of sea ice algae and phytoplankton blooms and identification of areas of upwelling and downwelling;
- Characterization of the oceanography across the region throughout the year;
- Abundance, distribution, and habitat use by birds, including of polynyas; and
- Locations and ecological significance of kelp beds across the QSA.

REFERENCES CITED

Ahmed, M.M.M., Else, B.G.T., Butterworth, B. and Capelle, D.W. 2021. Widespread surface water pCO2 undersaturation during ice-melt season in an Arctic continental shelf (Hudson Bay, Canada). Elementa: Science of the Anthropocene 9(1): 1–22.

Algae Base. 2022. Algae Species Database [online]. Available from https://www.algaebase.org/search/species/ [accessed 16 December 2022].

AMAP. 2017. Snow, Water, Ice and Permafrost in the Arctic (SWIPA). Arctic Monitoring and Assessment Programme (AMAP), Oslo, NO. xiv + 269 p. Available from https://www.amap.no/documents/doc/snow-water-ice-and-permafrost-in-the-arctic-swipa-2017/1610

Andersen, L.W., Born, E.W., Doidge, D.W., Gjertz, I., Wiig, Ø., and Waples, R.S. 2009. Genetic Signals of Historic and Recent Migration Between Sub-Populations of Atlantic Walrus *Odobenus rosmarus rosmarus* West and East of Greenland. Endangered Species Research 9: 197-211. doi:10.3354/esr00242.

Andersen, L.W., Born, E.W., Stewart, R.E.A., Dietz, R., Doidge, D.W., and Lanthier, C. 2014. A Genetic Comparison of West Greenland and Baffin Island (Canada) Walruses: Management Implications. NAMMCO Sci. Publ. 9: 33-52. Available from https://septentrio.uit.no/index.php/NAMMCOSP/article/view/2610/3275

Anderson, J.T., and Roff, J.C. 1980. Seston Ecology of the Surface Waters of Hudson Bay. Canadian Journal of Fisheries and Aquatic Sciences 37: 2242-2253.

Andrews, J., Babb, D., McKernan, M., Horton, B., and Barber, D. 2016. Climate Change in the Hudson Bay Complex: Opportunities and Vulnerabilities for the Port of Churchill's Marine Operations. University of Manitoba The Centre for Earth Observation Science, Winnipeg, MB. 130 p. Available from https://mspace.lib.umanitoba.ca/xmlui/handle/1993/31138

Andrews, J., Babb, D., and Barber, D.G. 2017. Climate Change and Sea Ice: Shipping Accessibility on the Marine Transportation Corridor Through Hudson Bay and Hudson Strait (1980–2014). Elem. Sci. Anth. 5(15): 1-17. doi:10.1525/journal.elementa.130. Available from https://doi.org/10.1525/elementa.130

Andrews, J., Babb, D., and Barber, D.G. 2018. Climate change and sea ice: Shipping in Hudson Bay, Hudson Strait, and Foxe Basin (1980–2016). Elem. Sci. Anth. 6: 19. doi:10.1525/journal.elementa.281. Available from https://online.ucpress.edu/elementa/article/doi/10.1525/elementa.281/112786/Climate-change-and-sea-ice-Shipping-in-Hudson-Bay

Archambault, P., Snelgrove, P.V., Fisher, J.A., Gagnon, J.M., Garbary, D.J., Harvey, M., Kenchington, E.L., Lesage, V., Levesque, M., Lovejoy, C., Mackas, D.L., McKindsey, C.W., Nelson, J.R., Pepin, P., Piche, L., and Poulin, M. 2010. From Sea to Sea: Canada's Three Oceans of Biodiversity. PLoS One. 5(8): 26. doi:10.1371/journal.pone.0012182. Available from https://www.ncbi.nlm.nih.gov/pubmed/20824204

Arctic Eider Society. 2011. People of a Feather [[online movie]]. Available from https://arcticeider.com/pof/watch/ [accessed October 28 2022].

Ardyna, M., and Arrigo, K.R. 2020. Phytoplankton dynamics in a changing Arctic Ocean. Nature Climate Change 10(10): 892-903. doi:10.1038/s41558-020-0905-y.

Ardyna, M., Babin, M., Gosselin, M., Devred, E., Rainville, L., and Tremblay, J.-É. 2014. Recent Arctic Ocean Sea Ice Loss Triggers Novel Fall Phytoplankton Blooms. Geophysical Research Letters 41(17): 6207-6212. doi:10.1002/2014gl061047. Available from https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1002/2014GL061047

Ardyna, M., Mundy, C.J., Mills, M.M., Oziel, L., Grondin, P.-L., Lacour, L., Verin, G., Van Dijken, G.L., Ras, J., Alou-Font, E., Babin, M., Gosselin, M., Tremblay, J.-E., Raimbault, P., Assmy, P., Nicolaus, M., Claustre, H., and Arrigo, K.R. 2020. Environmental drivers of under-ice phytoplankton bloom dynamics in the Arctic Ocean. Elementa: Science of the Anthropocene 8: 30. doi:10.1525/journal.elementa.430.

Arrigo, K.R., van Dijken, G., and Pabi, S. 2008. Impact of a Shrinking Arctic Ice Cover on Marine Primary Production. Geophysical Research Letters 35(19): 6. doi:10.1029/2008gl035028. Available from https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2008GL035028

Arrigo, K.R., Perovich, D.K., Pickart, R.S., Brown, Z.W., van Dijken, G.L., Lowry, K.E., Mills, M.M., Palmer, M.A., Balch, W.M., Bahr, F., Bates, N.R., Benitez-Nelson, C., Bowler, B., Brownlee, E., Ehn, J.K., Frey, K.E., Garley, R., Laney, S.R., Lubelczyk, L., Mathis, J., Matsuoka, B.G., Mitchell, G.W.K., Moore, E., Ortega-Retuerta, S., Pal, C.M., Polashenski, R.A., Reynolds, A., Schieber, B., Sosik, H.M., Stephens, M., and Swift, J.H. 2012. Massive Phytoplankton Blooms Under Arctic Sea Ice. Sci. 336: 1408. doi:10.5061/dryad.4dn793t6. Available from https://science.sciencemag.org/content/336/6087/1408

Art Nunavik. 2022a. Inukjuak ᐃᓄᒃᔪᐊᒃ. Available from https://artnunavik.ca/pages/inukjuak [accessed 14 November 2022].

Art Nunavik. 2022b. Kuujjuarapik ᑰᔾᔪᐊᕌᐱᒃ [online]. Available from https://artnunavik.ca/pages/kuujjuarapik [accessed 14 November 2022].

Atkinson, E.G., and Wacasey, J.W. 1989. Benthic Invertebrates Collected from Hudson Bay, Canada, 1953 to 1965. Can. Data Rep. Fish. Aquat. Sci. 744: iv + 121 p.

Atwood, T.C., Rode, K.D., Douglas, D.C., Simac, K., Pagano, A.M., and Bromaghin, J.F. 2021. Long-term variation in polar bear body condition and maternal investment relative to a changing environment. GECCO 32: e01925. doi:10.1016/j.gecco.2021.e01925.

Azetsu-Scott, K., Starr, M., Mei, Z.-P. and Granskog, M. 2014. Low calcium carbonate saturation state in an Arctic inland sea having large and varying fluvial inputs: The Hudson Bay system, J. Geophys. Res. Oceans, 119, 6210–6220, doi:10.1002/2014JC009948

Bailleul, F., Lesage, V., Power, M., Doidge, D.W., and Hammill, M.O. 2012. Differences in diving and movement patterns of two groups of beluga whales in a changing Arctic environment reveal discrete populations. Endanger. Species Res. 17(1): 27-41. doi:10.3354/esr00420.

Bain, H., and Sekerak, A.D. 1978. Aspects of the Biology of Arctic Cod, *Boreogadus saida*, in the Central Canadian Arctic. A report prepared for Polar Gas Project by LGL Ltd. LGL Ltd., Toronto, ON. 104 p. Available from https://cat.fsl-bsf.scitech.gc.ca/record=3851187&searchscope=06

Bain, H., Thomson, U., Foy, M., and Griffiths, W. 1977. Marine Ecology of Fast-Ice Edges in Wellington Channel and Resolute Passage, NWT. A report prepared by LGL Ltd. for Polar Gas Project. LGL Ltd, Toronto, ON. 262 p. Available from https://cat.fsl-bsf.scitech.gc.ca/record=3863005~S6

Barber, D.G., and Massom, R.A. 2007. Chapter 1: Role of sea ice in Arctic and Antarctic polynyas. *In* Polynyas: Windows to the World. *Edited by* W. O. Jr. Smith and D. G. Barber. Elsevier Science & Technology, Amsterdam, NL. pp. 1-54.

Barber, D.G., Hop, H., Mundy, C.J., Else, B.G.T., Dmitrenko, I.A., Tremblay, J.-E., Ehn, J.K., Assmy, P., Daase, M., Candlish, L.M., and Rysgaard, S. 2015. Selected Physical, Biological and Biogeochemical Implications of a Rapidly Changing Arctic Marginal Ice Zone. Prog. Oceanogr. 139: 122-150. doi:10.1016/j.pocean.2015.09.003. Available from https://www.sciencedirect.com/science/article/abs/pii/S0079661115300148

Barber, F. 1968. The Water and Ice of Hudson Bay Part I: The Water. *In* Science, history and Hudson Bay. *Edited by* C. S. Beals. Department of Energy, Mines, and Resources, Ottawa, ON. pp. 287-318.

Barber, F.G. 1967. A contribution to the oceanography of Hudson Bay. Department of Energy, Mines, and Resources, Ottawa, ON. 69 p.

Barnhart, K.R., Overeem, I., and Anderson, R.S. 2014. The effect of changing sea ice on the physical vulnerability of Arctic coasts. The Cryosphere 8(5): 1777-1799. doi:10.5194/tc-8-1777-2014. Available from https://tc.copernicus.org/articles/8/1777/2014/tc-8-1777-2014.pdf

Beck, B., Smith, T.G., and Mansfield, A.W. 1970. Occurrence of the Harbour Seal, *Phoca vitulina*, Linnaeus in the Thlewiaza River, N.W.T. Can. Field-Nat. 84: 297-300. Available from https://www.biodiversitylibrary.org/bibliography/39970

Bélanger, S., Babin, M., and Tremblay, J.É. 2013. Increasing Cloudiness in Arctic Damps the Increase in Phytoplankton Primary Production due to Sea Ice Receding. Biogeosciences. 10(6): 4087-4101. doi:10.5194/bg-10-4087-2013. Available from https://www.biogeosciences.net/10/4087/2013/

Bilous, M. and K.M. Dunmall. 2020. Atlantic salmon in the Canadian Arctic: potential dispersal, establishment, and interaction with Arctic char. Reviews in Fish Biology and Fisheries 30: 463-483.

Birdlife International. 2022. Important Bird Areas factsheet: North Belcher Islands [online] [accessed 13 October 2022].

Boetius, A., Albrecht, S., Bakker, K., Bienhold, C., Felden, J., Fernández-Méndez, M., Hendricks, S., Katlein, C., Lalande, C., Krumpen, T., Nicolaus, M., Peeken, I., Rabe, B., Rogacheva, A., Rybakova, E., Somavilla, R., Wenzhöfer, F., and RV Polarstem ARK27-3 Shipboard Science Party. 2013. Export of Algal Biomass from the Melting Arctic Sea Ice. Sci. 339(6126): 1430-1432. doi:10.1594/PANGAEA.803293. Available from https://science.sciencemag.org/content/339/6126/1430

Bolduc, F., Guillemette, M., and Titman, R.D. 2005. Nesting success of common eiders *Somateria mollissima* as influenced by nest-site and female characteristics in the Gulf of the St. Lawrence. Wildlife Biol. 11(4): 273-279. doi:10.2981/0909-6396(2005)11[273:Nsoces]2.0.Co;2.

Born, E.W., Andersen, L.W., Gjertz, I., and Wiig, Ø. 2001. A Review of the Genetic Relationships of Atlantic Walrus (*Odobenus rosmarus rosmarus*) East and West of Greenland. Polar Biology 24(10): 713-718. doi:10.1007/s003000100277.

Bourdages, M.P.T., Provencher, J.F., Sudlovenick, E., Ferguson, S.H., Young, B.G., Pelletier, N., Murphy, M.J.J., D'Addario, A., and Vermaire, J.C. 2020. No plastics detected in seal (Phocidae) stomachs harvested in the eastern Canadian Arctic. Mar. Pollut. Bull. 150: 110772. doi:10.1016/j.marpolbul.2019.110772. Available from https://carleton.ca/geography/wp-content/uploads/Madelaine.pdf

Bowen, W., Ellis, S.L., Iverson, S.J., and Boness, D.J. 2003. Maternal and newborn life-history traits during periods of contrasting population trends: implications for explaining the decline of harbour seals (*Phoca vitulina*), on Sable Island. J. Zool. 261(2): 155-163. doi:10.1017/s0952836903004047.

Bradstreet, M.S.W. 1980. Thick-Billed Murres and Black Guillemots in the Barrow Strait Area, N.W.T., During Spring: Diets and Food Availability Along Ice Edges. Can. J. Zool. 58: 2120-2140. Available from http://www.nrcresearchpress.com/doi/pdf/10.1139/z80-292.

Breton-Honeyman, K., Hammill, M.O., Furgal, C.M., and Hickie, B. 2016. Inuit Knowledge of Beluga Whale (*Delphinapterus leucas*) Foraging Ecology in Nunavik (Arctic Quebec), Canada. Can. J. Zool. 94(10): 713-726. doi:10.1139/cjz-2015-0259.

Bring, A., Shiklomanov, A., and Lammers, R.B. 2017. Pan-Arctic river discharge: Prioritizing monitoring of future climate change hot spots. Earth's Future 5(1): 72-92. doi:10.1002/2016ef000434.

Brunelle, C.B., Larouche, P., and Gosselin, M. 2012. Variability of Phytoplankton Light Absorption in Canadian Arctic Seas. J. Geophys. Res. 117(C9): 17. doi:10.1029/2011jc007345. Available from http://www.quebec-ocean.ulaval.ca/pdf_xls_files/recentpub/Brunelle,_Larouche,_Gosselin_2012.pdf

Buchanan, R.A., Cross, W.E., and Thomson, D.H. 1977. Survey of the Marine Environment of Bridport Inlet, Melville Island. A report prepared by L.G.L. Ltd. for Petro-Canada. L.G.L. Ltd., Toronto, ON. 265 p. Available from https://cat.fsl-bsf.scitech.gc.ca/record=3862970&searchscope=06

Buck, W., Dubnie, A., and Branch, M. 1968. Economic Possibilities. *In* Science, history and Hudson Bay. *Edited by* C. S. Beals. Department of Energy, Mines and Mines and Resources, Ottawa, ON. pp. 935-984.

Burt, W.J., Thomas, H., Miller, L.A., Granskog, M.A., Papakyriakou, T.N. and Pengelly, L. 2016. Inorganic carbon cycling and biogeochemical processes in an Arctic inland sea (Hudson Bay). Biogeosciences 13(16): 4659–4671. DOI: http://dx.doi.org/10.5194/bg-13-4659-2016.

Cairns, D.K., Keen, D.M., Daoust, P.-Y., Gillis, D.J., and Hammill, M.O. 2000. Conflicts between seals and fishing gear on Prince Edward Island. Canadian Technical Report of Fisheries and Aquatic Sciences No. 2333: 38 p.

Calvert, W., & Stirling, I. 1990. Interactions between Polar Bears and Overwintering Walruses in the Central Canadian High Arctic. Bears: Their Biology and Management, 8, 351–356. https://doi.org/10.2307/3872939

Cameron, M.F., Bengtson, J.L., Boveng, P.L., Jansen, J.K., Kelly, B.P., Dahle, S.P., Logerwell, E.A., Overland, J.E., Sabine, C.L., Waring, G.T., and Wilder, J.M. 2010. Status Review of the Bearded Seal (*Erignathus barbatus*). NOAA Tech. Memo.: NMFS-AFSC-211. Springfield, VA. 247 p.

Campbell, K., Mundy, C.J., Barber, D.G., and Gosselin, M. 2015. Characterizing the sea ice algae chlorophyll *a*–snow depth relationship over Arctic spring melt using transmitted irradiance. Journal of Marine Systems 147: 76-84. doi:0.1016/j.jmarsys.2014.01.008.

Canada. 1996. *Oceans Act*. Government of Canada, Ottawa, ON. p. 56. Available from http://laws-lois.justice.gc.ca/eng/acts/O-2.4/

Chambellant, M., Stirling, I., Gough, W.A., and Ferguson, S.H. 2012. Temporal variations in Hudson Bay ringed seal (*Phoca hispida*) life-history parameters in relation to environment. J. Mammal. 93(1): 267-281. doi:10.1644/10-mamm-a-253.1.

Chambellant, M., Stirling, I., and Ferguson, S.H. 2013. Temporal variation in western Hudson Bay ringed seal *Phoca hispida* diet in relation to environment. Mar. Ecol. Prog. Ser. 481: 269-287. doi:10.3354/meps10134.

Chen, C.C., Gao, G., Qi, J., Proshutinsky, A., Beardsley, R.C., Kowalik, Z., Lin, H., and Cowles, G. 2009. A new high-resolution unstructured grid finite volume Arctic Ocean model (AO-FVCOM): An application for tidal studies. J. Geophys. Res. 114(C8): C08017. doi:10.1029/2008jc004941.

Cheung, W.W.L., Lam, V.W.Y., and Pauly, D. 2008. Modelling Present and Climate-Shifted Distribution of Marine Fishes and Invertebrates. Fish. Centre Res. Rep. 16 (3): 72 p. Available from https://open.library.ubc.ca/cIRcle/collections/facultyresearchandpublications/52383/items/1.0074754

Cheung, W.W.L., Lam, V.W.Y., Sarmiento, J.L., Kearney, K., Watson, R., and Pauly, D. 2009. Projecting Global Marine Biodiversity Impacts Under Climate Change Scenarios. Fish Fish. 10(3): 235-251. doi:10.1111/j.1467-2979.2008.00315.x. Available from https://onlinelibrary.wiley.com/doi/10.1111/j.1467-2979.2008.00315.x

CIS. 2021. Canadian Ice Service Digital Ice Chart Archive (CISDA) [online]. Available from https://iceweb1.cis.ec.gc.ca/Archive/page1.xhtml [accessed 1 November 2022].

ClimateData.ca. 2018. Time-series of the mean temperature data variable in Sanikiluaq, Nunavut [online]. Available from https://climatedata.ca/explore/location/?loc=OAOKW&location-select-temperature=tx_max&location-select-precipitation=r1mm&location-select-other=frost_days [accessed 27 October 2022].

CMS. 2017. Polar Bear *Ursus maritimus* [online]. Available from http://www.cms.int/en/node/5517 [accessed 10 October 2017].

Coad, B.W., and Reist, J.D. 2018. Marine Fishes of Arctic Canada. Canadian Museum of Nature and University Press, Toronto, ON. 316 p. Available from https://cat.fsl-bsf.scitech.gc.ca/record=4064616&searchscope=06

Cobb, D., Fast, H., Papst, M.H., Rosenberg, D., Rutherford, R., and Sareault, J.E. 2008. Beaufort Sea Large Ocean Management Area: Ecosystem Overview and Assessment Report. Can. Tech. Rep. Fish. Aquat. Sci. 2780: ix + 188 p. Available from www.beaufortseapartnership.ca/wp-content/uploads/2015/04/eoar2008march.pdf

Cohen, S.J. 1994. Climate variability, climatic change and implications for the future of the Hudson Bay bioregion. Hudson Bay Programme, Ottawa,ON. 113 p.

Collins, M., Knutti, R., Arblaster, J., Dufresne, J.-L., Fichefet, T., Friedlingstei, F., Gao, X., Gutowski, W.J., Johns, T., Krinner, G., Shongwe, M., Tebaldi, C., Weaver, A.J., and Wehner, M. 2013. Long-term climate change: projections, commitments and irreversibility. *In* Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. *Edited by* T. F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, and P.M. Midgley. Cambridge University Press, Cambridge, UK and New York, NY. pp. 1029-1139. Available from https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter12_FINAL.pdf

Comiso, J.C. 2003. Warming Trends in the Arctic from Clear Sky Satellite Observations. Journal of Climate 16: 3498-3510.

Community Environmental Monitoring Systems Workshop. 2008. Community Environmental Monitoring Systems (CEMS) Workshop summary report, January 17, 2008 - January 21, 2008. Nunavuummi Tasiujarjuamiuguqatigiit Katutjiqatigiingit (NTK), Sanikiluaq, NU. 41 p.

COSEWIC. 2004. COSEWIC Assessment and Update Status Report on the Narwhal *Monodon monoceros* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON. vii + 50 p. Available from https://www.sararegistry.gc.ca/virtual_sara/files/cosewic/sr_narwhal_e.pdf

COSEWIC. 2005. COSEWIC Assessment and Update Status Report on the Bowhead Whale *Balaena mysticetus* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON. viii + 51 p.

COSEWIC. 2007. COSEWIC Assessment and Update Status Report on the Harbour Seal Atlantic and Eastern Arctic Subspecies *Phoca vitulina concolor* and Lacs des Loups Marins subspecies *Phoca vitulina mellonae* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON. vii + 40 p.

COSEWIC. 2008a. COSEWIC Assessment and Update Status Report on the Harbour Seal *Phoca vitulina*. Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON.

COSEWIC. 2008b. COSEWIC Assessment and Update Status Report on the Killer Whale *Orcinus orca*, Southern Resident Population, Northern Resident Population, West Coast Transient population, Offshore Population and Northwest Atlantic / Eastern Arctic Population, in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON. viii + 65 p.

COSEWIC. 2013. COSEWIC assessment and status report on the Harlequin Duck *Histrionicus histrionicus* Eastern population in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON. ix + 38 p. Available from www.registrelep-sararegistry.gc.ca/default_e.cfm

COSEWIC. 2016. Designatable Units for Beluga Whales (*Delphinapterus leucas*) in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON. 73 p. Available from http://www.cosewic.ca/images/cosewic/pdf/beluga_whale_dus_en.pdf

COSEWIC. 2017. COSEWIC Assessment and Status Report on the Atlantic Walrus *Odobenus rosmarus rosmarus*, High Arctic Population, Central-Low Arctic Population and Nova Scotia-Newfoundland-Gulf of St. Lawrence Population in Canada. COSEWIC, Ottawa,ON. xxxi + 89 p. Available from https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry/cosewic-assessments-status-reports/atlantic-walrus-2017.html

COSEWIC. 2018. COSEWIC Assessment and Status Report on the Polar Bear *Ursus maritimus* in Canada 2018. Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON. 128 p. Available from https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry/cosewic-assessments-status-reports/polar-bear-2018.html

COSEWIC. 2019. COSEWIC assessment and status report on the Ringed Seal *Pusa hispida* in Canada. COSEWIC, Ottawa, ON. xii + 82 p. Available from https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry.html

COSEWIC. 2020. COSEWIC assessment and status report on the Beluga Whale *Delphinapterus leucas*, Eastern High Arctic - Baffin Bay population, Cumberland Sound population, Ungava Bay population, Western Hudson Bay population, Eastern Hudson Bay population and James Bay poplation in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON. xxxv + 84 pp. p. Available from https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry.html

Courtland, R. 2008. Polar Bear numbers set to fall. Nature 453(22): 432-433.

Crompton, A.E., Obbard, M., Peterson, S.D., and Wilson, P.J. 2008. Population genetic structure in polar bears (*Ursus maritimus)* from Hudson Bay, Canada: Implications of future climate change. Biol. Conserv. 141(2008): 2528 –2539. Available from https://pdfs.semanticscholar.org/bda7/ab18d30f7401df8c4914f66f81fa320294d9.pdf?_ga=2.147810931.53243622.1585160123-805737118.1583785669

Crompton, A.E., Obbard, M.E., Petersen, S.D., and Wilson, P.J. 2014. Corrigendum to “Population Genetic Structure in Polar Bears (*Ursus maritimus*) from Hudson Bay, Canada: Implications of Future Climate Change” [Biol. Conserv. 141(10) (2008) 2528–2539]. Biol. Conserv. 179. doi:10.1016/j.biocon.2014.08.015.

Cusson, M., Archambault, P., and Aitken, A. 2007. Biodiversity of Benthic Assemblages on the Arctic Continental Shelf: Historical Data from Canada. Mar. Ecol. Prog. Ser. 331: 291-304. doi:10.3354/meps331291. Available from http://www.int-res.com/articles/meps2007/331/m331p291.pdf

CWS (Canadian Wildlife Service). 2009. Nunavut Consultation Report. Consultations on the Proposed Listing of the Polar Bear as Special Concern under the Species at Risk Act. February-April 2009. Iqaluit NU.

Danielson, E.W. 1969. The surface heat budget of Hudson Bay. Thesis (M. Sc), McGill University, Montreal, QC. 196 p.

Darnis, G., Robert, D., Pomerleau, C., Link, H., Archambault, P., Nelson, R.J., Geoffroy, M., Tremblay, J.-É., Lovejoy, C., Ferguson, S.H., Hunt, B.P.V., and Fortier, L. 2012. Current State and Trends in Canadian Arctic Marine Ecosystems: II. Heterotrophic Food Web, Pelagic-Benthic Coupling, and Biodiversity. Clim. Change. 115(1): 179-205. doi:10.1007/s10584-012-0483-8. Available from https://link.springer.com/article/10.1007%2Fs10584-012-0483-8

Das, S. and Mangwani, N. 2015. Ocean acidification and marine microorganisms: responses and consequences, Oceanologia, Volume 57, Issue 4, Pages 349-361, https://doi.org/10.1016/j.oceano.2015.07.003.

Defossez, M., Saucier, F.J., Myers, P.G., Caya, D., and Dumais, J.F. 2010. Analysis of a dense water pulse following mid-winter opening of polynyas in western Foxe Basin, Canada. Dynamics of Atmospheres and Oceans 49(1): 54-74. doi:10.1016/j.dynatmoce.2008.12.002.

DeJong, R.A. 2017. Life history characteristics of Lake Whitefish (*Coregonus clupeaformis*), Cisco (*Coregonus artedi*), and Northern Pike (*Esox lucius*) in rivers of the Hudson Bay Lowlands. Thesis (M.Sc), University of Waterloo, Waterloo, ON

Dempson, J.B., Shears, M., and Bloom, M. 2002. Spatial and temporal variability in the diet of anadromous Arctic Char, *Salvelinus alplinus,* in Northern Labrador. Environmental Biology of Fishes 64(1): 49-62. doi:10.1023/A:1016018909496.

Derksen, C., Burgess, D., Duguay, C., Howell, S., Mudryk, L., Smith, S., Thackeray, C., and Kirchmeier-Young, M. 2019. Changes in snow, ice, and permafrost across Canada. *In* Canada's Changing Climate Report. *Edited by* E. Bush and D. S. Lemmen. Government of Canada, Ottawa, ON. pp. 194-260. Available from https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/Climate-change/pdf/CCCR-Chapter5-ChangesInSnowIcePermafrostAcrossCanada.pdf

Derocher, A.E., Andersen, M., Wiig, Ø. 2005. Sexual Dimorphism of Polar Bears, Journal of Mammalogy 86(5): 895–901, https://doi.org/10.1644/1545-1542(2005)86[895:SDOPB]2.0.CO;2

Derocher, A.E., Lunn, N.J., and Stirling, I. 2004. Polar Bears in a Warming Climate. Integrative and Comparative Biology 44: 163-176. doi:10.1093/icb/44.2.163. Available from https://academic.oup.com/icb/article/44/2/163/674253

Dery, S.J., Stieglitz, M., McKenna, E.C., and Wood, E.F. 2005. Characteristics and Trends of River Discharge into Hudson, James, and Ungava Bays, 1964–2000. Journal of Climate 18: 2540-2557. Available from https://journals.ametsoc.org/configurable/content/journals$002fclim$002f18$002f14$002fjcli3440.1.xml?t%3Aac=journals%24002fclim%24002f18%24002f14%24002fjcli3440.1.xml&tab_body=pdf

Déry, S.J., Mlynowski, T.J., Hernández-Henríquez, M.A., and Straneo, F. 2011. Interannual variability and interdecadal trends in Hudson Bay streamflow. Journal of Marine Systems 88(3): 341-351. doi:10.1016/j.jmarsys.2010.12.002.

DFO. 1998. Hudson Bay Narwhal. Stock Stat. Rep.: E5-44. 4 p.

DFO. 1999. National Framework for Establishing and Managing Marine Protected Areas. Fisheries and Oceans Canada, Ottawa, ON. 21 p. Available from http://www.dfo-mpo.gc.ca/oceans/publications/mpaframework-cadrezpm/index-eng.html

DFO. 2009. Development of a Framework and Principles for the Biogeographic Classification of Canadian Marine Areas. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep.: 2009/056. 17 p.

DFO. 2010a. Science Guidance on the Development of Networks of Marine Protected Areas (MPAs). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep.: 2009/061. 12 p.

DFO. 2010b. Science Evaluation of Instream Flow Needs (IFN) for the Lower Athabasca River. Canadian Science Advisory Secretariat Science Advisory Report. 22 p. Available from https://waves-vagues.dfo-mpo.gc.ca/Library/341749.pdf

DFO. 2011. Identification of Ecologically and Biologically Significant Areas (EBSAs) in the Canadian Arctic. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep.: 2011/055. 40 p. Available from https://waves-vagues.dfo-mpo.gc.ca/Library/344747.pdf

DFO. 2014. Status of Northwest Atlantic harp seals, *Pagophilus groenlandicus*. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep.: 2014/011. 15 p.

DFO. 2018. Harvest advice for eastern and western Hudson Bay Beluga (*Delphinapterus leucas*). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep.: 2018/008 (Erratum : September 2020). 16 p.

DFO. 2022. Harvest advice for eastern Hudson Bay and James Bay beluga (Delphinapterus leucas). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2022/024.

Diaconescu, E.P., Mailhot, A., Brown, R., and Chaumont, D. 2017. Evaluation of CORDEX-Arctic daily precipitation and temperature-based climate indices over Canadian Arctic land areas. Climate Dynamics 50(5-6): 2061-2085. doi:10.1007/s00382-017-3736-4.

Dmitrenko, I.A., Kirillov, S.A., and Tremblay, L.B. 2008. The long-term and interannual variability of summer fresh water storage over the eastern Siberian shelf: Implication for climatic change. J. Geophys Res. 113: C03007. doi:10.1029/2007jc004304.

Dohler, G. 1968. Transportation and Communications Part IV: Tides and currents. *In* Science, history and Hudson Bay. *Edited by* C.S. Beals. Department of Energy, Mines, and Resources, Ottawa, ON. pp. 824-837.

Donaldson, J.A. 1986. Precambrian Geology. *In* Canadian Inland Seas. *Edited by* I.P. Martini. Elsevier Science Publishing Company, New York, NY. pp. 1-16.

Doniol-Valcroze, T., Hammill, M.O., and Lesage, V. 2011. Information on abundance and harvest of eastern Hudson Bay beluga (*Delphinapterus leuca*s). DFO Can. Sci. Advis. Sec. Res. Doc.: 2010/121. iv + 13 p.

Drinkwater, K.F. 1988. On the mean and tidal currents in Hudson strait. Atmos. Ocean 26(2): 252-266. doi:10.1080/07055900.1988.9649302.

Drolet, R., Fortier, L., Ponton, D., and Gilbert, M. 1991. Production of fish larvae and their food resource in subarctic southeastern Hudson Bay. Mar. Ecol. Prog. Ser. 77: 105-118. doi:10.3354/meps077105.

Duke, P.J., Else, B.G.T., Jones, S.F., Marriot, S., Ahmed, M.M.M., Nandan, V., Butterworth, B., Gonski, S.F., Dewey, R., Sastri, A., Miller, L.A., Simpson, K.G., Thomas, H. 2021. Seasonal marine carbon system processes in an Arctic coastal landfast sea ice environment observed with an innovative underwater sensor platform. Elementa: Science of the Anthropocene 9(1) DOI: https://doi.org/10.1525/elementa.2021.00103.

Dunbar, M.J. 1981. Physical Causes and Biological Significance of Polynyas and Other Open Water in Sea Ice. *In* Polynyas in the Canadian Arctic. *Edited by* I. Stirling and H. Cleator. Environment Canada, Ottawa, ON. pp. 29-43.

Dyke, A.S., Vincent, J.-S., Andrews, J.T., Dredge, L.A., and Cowan, W.R. 1989. The Laurentide Ice Sheet and an introduction to the Quaternary Geology of the Canadian Shield. *In* Quaternary Geology of Canada and Greenland. *Edited by* R. J. Fulton. Geological Survey of Canada, Ottawa, ON. pp. 178-189.

Eastwood, R.A. 2018. Physical properties and isotopic characteristics of the winter water column and landfast sea-ice surrounding the Belcher Islands, southeast Hudson Bay. Thesis (M. Sc.), Department of Environment and Geography, Univeristy of Manitoba, Winnipeg, MB. 96 p.

Eastwood, R.A., Macdonald, R.W., Ehn, J.K., Heath, J., Arragutainaq, L., Myers, P.G., Barber, D.G., and Kuzyk, Z.A. 2020. Role of River Runoff and Sea Ice Brine Rejection in Controlling Stratification Throughout Winter in Southeast Hudson Bay. Estuar. Coasts 43(4): 756-786. doi:10.1007/s12237-020-00698-0.

ECCC. 2019. Canadian Environmental Sustainability Indicators: Sea Ice in Canada. Environment and Climate Change Canada, Gatineau, QC. 27 p. Available from https://www.canada.ca/content/dam/eccc/documents/pdf/cesindicators/sea-ice/2019/SeaIce-EN.pdf

ECCC. 2022. Environment and Climate Change Canada [online]. Available from https://www.canada.ca/en/environment-climate-change.html [accessed 27 October 2022].

Ecoregions Working Group. 1989. Ecoclimatic regions of Canada: First approximation. Ecological Land Classification Series No.: 23. Environment Canada, Ottawa, ON.

Elliott, J., Clayden, M.G., Clouter, K., Collins, S., Tremblay, T., and LeBlanc-Havard, M. 2022. Community water quality data across Nunavut: an introduction to available data for community water supplies. *In* Summary of Activities 2021. Canada-Nunavut Geoscience Office, Iqaluit, NU. pp. 57-68.

Elliott, J.M., and Elliott, J.A. 2010. Temperature requirements of Atlantic salmon *Salmo salar,* brown trout *Salmo trutta* and Arctic charr *Salvelinus alpinus*: predicting the effects of climate change. J. Fish Biol. 77: 1793-1817. doi:10.1111/j.1095-8649.2010.02762.x. Available from https://www.ncbi.nlm.nih.gov/pubmed/21078091

Elliott, K.H., Woo, K.J., Gaston, A.J., Benvenuti, S., Dall'Antonia, L., and Davoren, G.K. 2009. Central-Place Foraging in an Arctic Seabird Provides Evidence for Storer-Ashmole's Halo. The Auk 126(3): 613-625. doi:10.1525/auk.2009.08245.

Else, B.G.T., Papakyriakou, T.N., Granskog, M.A., Yackel, J.J. 2008. Observations of sea surface fCO2 distributions and estimated air–sea CO2 fluxes in the Hudson Bay region (Canada) during the open water season. Journal of Geophysical Research: Oceans 113(C8): C08026. DOI: http://dx.doi.org/10.1029/2007jc004389.

Else, B. G. T., Whitehead, J. J., Galindo, V., Ferland, J., Mundy, C. J., Gonski, S. F., Ehn, J.K., Rysgaard, S., Babin, M. 2019. Response of the Arctic marine inorganic carbon system to ice algae and under-ice phytoplankton blooms: A case study along the fast-ice edge of Baffin Bay. Journal of Geophysical Research: Oceans, 124, 1277– 1293. https://doi.org/10.1029/2018JC013899

Environment Canada. 2021. 30-year ice climate normals [online]. Available from https://iceweb1.cis.ec.gc.ca/30Atlas/page1.xhtml?lang=en [accessed November 10 2022].

Estrada, R., Harvey, M., Gosselin, M., Starr, M., Galbraith, P.S., and Straneo, F. 2012. Late-summer zooplankton community structure, abundance, and distribution in the Hudson Bay system (Canada) and their relationships with environmental conditions, 2003–2006. Prog. Oceanogr. 101(1): 121-145. doi:10.1016/j.pocean.2012.02.003.

Etkin, D.A. 1991. Break-Up in Hudson Bay: Its Sensitivity to Air Temperatures and Implications for Climate Warming. Clim. Bulletin 25(1): 21-34.

Falkingham, J.C., Chagnon, R., and McCourt, S. 2002. Trends in Sea Ice in the Canadian Arctic. *In* Ice in the Environment: Proceedings of the 16th IAHR International Symposium on Ice. Dunedin, NZ, 2-6 December 2002. p. 8. Available from https://www.coldregions.org/vufind/Record/245692

Fay FH. 1982. Ecology and biology of the Pacific walrus, *Odobenus rosmarus divergens Illiger*. North American Fauna. p. 1–279.

Ferguson, S.H., Stirling, I., and McLoughlin, P. 2005. Climate Change and Ringed Seal (*Phoca hispida*) Recruitment in Western Hudson Bay. Marine Mammal Science 21: 121-135. doi:10.1111/j.1748-7692.2005.tb01212.x. Available from https://onlinelibrary.wiley.com/doi/10.1111/j.1748-7692.2005.tb01212.x

Ferguson, S.H., Young, B.G., Yurkowski, D.J., Anderson, R., Willing, C., and Nielsen, O. 2017. Demographic, Ecological, and Physiological Responses of Ringed Seals to an Abrupt Decline in Sea Ice Availability. PeerJ. 5: e2957. doi:10.7717/peerj.2957. Available from https://www.ncbi.nlm.nih.gov/pubmed/28168119

Ferguson, S.H., Yurkowski, D.J., Young, B.G., Willing, C., Zhu, X., Muir, D.C.G., Fisk, A.T., and Thiemann, G.W. 2019. Do intraspecific life history patterns follow interspecific predictions? A test using latitudinal variation in ringed seals. Popul. Ecol. 61(4): 371-382. doi:10.1002/1438-390x.12008.

Ferland, J., Gosselin, M., and Starr, M. 2011. Environmental Control of Summer Primary Production in the Hudson Bay System: The Role of Stratification. Journal of Marine Systems 88(3): 385-400. doi:10.1016/j.jmarsys.2011.03.015.

Finley, K.J., and Evans, C.R. 1983. Summer Diet of the Bearded Seal (*Erignuthus burbutus*) in the Canadian High Arctic. Arctic 36(1): 82-89.

Finstad, A.G., and Hein, C.L. 2012. Migrate or stay: terrestrial primary productivity and climate drive anadromy in Arctic char. Glob. Chang. Biol. 18(8): 2487-2497. doi:10.1111/j.1365-2486.2012.02717.x.

Fisk, A.T., Holst, M., Hobson, K.A., Duffe, J., Moisey, J., and Norstrom, R.J. 2002. Persistent Organochlorine Contaminants and Enantiomeric Signatures of Chiral Pollutants in Ringed Seals (*Phoca hispida*) Collected on the East and West side of the Northwater Polynya, Canadian Arctic. Arch. Environ. Contam. Toxicol. 42(1): 118-126. doi:10.1007/s002440010299. Available from https://www.ncbi.nlm.nih.gov/pubmed/11706376

Florko, K.R.N., Bernhardt, W., Breiter, C.J.C., Ferguson, S.H., Hainstock, M., Young, B.G., and Petersen, S.D. 2018. Decreasing sea ice conditions in western Hudson Bay and an increase in abundance of harbour seals (*Phoca vitulina*) in the Churchill River. Polar Biology 41(6): 1187-1195. doi:10.1007/s00300-018-2277-6.

Florko, K.R.N., Derocher, A.E., Breiter, C.J.C., Ghazal, M., Hedman, D., Higdon, J.W., Richardson, E.S., Sahanatien, V., Trim, V., and Petersen, S.D. 2020. Polar bear denning distribution in the Canadian Arctic. Polar Biology 43(5): 617-621. doi:10.1007/s00300-020-02657-8.

Florko, K.R.N., Tai, T.C., Cheung, W.W.L., Ferguson, S.H., Sumaila, U.R., Yurkowski, D.J., and Auger-Methe, M. 2021. Predicting how climate change threatens the prey base of Arctic marine predators. Ecol. Lett. 24(12): 2563-2575. doi:10.1111/ele.13866. Available from https://www.ncbi.nlm.nih.gov/pubmed/34469020

Fortier, L., Gilbert, M., Ponton, D., Ingram, R.G., Robineau, B., and Legendre, L. 1996. Impact of Freshwater on a Subarctic Coastal Ecosystem Under Seasonal Sea Ice (Southeastern Hudson Bay, Canada). III. Feeding Success of Marine Fish Larvae. Journal of Marine Systems 7: 251-265.

Freeman, M.M.R. 1971. The birds of the Belcher Islands, NWT. Can. Field-Nat. 84: 277-290.

Frey, K.E., Arrigo, K.R., and Gradinger, R.R. 2011. Arctic Ocean Primary Productivity. *In* Arctic Report Card 2011. *Edited by* J. Richter-Menge, M. O. Jeffries, and J. E. Overland. Conservation of Arctic Flora and Fauna, Akureyri, IS. pp. 69-71. Available from https://caff.is/monitoring-series/5-arctic-report-card-2011

Gabel, F., Lorenz, S., and Stoll, S. 2017. Effects of ship-induced waves on aquatic ecosystems. Science of the Total Environment 601-602: 926-939. doi:10.1016/j.scitotenv.2017.05.206. Available from https://www.ncbi.nlm.nih.gov/pubmed/28582738

Gagnon, A.S., and Gough, W.A. 2005a. Climate Change Scenarios for the Hudson Bay Region: An Intermodel Comparison. Clim. Change. 69(2-3): 269-297. doi:10.1007/s10584-005-1815-8. Available from https://www.researchgate.net/publication/225195938_Climate_Change_Scenarios_for_the_Hudson_Bay_Region_An_Intermodel_Comparison

Gagnon, A.S., and Gough, W.A. 2005b. Trends in the Dates of Ice Freeze-up and Breakup over Hudson Bay, Canada. Arctic. 58(4): 370-382. Available from http://pubs.aina.ucalgary.ca/arctic/Arctic58-4-370.pdf

Gagnon, A.S., and Gough, W.A. 2006. East-West Asymmetry in Long-Term Trends of Landfast Ice Thickness in the Hudson Bay Region, Canada. Climate Research 32: 177-186.

Galbraith, P.S., and Larouche, P. 2011. Sea-Surface Temperature in Hudson Bay and Hudson Strait in Relation to Air Temperature and Ice Cover Breakup, 1985–2009. Journal of Marine Systems 87(1): 66-78. doi:10.1016/j.jmarsys.2011.03.002.

Galicia, M.P., Thiemann, G.W., Dyck, M.G., Ferguson, S.H., and Higdon, J.W. 2016. Dietary Habits of Polar Bears in Foxe Basin, Canada: Possible Evidence of a Trophic Regime Shift Mediated by a New Top Predator. Ecol. Evol. 6(16): 6005-6018. doi:10.1002/ece3.2173. Available from https://www.ncbi.nlm.nih.gov/pubmed/27547372

Gallagher, C.P., and Dick, T.A. 2010. Trophic structure of a landlocked Arctic char *Salvelinus alpinus* population from southern Baffin Island, Canada. Ecology of Freshwater Fish 19(1): 39-50. doi:10.1111/j.1600-0633.2009.00387.x.

Gaston, A.J., Woo, K.J., and Hipfner, J.M. 2003. Trends in Forage Fish Populations in Northern Hudson Bay since 1981, as Determined from the Diet of Nestling Thick-Billed Murres *Uria lomvia*. Arctic 56(3): 227-233. Available from http://pubs.aina.ucalgary.ca/arctic/Arctic56-3-227.pdf

Gilbert, G., Helie, R.G., and Mondoux, J.M. 1985. Ecosystem sensitivity to acid precipitation for Quebec, Part A: Ecoregions and ecodistricts of Quebec. Ecological Land Classification Series. Environment Canada. 76 p.

Gilbert, M., Fortier, L., Ponton, D., and Drolet, R. 1992. Feeding Ecology of Marine Fish Larvae across the Great Whale River Plume in Seasonally Ice-Covered Southeastern Hudson Bay. Mar. Ecol. Prog. Ser. 84(1): 19-30. doi:10.3354/meps084019.

Gilbert, M.J.H., Harris, L.N., Malley, B.K., Schimnowski, A., Moore, J.S., and Farrell, A.P. 2020. The thermal limits of cardiorespiratory performance in anadromous Arctic char (Salvelinus alpinus): a field-based investigation using a remote mobile laboratory. Conserv Physiol 8(1): coaa036. doi:10.1093/conphys/coaa036. Available from https://www.ncbi.nlm.nih.gov/pubmed/32346481

Gilbert, M.J.H., and Farrell, A.P. 2021. The thermal acclimation potential of maximum heart rate and cardiac heat tolerance in Arctic char (*Salvelinus alpinus*), a northern cold-water specialist. J. Therm. Biol. 95. doi:10.1016/j.jtherbio.2020.102816.

Gilbert, M.J.H., Middleton, E.K., Kanayok, K., Harris, L., Moore, J., Farrell, A.P., and Speers-Roesch, B. 2022. Rapid cadiac thermal acclimation in wild anadromous Arctic char (*Salvelinus alpinus*). J Exp Biol 225(17). doi:10.1242/jeb244055.

Gilchrist, G., Mallory, M., and Merkel, F. 2005. Can local ecological knowledge contribute to wildlife management? Case studies of migratory birds. Ecology and Society 10(1): 20.

Gilchrist, H.G., and Robertson, G.J. 2000. Observations of Marine Birds and Mammals Wintering at Polynyas and Ice Edges in the Belcher Islands, Nunavut, Canada. Arctic 53(1): 61-68.

Gilliland, S.G., Gilchrist, H.G., Bordage, D., Lepage, C., Merkel, F.R., Mosbech, A., Letournel, B., and Savard, J.-P.L. 2008. Winter Distribution and Abundance of Common Eiders in the Northwest Atlantic and Hudson Bay. *In* 3rd North American Sea Duck Conference, Quebec City, Quebec, Canada. 95 p.

Goldsmit, J., McKindsey, C., Archambault, P., and Howland, K.L. 2019. Ecological risk assessment of predicted marine invasions in the Canadian Arctic. PLoS One. 14(2): e0211815. doi:10.1371/journal.pone.0211815. Available from https://www.ncbi.nlm.nih.gov/pubmed/30730941

Goldsmit, J., McKindsey, C.W., Schlegel, R.W., Stewart, D.B., Archambault, P., and Howland, K.L. 2020. What and where? Predicting invasion hotspots in the Arctic marine realm. Glob. Chang. Biol. 26(9): 4752-4771. doi:10.1111/gcb.15159. Available from https://www.ncbi.nlm.nih.gov/pubmed/32407554

Goldsmit, J., McKindsey, C.W., Stewart, D.B., and Howland, K.L. 2021. Screening for High-Risk Marine Invaders in the Hudson Bay Region, Canadian Arctic. Front. Ecol. Evol. 9: 627497. doi:10.3389/fevo.2021.627497. Available from https://www.frontiersin.org/articles/10.3389/fevo.2021.627497/full

Goldsmit, J., Schlegel, R.W., Filbee-Dexter, K., MacGregor, K.A., Johnson, L.E., Mundy, C.J., Savoie, A.M., McKindsey, C.W., Howland, K.L. and Archambault, P. 2021. Kelp in the Eastern Canadian Arctic: current and future predictions of habitat suitability and cover. Frontiers in Marine Science 18: 742209.

Goodison, B.E., Louie, P.Y. and Yang, D., 1998. WMO solid precipitation measurement intercomparison.

Gormezano, L.J., and Rockwell, R.F. 2013. What to eat now? Shifts in polar bear diet during the ice-free season in western Hudson Bay. Ecol. Evol. 3(10): 3509-3523. doi:10.1002/ece3.740. Available from https://www.ncbi.nlm.nih.gov/pubmed/24223286

Gosselin, M., Legendre, L., Demers, S., and Therriault, J.C. 1990. Light and nutrient limitation of sea-ice microalgae (Hudson Bay, Canadian Arctic). Journal of Phycology 26: 220-236. doi:10.1111/j.0022-3646.1990.00220.x.

Gosselin, M., Archambault, P., and Tremblay, J.-E. 2015. Marine Biological Hotspots: Ecosystem Services and Susceptibility to Climate Change. *In* ArcticNet Annual Research Compendium (2013-14). ArcticNet Inc., Quebec City, QC. pp. 1-31.

Gosselin, J-F, Hammill, M.O., and Mosnier, A. 2017. Indices of abundance for beluga (*Delphinapterus leucas*) in James and eastern Hudson Bay in summer 2015. DFO Can. Sci. Advis. Sec. Res. Doc. 2017/067. iv + 25 p.

Government of Canada. 2010. *Fisheries Act: Chapter F-14*. Minister of Justice, Ottawa, ON. p. 52.

Government of Canada. 2016. 2016 Census Data [online]. Available from https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/details/page.cfm?Lang=E&Geo1=CSD&Code1=6204001&Geo2=PR&Code2=62&SearchText=Sanikiluaq&SearchType=Begins&SearchPR=01&B1=All&GeoLevel=PR&GeoCode=6204001&TABID=1&type=0 [accessed 8 December 2021].

Government of Canada. 2019. Species at Risk Public Registry, Species List, Species Profile – Ringed Seal [online]. Available from https://wildlife-species.canada.ca/species-risk-registry/species/speciesDetails_e.cfm?sid=347 [accessed 8 January 2019].

Government of Canada. 2022. Canadian Climate Normals 1981-2010 Station Data [online]. Available from https://climate.weather.gc.ca/climate_normals/results_1981_2010_e.html?stnID=6083&autofwd=1 [accessed November 10 2022].

Government of Nunavut. 2010. Nunavut Coastal Resource Inventory - Sanikiluaq. Government of Nunavut, Iqaluit, NU. 117 p. Available from https://www.gov.nu.ca/sites/default/files/ncri_sanikiluaq_en_0.pdf

Grainger, E.H. 1959. The Annual Oceanographic Cycle at Igloolik in the Canadian Arctic. 1. The Zooplankton and Physical and Chemical Observations. J. Fish. Res. Bd. Can. 16(4): 453-501.

Grainger, E.H. 1962. Zooplankton of Foxe Basin in the Canadian Arctic. J. Fish. Res. Bd. Can. 19(3): 377-400.

Grainger, E.H. 1965. Zooplankton From the Arctic Ocean and Adjacent Canadian Waters. J. Fish. Res. Board Can. 22: 543-564. doi:10.1139/f65-049. Available from https://www.nrcresearchpress.com/doi/abs/10.1139/f65-049?journalCode=jfrbc#.XnupFYhKjIU

Grainger, E.H. 1988. The influence of a river plume on the sea-ice meiofauna in south-eastern Hudson Bay. Estuar. Coast Shelf. Sci. 27: 131-141. doi:10.1016/0272-7714(88)90086-8.

Granskog, M.A., Macdonald, R.W., Kuzyk, Z.Z.A., Senneville, S., Mundy, C.J., Barber, D.G., Stern, G.A., and Saucier, F. 2009. Coastal conduit in southwestern Hudson Bay (Canada) in summer: Rapid transit of freshwater and significant loss of colored dissolved organic matter. J. Geophys. Res. 114(C8). doi:10.1029/2009jc005270.

Granskog, M.A., Kuzyk, Z.Z.A., Azetsu-Scott, K., and Macdonald, R.W. 2011. Distributions of runoff, sea-ice melt and brine using δ18O and salinity data — A new view on freshwater cycling in Hudson Bay. Journal of Marine Systems 88(3): 362-374. doi:10.1016/j.jmarsys.2011.03.011.

Grebmeier, J.M. 2012. Shifting patterns of life in the Pacific Arctic and sub-Arctic seas. Annual Review of Marine Science 4: 63-78. doi:https://dx.doi.org/10.1146/annurev-marine-120710-100926.

Grebmeier, J.M., Overland, J.E., Moore, S.E., Farley, E.V., Carmack, E.C., Cooper, L.W., Frey, K.E., Helle, J.H., McLaughlin, F.A., and McNutt, S.L. 2006. A major ecosystem shift in the northern Bering Sea. Science 311: 1461-1464. doi:https://dx.doi.org/10.1146/annurev-marine-120710-100926.

Gupta, K., Mukhopadhyay, A., Babb, D. G., Barber, D. G., & Ehn, J. K. 2022. Landfast sea ice in Hudson Bay and James BayAnnual cycle, variability and trends, 2000–2019. Elementa: Science of the Anthropocene, 10: 00073.

Halpern, B.S., Walbridge, S., Selkoe, K.A., Kappel, C.V., Micheli, F., D'Agrosa, C., Bruno, J.F., Casey, K.S., Ebert, C., Fox, H.E., Fujita, R., Heinemann, D., Lenihan, H.S., Madin, E.M., Perry, M.T., Selig, E.R., Spalding, M., Steneck, R., and Watson, R. 2008. A global map of human impact on marine ecosystems. Science 319(5865): 948-952. doi:10.1126/science.1149345. Available from https://www.ncbi.nlm.nih.gov/pubmed/18276889

Hammill, M.O., Mosnier, A., Gosselin, J.F., Higdon, J.W., Stewart, D.B., Doniol-Valcroze, T., Ferguson, S.H., and Dunn, J.B. 2016. Estimating Abundance and Total Allowable Removals for Walrus in the Hudson Bay-Davis Strait and South and East Hudson Bay Stocks During September 2014. DFO Can. Sci. Advis. Sec. Res. Doc.: 2016/036. v + 37 p. Available from https://waves-vagues.dfo-mpo.gc.ca/Library/365821.pdf

Hammill, M.O., Mosnier, A., Gosselin, J-F, Matthews, C.J., Marcoux, M., and Ferguson, S.H. 2017. Management Approaches, Abundance Indices and Total Allowable Harvest levels of Belugas in Hudson Bay. DFO Can. Sci. Advis. Sec. Res. Doc. 2017/062. iv + 43 p

Hansen, B.B., Isaksen, K., Benestad, R.E., Kohler, J., Pedersen, Å.Ø., Loe, L.E., Coulson, S.J., Larsen, J.O., and Varpe, Ø. 2014. Warmer and wetter winters: characteristics and implications of an extreme weather event in the High Arctic. Environmental Research Letters 9(11). doi:10.1088/1748-9326/9/11/114021. Available from https://www.ipcc.ch/site/assets/uploads/2017/09/WG1AR5_Chapter02_FINAL.pdf

Härkönen, T., and Heide-Jørgensen, M.P. 1990. Comparative life histories of East Atlantic and other harbour seal populations. Ophelia 32(3): 211-235. doi:10.1080/00785236.1990.10422032.

Harris, L.N., Yurkowski, D.J., Gilbert, M.J.H., Else, B.G.T., Duke, P.J., Ahmed, M.M.M., Tallman, R.F., Fisk, A.T., and Moore, J.S. 2020. Depth and temperature preference of anadromous Arctic char Salvelinus alpinus in the Kitikmeot Sea, a shallow and low-salinity area of the Canadian Arctic. Marine Ecology Progress Series 634: 175-197. doi:10.3354/meps13195.

Harris, L., Yurkowski, D., Malley, B., Jones, S., Else, B., Tallman, R., Fisk, A., Moore, J.-S. (2022) Acoustic Telemetry Reveals the Complex Nature of Mixed-Stock Fishing in Canada's Largest Arctic Char (Salvelinus alpinus) Commercial Fishery. North American Journal of Fisheries Management 42:1250–1268

Hartmann, D.L., Klein Tank, A.M.G., Rusticucci, M., Alexander, L.V., Brönnimann, S., Charabi, Y., Dentener, F.J., Dlugokencky, E.J., Easterling, D.R., Kaplan, A., Soden, B.J., Thorne, P.W., Wild, M., and Zhai, P.M. 2013. Observations: Atmosphere and Surface. *In* Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. *Edited by* T. F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, and P.M. Midgley. Cambridge University Press, Cambridge, UK and New York, NY. pp. 159-254. Available from https://www.ipcc.ch/site/assets/uploads/2017/09/WG1AR5_Chapter02_FINAL.pdf

Harvey, M., Therriault, J.-C., and Simard, N. 2001. Hydrodynamic Control of Late Summer Species Composition and Abundance of Zooplankton in Hudson Bay and Hudson Strait (Canada). Journal of Plankton Research 23(5): 481-496.

Harwood, L.A., Smith, T.G., and Melling, H. 2000. Variation in Reproduction and Body Condition of the Ringed Seal (*Phoca hispida*) in Western Prince Albert Sound, NT, Canada, as Assessed Through a Harvest-based Sampling Program. Arctic 53(4): 422-431.

Harwood, L.A., Quakenbush, L.T., Small, R.J., George, J.C., Pokiak, J., Pokiak, C., Heide-Jørgensen, M.P., Lea, E.V., and Brower, H. 2017. Movements and Inferred Foraging by Bowhead Whales in the Canadian Beaufort Sea during August and September, 2006–12. Arctic. 70(2): 161-176. doi:10.14430/arctic4648. Available from https://journalhosting.ucalgary.ca/index.php/arctic/article/view/67686/51582

Haycock-Chavez, N. 2021. Indigenous-driven conservation: Exploring the planning of Qikiqtait protected area in Sanikiluaq, Nunavut. Thesis (M.sc.), Memorial University of Newfoundland, St. John's, NL. 124 p.

Hein, C.L., Ohlund, G., and Englund, G. 2012. Future distribution of Arctic char *Salvelinus alpinus* in Sweden under climate change: effects of temperature, lake size and species interactions. Ambio 41(3): 303-312. doi:10.1007/s13280-012-0308-z. Available from https://www.ncbi.nlm.nih.gov/pubmed/22864703

Higdon, J. 2007. Status of Knowledge on Killer Whales (*Orcinus orca*) in the Canadian Arctic. DFO Can. Sci. Advis. Sec. Res. Doc.: 2007/048. ii + 37 p.

Higdon, J.W. 2016. Walrus Haulouts in the Eastern Canadian Arctic: a Database to Assist in Land Use Planning Initiatives. A report prepared for WWF Canada by Higdon Wildlife Consulting. Higdon Wildlife Consulting, Winnipeg, MB. 18 p.

Higdon, J.W. and Ferguson, S.H. (2009), Loss of Arctic sea ice causing punctuated change in sightings of killer whales (*Orcinus orca*) over the past century. Ecological Applications, 19: 1365-1375.

Higdon J. W., Hauser D. D. W., Ferguson S. H. 2012. Killer whales (*Orcinus orca*) in the Canadian Arctic: Distribution, prey items, group sizes, and seasonality. Mar. Mamm. Sci. 28, E93–E109. doi: 10.1111/j.1748-7692.2011.00489.x

Higdon, J.W., Westdal, K.H., and Ferguson, S.H. 2013. Distribution and Abundance of Killer Whales (*Orcinus orca*) in Nunavut, Canada— An Inuit Knowledge Survey. Journal of the Marine Biological Association of the United Kingdom 94(6): 1293-1304. doi:10.1017/s0025315413000921.

Hobbs, R. C., Reeves, R. R., Prewitt, J. S., Desportes, G., Breton-Honeyman, K., Christensen, T., ... & Watt, C. A. 2019. Global review of the conservation status of monodontid stocks. Marine Fisheries Review 81:1-62.

Hochheim, K., Barber, D.G., and Lukovich, J.V. 2010. Changing Sea Ice Conditions in Hudson Bay, 1980–2005. *In* A Little Less Arctic: Top Predators in the World's Largest Northern Inland Sea, Hudson Bay. *Edited by* S. H. Ferguson, L. L. Loseto, and M. L. Mallory. Springer, Dordrecht, NL. pp. 39-51. Available from https://link.springer.com/chapter/10.1007/978-90-481-9121-5_2

Hochheim, K.P., and Barber, D.G. 2014. An Update on the Ice Climatology of the Hudson Bay System. Arct. Alp. Res. 46(1): 66-83. doi:10.1657/1938-4246-46.1.66.

Hochheim, K.P., Lukovich, J.V., and Barber, D.G. 2011. Atmospheric forcing of sea ice in Hudson Bay during the spring period, 1980–2005. Journal of Marine Systems 88(3): 476-487. doi:10.1016/j.jmarsys.2011.05.003.

Hodgskiss, M.S.W., and Sperling, E.A. 2020. Stratigraphy and shale geochemistry of the Belcher Group, Belcher Islands, southern Nunavut. *In* Summary of Activities 2019. Canada-Nunavut Geoscience Office, Iqaluit, NU. pp. 65-78.

Hoffman, P.F. 1990. Subdivision of the Churchill Province and the extent of the Trans-Hudson Orogen. *In* The Early Proterozoic Trans-Hudson Orogen of North America. *Edited by* J. F. Lewry and M. R. Stauffer. Geological Association of Canada, St. John's, NL. pp. 15-39.

Hop, H., Welch, H.E., and Crawford, R.E. 1997. Population Structure and Feeding Ecology of Arctic Cod Schools in the Canadian High Arctic. Am. Fish. Soc. Symp. 19: 68-80.

Hudon, C. 1994. Biological events during ice breakup in the Great Whale River (Hudson Bay). Canadian Journal of Fisheries and Aquatic Sciences 51: 2467-2481. doi:10.1139/f94-246.

IBA Canada. [s.d.]. What is an Important Bird Area? [online]. Available from https://www.ibacanada.org/iba_what.jsp?lang=en [accessed 11 October 2022].

Iles, D.T., Rockwell, R.F., Matulonis, P., Robertson, G.J., Abraham, K.F., Davies, J.C., and Koons, D.N. 2013. Predators, alternative prey and climate influence annual breeding success of a long-lived sea duck. J. Anim. Ecol. 82(3): 683-693. doi:10.1111/1365-2656.12038. Available from https://www.ncbi.nlm.nih.gov/pubmed/23362924

Ingram, R.G., and Larouche, P. 1987. Variability of an Under-ice River Plume in Hudson Bay. J. Geophys. Res. 92(C9): 9541-9547. doi:10.1029/JC092iC09p09541. Available from https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/JC092iC09p09541

Ingram, R.G., and Prinsenberg, S. 1998. Coastal Oceanography of Hudson Bay and Surrounding Eastern Canadian Arctic Waters Coastal Segment. *In* The Sea, Volume 11: The Global Coastal Ocean: Regional Studies and Syntheses. *Edited by* A. R. Robinson and K. H. Brink. John Wiley & Sons, Inc., Cambridge, MA. pp. 835-861.

Ingram, R.G., Wang, J., Lin, C., Legendre, L., and Fortier, L. 1996. Impact of freshwater on a subarctic coastal ecosystem under seasonal sea ice (southeastern Hudson Bay, Canada). I. Interannual variability and predicted global warming influence on river plume dynamics and sea ice. Journal of Marine Systems 7: 221-231.

IPCC. 2013. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, NY. 1535 p.

Jackson, G.D. 1960a. Belcher Islands, Northwest Territories. Geological Survey of Canada

Jackson, G.D. 1960b. Belcher Islands, Northwest Territories 33M, 34D, E. Geological Survey of Canada Paper No.: 60-20. Department of Mines and Technical Surveys, Ottawa, ON. 13 p.

Jackson, G.D. 2013. Geology, Belcher Islands, Nunavut. Geological Survey of Canada Open File: 4923. Natural Resources Canada, Ottawa, ON. 159 p.

Jacquemot, L., Kalenitchenko, D., Matthes, L.C., Vigneron, A., Mundy, C.J., Tremblay, J.-É., and Lovejoy, C. 2021. Protist communities along freshwater–marine transition zones in Hudson Bay (Canada). Elem. Sci. Anth. 9(1): 1. doi:10.1525/elementa.2021.00111.

Jansen, J.K., Boveng, P.L., Dahle, S.P., and Bengtson, J.L. 2010. Reaction of Harbor Seals to Cruise Ships. J. Wildl. Manage. 74(6): 1186-1194. doi:10.2193/2008-192.

Jenssen, B.M., Villanger, G.D., Gabrielsen, K.M., Bytingsvik, J., Bechshoft, T., Ciesielski, T.M., Sonne, C., and Dietz, R. 2015. Anthropogenic flank attack on polar bears: Interacting consequences of climate warming and pollutant exposure. Front. Ecol. Evol. 3: 1-7. doi:10.3389/fevo.2015.00016.

Johnson, R.D., Joubin, F.R., Nelson, S.J., and Olsen, E. 1986. Mineral Resources. *In* Canadian Inland Seas. *Edited by* I.P. Martini. Elsevier Science Publishing Company, New York, NY. pp. 387-402.

Joly, S., Senneville, S., Caya, D., and Saucier, F.J. 2011. Sensitivity of Hudson Bay Sea Ice and Ocean Climate to Atmospheric Temperature Forcing. Climate Dynamics 36(9-10): 1835-1849. doi:10.1007/s00382-009-0731-4. Available from https://link.springer.com/article/10.1007/s00382-009-0731-4

Jones, B.R., Kelley, A.L., and Mincks, S.L. 2021. Changes to benthic community structure may impact organic matter consumption on Pacific Arctic shelves. Conserv. Physiol. 9(1): coab007. doi:10.1093/conphys/coab007. Available from https://www.ncbi.nlm.nih.gov/pubmed/33833867

Jonkel, C., Smith, P., Stirling, I., and Kolenosky, G.B. 1976. The present status of the polar bear in the James Bay and Belcher Islands area. Canadian Wildlife Service Occasional Paper No. 26

Keighley, X., Olsen, M. T., & Jordan, P. 2022. Integrating cultural and biological perspectives on long-term human-walrus (*Odobenus rosmarus rosmarus*) interactions across the North Atlantic. Quaternary Research, 108, 5-25.

Kelley, T.C., Loseto, L.L., Stewart, R.E.A., Yurkowski, M., and Ferguson, S.H. 2010. Importance of eating capelin: unique dietary habits of Hudson Bay beluga. *In* A Little Less Arctic: Top Predators in the World's Largest Northern Inland Sea, Hudson Bay. *Edited by* S. H. Ferguson, L. L. Loseto, and M. L. Mallory. Springer Science, New York, NY. pp. 53-69.

Kelly, B.P., Bengtson, J.L., Boveng, P.L., Cameron, M.F., Dahle, S.P., Jansen, J.K., Logerwell, E.A., Overland, J.E., Sabine, C.L., Waring, G.T., and Wilder, J.M. 2010. Status review of the ringed seal (*Phoca hispida*). NOAA Technical Memorandum NMFS-AFSC-: 212. U.S. Department of Commerce, Springfield, VA. 265 p.

Kemeny, R. 2019. Killer Whales are expanding into the Arctic, then dying as the ice sets In. Tula Foundation, Victoria, B.C. 4 p. Available from https://hakaimagazine.com/news/killer-whales-are-expanding-into-the-arctic-then-dying-as-the-ice-sets-in/

Kemp, A., Bernatchez, L., and Dodson, J.J. 1989. A revision of coregonine fish distribution and abundance in eastern James-Hudson Bay. Environ. Biol. Fishes 26: 247-255.

Kenchington, E., Link, H., Roy, V., Archambault, P., Siferd, T., Treble, M., and Wareham, V. 2011. Identification of Mega- and Macrobenthic Ecologically and Biologically Significant Areas (EBSAs) in the Hudson Bay Complex, the Western and Eastern Canadian Arctic. DFO Can. Sci. Advis. Sec. Res. Doc.: 2011/072. 52 p. Available from http://science-catalogue.canada.ca/record=4041871&searchscope=06

Kingsley, M.C.S. 1990. Status of the ringed seal, *Phoca hispida*, in Canada. Can. Field-Nat. 104: 138-145.

Kolenosky, G.B., and Prevett, J.P. 1983. Productivity and maternity denning of polar bears in Ontario. Int. Conf. Bear Res. and Manag. 5: 238-245.

Kostylev, V., Hannah, C., Soukhovtsev, V., and Dickson, C. 2015. Canada Wide Benthic Scope for Growth: Preliminary Classification. Can. Tech. Rep. Hydrogr. Ocean Sci. 305: vi + 24 p. Available from http://publications.gc.ca/collections/collection_2015/mpo-dfo/Fs97-18-305-eng.pdf

Kovacs, K.M. 2018. Bearded Seal: *Erignathus barbatus*. Edited by B. Würsig, J. Thewissen, and K.M. Kovacs. Academic Press. pp. 83–86. doi:https://doi.org/10.1016/B978-0-12-804327-1.00063-7

Kovacs, K.M., and Michel, C. 2011. Chapter 9.3: Biological impacts of changes to sea ice in the Arctic. *In* Snow, Water, Ice and Permafrost in the Arctic (SWIPA): Climate Change and the Cryosphere. Arctic Monitoring and Assessment Programme (AMAP), Oslo, NO. pp. 32-52.

Kovacs, K.M. 2014. Circumpolar ringed seal (*Pusa hispida*) monitoring. Norwegian Polar Institute, Tromsø, NO. 45 p.

Kovacs, K.M. 2016. Bearded Seal (*Erignathus barbatus)*. The IUCN Red List of Threatened Species 2016: e.T8010A45225428. International Union for Conservation of Nature and Natural Resources, Gland, CH. 16 p. Available from http://dx.doi.org/10.2305/IUCN.UK.2016-1.RLTS.T8010A45225428.en

Kovacs, K.M., Lydersen, C., and Gjertz, I. 1996. Birth-site Characteristics and Prenatal Molting in Bearded Seals (*Erignathus barbatus*). J. Mamm. 77(4): 1085-1091. doi:10.2307/1382789. Available from https://academic.oup.com/jmammal/article-abstract/77/4/1085/938281

Kovacs, K.M., Aguilar, A., Aurioles, D., Burkanov, V., Campagna, C., Gales, N., Gelatt, T., Goldsworthy, S.D., Goodman, S.J., Hofmeyr, G.J.G., Härkönen, T., Lowry, L., Lydersen, C., Schipper, J., Sipilä, T., Southwell, C., Stuart, S., Thompson, D., and Trillmich, F. 2012. Global Threats to Pinnipeds (Seals). Marine Mammal Science 28(2): 414-436. doi:10.1111/j.1748-7692.2011.00479.x. Available from https://www.researchgate.net/publication/233406975_Global_threats_to_pinnipeds

Kovacs, K.M., Lemons, P., MacCracken, J., and Lydersen, C. 2015. Walruses in a Time of Climate Change. *In* Arctic Report Card 2015. *Edited by* M. O. Jeffries, J. Richter-Menge, and J. E. Overland. Conservation of Arctic Flora and Fauna, Washington, D.C. pp. 66-94. Available from ftp://ftp.oar.noaa.gov/arctic/documents/ArcticReportCard_full_report2015.pdf

Kowal, S., Gough, W.A., and Butler, K. 2015. Temporal evolution of Hudson Bay Sea Ice (1971–2011). Theoretical and Applied Climatology 127(3-4): 753-760. doi:10.1007/s00704-015-1666-9.

Krause-Jensen, D., Archambault, P., Assis, J., Bartsch, I., Bischof, K., Filbee-Dexter, K., Dunton, K.H., Maximova, O., Ragnarsdottir, S.B., Sejr, M., Simakova, U., Spiridonov, V., Wegeberg, S., Winding, M.H.S., and Duarte, C.M. 2020. Imprint of Climate Change on Pan-Arctic Marine Vegetation. frontiers in Marine Science 7: 26. doi:10.3389/fmars.2020.617324.

Kucklicka, J.R., Struntza, W.D.J., Beckera, P.R., York, G.W., O'Hara, T.M., and Bohonowych, J.E. 2002. Persistent Organochlorine Pollutants in Ringed Seals and Polar Bears Collected from Northern Alaska. Science of the Total Environment 287: 45-59.

Kuzyk, Z.A., Macdonald, R.W., Granskog, M.A., Scharien, R.K., Galley, R.J., Michel, C., Barber, D., and Stern, G. 2008. Sea ice, hydrological, and biological processes in the Churchill River estuary region, Hudson Bay. Estuarine, Coastal and Shelf Science 77(3): 369-384. doi:10.1016/j.ecss.2007.09.030.

Kuzyk, Z.A., and Candlish, L.M. 2019. From Science to Policy in the Greater Hudson Bay Marine Region: An Integrated Regional Impact Study (IRIS) of Climate Change and Modernization. ArcticNet, Quebec City, QC. 424 p.

Kuzyk, Z.A., Macdonald, R.W., Tremblay, J.-É., and Stern, G.A. 2010. Elemental and stable isotopic constraints on river influence and patterns of nitrogen cycling and biological productivity in Hudson Bay. Continental Shelf Research 30(2): 163-176. doi:10.1016/j.csr.2009.10.014.

Kuzyk, Z.A., Macdonald, R.W., Stern, G.A., and Gobeil, C. 2011. Inferences about the modern organic carbon cycle from diagenesis of redox-sensitive elements in Hudson Bay. Journal of Marine Systems 88(3): 451-462.

Labansen, A.L., Lydersen, C., Haug, T., and Kovacs, K.M. 2007. Spring Diet of Ringed Seals (*Phoca hispida*) from Northwestern Spitsbergen, Norway. ICES Techniques in Marine Environmental Sciences 64: 1246-1256.

Labun, P., and Debicki, C. 2018. Western Hudson Bay and Its Beluga Estuaries: Protecting Abundance for a Sustainable Future. Oceans North, Ottawa, ON. iv + 42 p.

Laidre, K.L., Stern, H., Kovacs, K.M., Lowry, L., Moore, S.E., Regehr, E.V., Ferguson, S.H., Wiig, O., Boveng, P., Angliss, R.P., Born, E.W., Litovka, D., Quakenbush, L., Lydersen, C., Vongraven, D., and Ugarte, F. 2015. Arctic Marine Mammal Population Status, Sea Ice Habitat Loss, and Conservation Recommendations for the 21st Century. Conserv. Biol. 29(3): 724-737. doi:10.1111/cobi.12474. Available from https://www.ncbi.nlm.nih.gov/pubmed/25783745

Lalande, C., and Fortier, L. 2011. Downward particulate organic carbon export and jellyfish blooms in southeastern Hudson Bay. J. Mar. Biol. 88(3): 446-450. doi:10.1016/j.jmarsys.2010.12.005.

Lalumière, R., and Lemieux, C. 2002. Suivi Environnemental des Projets La Grande-2-A et La Grande-1: La Zostère Marine de la Côte Nord-Est de la baie James-Rapport Synthèse pour la Période 1988-2000. Groupe conseil GENIVAR Inc., Montreal, QC.

Lamhonwah, D., Lafrenière, M.J., Lamoureux, S.F., and Wolfe, B.B. 2017. Evaluating the hydrological and hydrochemical responses of a High Arctic catchment during an exceptionally warm summer. Hydrol. Process. 31(12): 2296-2313. doi:10.1002/hyp.11191.

Landy, J.C., Ehn, J.K., Babb, D.G., Thériault, N., and Barber, D.G. 2017. Sea Ice Thickness in the Eastern Canadian Arctic: Hudson Bay Complex & Baffin Bay. Remote Sensing of Environment 200: 281-294. doi:10.1016/j.rse.2017.08.019.

Lapoussiere, A., Michel, C., Starr, M., Gosselin, M., and Poulin, M. 2011. Role of free-living and particle-attached bacteria in the recycling and export of organic material in the Hudson Bay system. Journal of Marine Systems 88(3): 434-445.

Lapoussière, A., Michel, C., Gosselin, M., and Poulin, M. 2009. Spatial Variability in Organic Material Sinking Export in the Hudson Bay System, Canada, During Fall. Continental Shelf Research 29(9): 1276-1288. doi:10.1016/j.csr.2009.02.004. Available from https://arcticnetmeetings.ca//docs/hudson_bay/posters/lapoussiere_et_al.pdf

Lapoussière, A., Michel, C., Gosselin, M., Poulin, M., Martin, J., and Tremblay, J.É. 2013. Primary production and sinking export during fall in the Hudson Bay system, Canada. Continental Shelf Research 52: 62-72.

Larouche, P., and Galbraith, P.S. 1989. Factors affecting fast-ice consolidation in Southeastern Hudson Bay, Canada. Atmos. Ocean 27(2): 367-375. doi:10.1080/07055900.1989.9649341.

Laverdière, C., and Guimont, P. 2011. Le vocabulaire de la géomorphologie glaciaire, IX. Terminologie illustrée des formes mineures d’érosion glaciaire. Geogr. Phys. Oust. 34(3): 363-377. doi:10.7202/1000419ar.

Lavoie, D., Denman, K., and Michel, C. 2005. Modeling Ice Algal Growth and Decline in a Seasonally Ice-Covered Region of the Arctic (Resolute Passage, Canadian Archipelago). J. Geophys. Res. 110: 17. doi:10.1029/2005jc002922. Available from https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1029/2005JC002922

Legendre, L. 1977. Relevés Préliminaires du Benthos Végétal et Animal dans le Détroit de Manitounuk en 1976. OGB 76-1. Université Laval, Laval, QC. 34 p.

Legendre, L., and Simard, Y. 1979. Océanographie biologique estivale et phytoplancton dans le sud-est de la baie d'Hudson. Mar. Biol. 52: 11-22.

Lepage, S., and Ingram, R.G. 1991. Variation of upper layer dynamics during breakup of the seasonal ice cover in Hudson Bay. J. Geophys. Res. 96(C7): 12711-12724. doi:10.1029/91jc00454.

Letcher, R.J., Bustnes, J.O., Dietz, R., Jenssen, B.M., Jorgensen, E.H., Sonne, C., Verreault, J., Vijayan, M.M., and Gabrielsen, G.W. 2010. Exposure and Effects Assessment of Persistent Organohalogen Contaminants in Arctic Wildlife and Fish. Science of the Total Environment 408(15): 2995-3043. doi:10.1016/j.scitotenv.2009.10.038. Available from https://www.ncbi.nlm.nih.gov/pubmed/19910021

Lewis, K.M., van Dijken, G.L., and Arrigo, K.R. 2020. Changes in phytoplankton concentration now drive increased Arctic Ocean primary production. Science 369: 198-202. Available from http://science.sciencemag.org/

Loewen, T.N., Hornby, C.A., Johnson, M., Chambers, C., Dawson, K., MacDonell, D., Bernhardt, W., Gnanapragasam, R., Pierrejean, M., and Choy, E. 2020. Ecological and Biophysical Overview of the Southampton Island Ecologically and Biologically Significant Area in support of the identification of an Area of Interest. DFO Can. Sci. Advis. Sec. Res.: 2020/032. vi + 96 p. Available from https://publications.gc.ca/collections/collection_2020/mpo-dfo/fs70-5/Fs70-5-2020-032-eng.pdf

Loseto, L.L., Stern, G.A., Connelly, T.L., Deibel, D., Gemmill, B., Prokopowicz, A., Fortier, L., and Ferguson, S.H. 2009. Summer Diet of Beluga Whales Inferred by Fatty Acid Analysis of the Eastern Beaufort Sea Food Web. Journal of Experimental Marine Biology and Ecology 374(1): 12-18. doi:10.1016/j.jembe.2009.03.015. Available from https://www.sciencedirect.com/science/article/pii/S0022098109001282

Lovejoy, C. 2014. Changing Views of Arctic Protists (Marine Microbial Eukaryotes) in a Changing Arctic. Acta Protozool. 53: 9. doi:10.4467/16890027AP.14.009.1446.

Lowry, L. 2016. Ringed Seal, *Pusa hispida*. The IUCN Red List of Threatened Species 2016: e.T41672A45231341. International Union for Conservation of Nature and Natural Resources, Gland, CH. 17 p. Available from http://dx.doi.org/10.2305/IUCN.UK.2016-1.RLTS.T41672A45231341.en

Lowry, L.F., Frost, K.J., and Burns, J.J. 1980. Variability in the Diet of Ringed Seals, *Phoca hispida*, in Alaska. Canadian Journal of Fisheries and Aquatic Sciences 37: 2254-2261.

Lunn, N.J., and Stirling, I. 1985. The Significance of Supplemental Food to Polar Bears During the Ice-Free Period of Hudson Bay. Can. J. Zool. 63(10): 2291-2297. doi:10.1139/z85-340. Available from https://www.nrcresearchpress.com/doi/pdf/10.1139/z85-340

Lunn, N.J., Stirling, I., and Nowicki, S.N. 1997. Distribution and Abundance of Ringed (*Phoca hispida*) and Bearded Seals (*Erignathus barbatus*) in Western Hudson Bay. Canadian Journal of Fisheries and Aquatic Sciences 54: 914-921.

Luque, S.P., Ferguson, S.H., and Breed, G.A. 2014. Spatial behaviour of a keystone Arctic marine predator and implications of climate warming in Hudson Bay. Journal of Experimental Marine Biology and Ecology 461: 504-515. doi:10.1016/j.jembe.2014.10.002.

Lynch, T. 1990. Current Research. Am. Antiq. 55: 410-420.

MacDonald, R.W. 2000. Arctic estuaries. *In* The Freshwater Budget of the Arctic Ocean. *Edited by* E. L. Lewis. Kluwer Academic, Dordrecht, NL. pp. 383-407.

Macdonald, R.W., and Carmack, E.C. 1991. The role of large-scale under-ice topography in separating estuary and ocean on an arctic shelf. Atmos. Ocean 29(1): 37-53. doi:10.1080/07055900.1991.9649391.

Macdonald, R.W., Paton, D.W., Carmack, E.C., and Omstedt, A. 1995. The freshwater budget and under-ice spreading of Mackenzie River water in the Canadian Beaufort Sea based on salinity and18O/16O measurements in water and ice. J. Geophys. Res. Oceans 100(C1): 895-919. doi:10.1029/94jc02700.

MacCracken, J.G., Beatty, W.S., Garlich-Miller, J.L., Kissling, M.L., Snyder, J.A., 2017. Final Species Status Assessment for the Pacific Walrus (*Odobenus rosmarus divergens*), U.S. Fish and Wildlife Service, Marine Mammals Management, Anchorage

Majewski, A., and Reist, J. 2015. The Offshore Marine Fishes Project-BREA Final Results Forum. Department of Fisheries and Oceans, Ottawa, ON. 2 p. Available from https://www.beaufortrea.ca/wp-content/uploads/2015/03/BREA_-_FINAL_RESULTS_FORUM_-_FISHES__HABITATS__AND_ECOSYSTEM_LINKAGES_TO_OIL_AND_GAS_DEVELOPMENT_IN_THE_BEAUFORT_SEA.pdf

Mallory, M.L. 2006. The Northern Fulmar (*Fulmarus glacialis*) in Arctic Canada: ecology, threats, and what it tells us about marine environmental conditions. Environ. Rev. 14(3): 187-216. doi:10.1139/a06-003. Available from https://cdnsciencepub.com/doi/pdf/10.1139/a06-003

Mallory, M.L., Gaston, A.J., Gilchrist, H.G., Robertson, G.J., and Braune, B.M. 2010. Effects of Climate Change, Altered Sea-Ice Distribution and Seasonal Phenology on Marine Birds. *In* A Little Less Arctic: Top Predators in the World's Largest Northern Inland Sea, Hudson Bay. *Edited by* S. H. Ferguson, L. L. Loseto, and M. L. Mallory. Springer, Dordredcht, NL. pp. 179-195.

Mallory, M.L., and Fontaine, A. 2004. Key Marine Habitat Sites for Migratory Birds in Nunavut and the Northwest Territories. Can. Wildl. Serv. Occ. Paper No. 109. Environment Canada, Iqaluit, NU. 93 p. Available from https://cat.fsl-bsf.scitech.gc.ca/record=3689779&searchscope=06

Mallory, M.L., Fontaine, A.J., and Akearok, J. 2003. Status of the Harlequin Duck *Histrionicus histrionicus* on Baffin Island, Nunavut, Canada. Wildfowl 54: 95-102.

Mallory, M.L., Gilchrist, H.G., Braune, B.M., and Gaston, A.J. 2006. Marine Birds as Indicators of Arctic Marine Ecosystem Health: Linking the Northern Ecosystem Initiative to Long-Term Studies. Environmental Monitoring and Assessment 113(1-3): 31-48. doi:10.1007/s10661-005-9095-3. Available from https://www.ncbi.nlm.nih.gov/pubmed/16514485

Mallory, M. L., Woo, K., Gaston, A. J., Davies, W. E., & Mineau, P. 2004. Walrus (*Odobenus rosmarus*) predation on adult thick-billed murres (*Uria lomvia*) at Coats Island, Nunavut, Canada. *Polar Research*, *23*(1), 111-114.

Manning, T.H. 1976. Birds and mammals of the Belcher, Sleeper, Ottawa and King George Islands, and Northwest Territories. Occasional Paper No.: 28. Environment Canada, Ottawa, ON. 42 p.

Mansfield, A.W. 1963. Seals of Arctic and Eastern Canada. Fish. Res. Bd. Can. Bull. 137: 36.

Markham, W.E. 1981. Ice Atlas: Canadian Arctic Waterways. Minister of Supply and Services Canada, Ottawa, ON. 43 p. Available from https://cat.fsl-bsf.scitech.gc.ca/record=3901980~S6

Martinez-Levasseur, L. M., Furgal, C. M., Hammill, M. O., Henri, D. A., & Burness, G. 2021. New migration and distribution patterns of Atlantic walruses (Odobenus rosmarus rosmarus) around Nunavik (Québec, Canada) identified using Inuit Knowledge. Polar Biology, 44: 1833-1845.

Martini, I.P. 1981. Morphology and Sediments of the Emergent Ontario Coast of James Bay, Canada. Geografiska Annaler. Series A, Physical Geography 63(1/2): 81-94.

Matthews, C. J., Luque, S. P., Petersen, S. D., Andrews, R. D., & Ferguson, S. H. 2011. Satellite tracking of a killer whale (Orcinus orca) in the eastern Canadian Arctic documents ice avoidance and rapid, long-distance movement into the North Atlantic. Polar Biology, 34: 1091-1096.

Matthews, C.J., Raverty, S.A., Noren, D.P., Arragutainaq, L., and Ferguson, S.H. 2019. Ice entrapment mortality may slow expanding presence of Arctic killer whales. Polar Biology 42(3): 639-644. doi:10.1007/s00300-018-02447-3.

Maxwell, J.B. 1986. A Climate Overview of the Canadian Inland Seas. *In* Canadian Inland Seas. *Edited by* I. P. Martini. Elsevier Science Publishers, New York, NY. pp. 79-100.

McClelland, J.W., Déry, S.J., Peterson, B.J., Holmes, R.M., and Wood, E.F. 2006. A pan-arctic evaluation of changes in river discharge during the latter half of the 20th century. Geophysical Research Letters 33(6): L06715. doi:10.1029/2006gl025753.

McDonald, M., Arraguutainaq, L., and Novalinga, Z. 1997. Traditional Ecological Knowledge of Inuit and Cree in the Hudson Bay Bioregion - Voices from the Bay. Canadian Arctic Resources Committee, Ottawa, ON. 98 p.

McKinney, M.A., Peacock, E., and Letcher, R.J. 2009. Sea Ice-Associated Diet Change Increases the Levels of Chlorinated and Brominated Contaminants in Polar Bears. Environ. Sci. Technol. 43(12): 4334-4339.

McLaren, I.A. 1958. Some Aspects of Growth and Reproduction of the Bearded Seal, *Erignathus barbatlrs* (Erxleben). J. Fish. Res. Bd. Can. 15(2): 219-227.

McNicholl, D.G., Walkusz, W., Davoren, G.K., Majewski, A.R., and Reist, J.D. 2015. Dietary characteristics of co-occurring polar cod (*Boreogadus saida*) and capelin (*Mallotus villosus*) in the Canadian Arctic, Darnley Bay. Polar Biology 39(6): 1099-1108. doi:10.1007/s00300-015-1834-5.

McNicholl, D.G., Harris, L.N., Loewen, T., May, P., Tran, L., Akeeagok, R., Methuen, K., Lewis, C., Jeppesen, R., Illasiak, S. and Green, B. 2021. Noteworthy occurrences among six marine species documented with community engagement in the Canadian Arctic. Animal Migration, 8: 74-83.

Middel, K.R. 2014. Movement parameters and space use for the Southern Hudson Bay Polar Bear subpopulation in the face of a changing climate. Thesis (M.Sc.), Trent University, Peterborough, ON. 142 p.

Moore, J.-S., Bajno, R., Reist, J.D., and Taylor, E.B. 2015. Post-glacial recolonization of the North American Arctic by Arctic char (*Salvelinus alpinus*): Genetic evidence of multiple northern refugia and hybridization between glacial lineages. J. Biogeogr. 42(11): 2089-2100. doi:10.1111/jbi.12600.

Moore, J.-S., L.N. Harris, S. Kessel, L. Bernatchez, R.F. Tallman, A.T. Fisk (2016) Preference for near-shore and estuarine habitats in anadromous Arctic char (Salvelinus alpinus) from the Canadian high Arctic (Victoria Island, NU) revealed by acoustic telemetry. Canadian Journal of Fisheries and Aquatic Sciences, 73(9): 1434-1445

Morin, R., Dodson, J., and Power, G. 1980. Estuarine fish communities of the eastern James-Hudson Bay coast. Environ. Biol. Fish. 5: 135-141.

Mundy, C.J., Barber, D.G., and Michel, C. 2005. Variability of Snow and Ice Thermal, Physical and Optical Properties Pertinent to Sea Ice Algae Biomass During Spring. Journal of Marine Systems 58(3-4): 107-120. doi:10.1016/j.jmarsys.2005.07.003. Available from https://www.sciencedirect.com/science/article/abs/pii/S0924796305001417?via%3Dihub

Murty, T.S., and Yuen, K.B. 1973. Balanced versus geostrophic wind-stress for Hudson Bay. J. Fish. Res. Bd. Can. 30: 53-62.

Nakashima, D. 1991. The ecological knowledge of Belcher Island Inuit: a traditional bases for contemporary wildlife co-management. Thesis (Ph.D), McGill University, Montreal, QC. 369 p.

Nakashima, D., and Murray, D.J. 1988. The Common Eider (Somateria mollissima sedentaria) of eastern Hudson Bay: A survey of nest colonies and Inuit ecological knowledge. Environmetnal Studies Revolving Funds, Ottawa, ON.

NAMMCO. 2006. Status of Marine Mammals in the North Atlantic, The Atlantic Walrus. North Atlantic Marine Mammal Commission, Tromso, NO. 7 p.

NAMMCO. [s.d.]. Status of Marine Mammals in the North Atlantic, The Ringed Seal. North Atlantic Marine Mammal Commission, Tromso, Norway. 8 p.

National Snow and Ice Data Center. 2022. Sea Ice in the Belcher Islands, Nunavut, Canada, Version 1 [online]. Available from https://nsidc.org/data/eloka002/versions/1 [accessed 12 October 2022].

Niemi, A., Bednaršek, N., Michel, C., Feely, R.A., Williams, W., Azetsu-Scott, K., Walkusz, W. and Reist, J.D. 2021. Biological impact of ocean acidification in the Canadian Arctic: widespread severe pteropod shell dissolution in Amundsen Gulf. Frontiers in Marine Science, 8: 600184.

NOAA Fisheries. 2022. Bearded Seal [online]. Available from https://www.fisheries.noaa.gov/species/bearded-seal#overview [accessed 20 October 2022].

Nozais, C., Vincent, W.F., Belzile, C., Gosselin, M., Blais, M.-A., Canário, J., and Archambault, P. 2021. The Great Whale River ecosystem: Ecology of a subarctic river and its receiving waters in coastal Hudson Bay, Canada. Écoscience 28(3-4): 327-346. doi:10.1080/11956860.2021.1926137.

Nunavik Marine Regional Wildlife Board (NMRWB). 2018. Nunavik Inuit Knowledge and Observations of Polar Bears: Polar bears of the Southern Hudson Bay sub-population. Project conducted and report prepared for the NMRWB by Basterfield, M., BretonHoneyman, K., Furgal, C., Rae, J. and M. O’Connor. xiv + 73 pp.

Nunavut Planning Commission. 2021. Nunavut Land Use Plan. Nunavut Planning Commission, Iqaluit, NT. 752 p.

Nunavut Tunngavik Inc. 2001. Elder's conference on climate change: final report. Nunavut Tunngavik Inc., Cambridge Bay, NU. 36 p.

Oakes, J. 1991. Environmental Factors Influencing Bird-Skin Clothing Production. Arct. Alp. Res. 23(1): 71-79. doi:10.2307/1551440.

Obbard, M.E., Stapleton, S., Szor, G., Middel, K.R., Jutras, C., and Dyck, M. 2018. Re-assessing abundance of Southern Hudson Bay polar bears by aerial survey: Effects of climate change at the southern edge of the range. Arct. Sci. 4(4): 634-655. doi:10.1139/as-2018-0004.

O’Corry-Crowe, G.M. 2018. Beluga Whale: Delphinapterus leucas. *In* Encyclopedia of Marine Mammals (Third Edition), Third Edition. *Edited by* B. Würsig, J.G.M. Thewissen, and K.M. Kovacs. Academic Press. pp. 93–96.

Parkinson, C.L., and Cavalieri, D.J. 2008. Arctic Sea Ice Variability and Trends, 1979–2006. J. Geophys. Res. 113: 28. doi:10.1029/2007jc004558. Available from https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2007JC004558

Peacock, E., Derocher, A.E., Lunn, N.J., and Obbard, M.E. 2010. Polar Bear Ecology and Management in Hudson Bay in the Face of Climate Change. *In* A Little Less Arctic: Top Predators in the World’s Largest Northern Inland Sea, Hudson Bay. *Edited by* S. H. Ferguson, L. L. Loseto, and M. L. Mallory. Springer, Dordredcht, NL. pp. 93-116.

Pelletier, B.R. 1998. Submarine physiography, bottom sediments, and models of sediment transport. *In* Earth Science Symposium on Hudson Bay. *Edited by* P. J. Hood. Department of Energy, Mines and Resources, Ottawa, ON. pp. 100-136.

Perovich, D.K., Nghiem, S.V., Markus, T., and Schweiger, A. 2007. Seasonal Evolution and Interannual Variability of the Local Solar Energy Absorbed by the Arctic Sea Ice–Ocean System. J. Geophys. Res. 112: 13. doi:10.1029/2006jc003558. Available from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1021.2&rep=rep1&type=pdf

Peterson, B.J., Holmes, R.M., McClelland, J.W., Vorosmarty, C.J., Lammers, R.B., Shiklomanov, A.I., Shiklomanov, I.A., and Rahmstorf, S. 2002. Increasing river discharge to the Arctic Ocean. Science 298(5601): 2171-2173. doi:10.1126/science.1077445. Available from https://www.ncbi.nlm.nih.gov/pubmed/12481132

Petrusevich, V.Y., Dmitrenko, I.A., Kozlov, I.E., Kirillov, S.A., Kuzyk, Z.Z.A., Komarov, A.S., Heath, J.P., Barber, D.G., and Ehn, J.K. 2018. Tidally-generated internal waves in Southeast Hudson Bay. Continental Shelf Research 167: 65-76. doi:10.1016/j.csr.2018.08.002.

Piepenburg, D., Archambault, P., Ambrose, W.G., Blanchard, A.L., Bluhm, B.A., Carroll, M.L., Conlan, K.E., Cusson, M., Feder, H.M., Grebmeier, J.M., Jewett, S.C., Lévesque, M., Petryashev, V.V., Sejr, M.K., Sirenko, B.I., and Włodarska-Kowalczuk, M. 2011. Towards a Pan-Arctic Inventory of the Species Diversity of the Macro- and Megabenthic Fauna of the Arctic Shelf Seas. Marine Biodiversity 41(1): 51-70. doi:10.1007/s12526-010-0059-7. Available from https://link.springer.com/article/10.1007/s12526-010-0059-7

Pierrejean, M., Grant, C., Nozais, C., and Archambault, P. 2019. Communities of Benthic invertebrates in the Hudson Bay Marine Region. *In* From science to policy in the greater Hudson Bay Marine region: An Integrated Regional Impact Study (IRIS) of climate change and modernization. *Edited by* T. Bell and T. M. Brown. ArcticNet, Quebec City, QC. pp. 245–253.

Pierrejean, M., Babb, D.G., Maps, F., Nozais, C., and Archambault, P. 2020. Spatial distribution of epifaunal communities in the Hudson Bay system. Elem. Sci. Anth. 8: 1. doi:10.1525/elementa.00044. Available from https://online.ucpress.edu/elementa/article/8/1/00044/114514/Spatial-distribution-of-epifaunal-communities-in

Polynya Consulting Group. 2021. The Hudson Bay, James Bay and Foxe Basin Marine Ecosystem: A Review. A report prepared for Oceans North by Polynya Consulting Group. Polynya Consulting Group, Winnipeg, MB. 193 p.

Pomerleau, C., Winkler, G., Sastri, A.R., Nelson, R.J., Vagle, S., Lesage, V., and Ferguson, S.H. 2011. Spatial Patterns in Zooplankton Communities Across the Eastern Canadian Sub-Arctic and Arctic Waters: Insights from Stable Carbon (13C) and Nitrogen (15N) Isotope Ratios. Journal of Plankton Research 33(12): 1779-1792. doi:10.1093/plankt/fbr080. Available from https://www.semanticscholar.org/paper/Spatial-patterns-in-zooplankton-communities-across-Pomerleau-Winkler/4085167aab558af1793a358995b8a8b171fa16ee

Ponton, D., and Fortier, L. 1992. Vertical Distribution and Foraging of Marine Fish Larvae Under the Ice Cover of Southeastern Hudson Bay. Mar. Ecol. Prog. Ser. 81: 215-227.

Ponton, D., Gagné, J.A., and Fortier, L. 1993. Production and Dispersion of Freshwater, Anadromous, and Marine Fish Larvae in and Around a River Plume in Subarctic Hudson Bay, Canada. Polar Biology 13: 321-331. Available from https://horizon.documentation.ird.fr/exl-doc/pleins_textes/pleins_textes_6/b_fdi_45-46/010009843.pdf.

Pope, S., Copland, L., and Alt, B. 2017. Recent Changes in Sea Ice Plugs Along the Northern Canadian Arctic Archipelago. *In* Arctic Ice Shelves and Ice Islands. *Edited by* L. Copland and D. Mueller. Springer Nature, Dondrecht, NL. pp. 317-342. Available from https://link.springer.com/chapter/10.1007/978-94-024-1101-0_12

Prest, V. 1990. Laurentide Ice-Flow Patterns: A Historical Review, and Implications of the Dispersal of Belcher Islands Erratics. Géographie physique et Quaternaire 44(2): 113-136.

Prest, V.K., Donaldson, J.A., and Mooers, H.D. 2002. The Omar Story: The Role of Omars in Assessing Glacial History of West-Central North America. Géographie physique et Quaternaire 54(3): 257-270. doi:10.7202/005654ar.

Priest, H., and Usher, P.J. 2004. The Nunavut Wildlife Harvest Study. Nunavut Wildlife Management Board, Iqaluit, NU. 822 p. Available from https://www.nwmb.com/inu/publications/harvest-study/1824-156-nwhs-report-2004-156-0003/file

Prinsenberg, S. 1982. Time variability of physical oceanographic parameters in Hudson Bay. Le Naturaliste Canadien 109: 685-700.

Prinsenberg, S.J. 1986a. Salinity and Temperature Distributions of Hudson Bay and James Bay. *In* Canadian Inland Seas. *Edited by* I. P. Martini. Elsevier Science Publishing Company Inc., New York, NY. pp. 163-186.

Prinsenberg, S.J. 1986b. The Circulation Pattern and Current Structure of Hudson Bay. *In* Canadian Inland Seas. *Edited by* I. P. Martini. Elsevier Science Publishing Company Inc., New York, NY. pp. 187-204.

Prinsenberg, S.J. 1987. Seasonal Current Variations Observed in Western Hudson Bay. J. Geophys. Res. Oceans 92(C10): 10756-10766. doi:10.1029/JC092iC10p10756.

Prinsenberg, S.J. 1988. Ice-Cover and Ice-Ridge Contributions to the Freshwater Contents of Hudson Bay and Foxe Basin. Arctic 41(1): 6-11.

Prinsenberg, S.J., and Freeman, N.G. 1986. Tidal Heights and Currents in Hudson Bay and James Bay. *In* Canadian Inland Seas. *Edited by* I.P. Martini. Elsevier Science Publishing Company, New York, NY. pp. 205-216.

Prinsenberg, S.J., and Ingram, R.G. 1991. Under-Ice Physical Oceanographic Processes. Journal of Marine Systems 2: 143-152. doi:10.1016/0924-7963(91)90020-U. Available from https://www.sciencedirect.com/science/article/abs/pii/092479639190020U

Prowse, T.D., Wrona, F.J., Reist, J.D., Gibson, J.J., Hobbie, J.E., Levesque, L.M.J., and Vincent, W.F. 2006. Climate Change Effects on Hydroecology of Arctic Freshwater Ecosystems. Ambio 15(1): 347-358.

Qikiqtani Inuit Association. 2014. Qikiqtani Truth Commission: Community Histories 1950-1975, Sanikiluaq. Inhabit Media Inc., Iqaluit, NU. 42 p.

Qikiqtani Inuit Association. 2015. Guide to the Community Histories and Special Studies of the Qikiqtani Truth Commission. Inhabit Media Inc., Iqaluit, NU. 127 p.

Qikiqtani Inuit Association Prospectus. 2022. A Regional Conservation Approach 2022. qia-prospectus-2022-1.pdf

Ramsay, M.A., and Stirling, I. 1988. Reproductive biology and ecology of female polar bears. The Zoological Society of London 214: 601-634. Available from https://www.researchgate.net/publication/229196509_Reproductive_biology_and_ecology_of_female_polar_bears_Ursus_maritimus

Reeves, R.R. 1998. Distribution, Abundance and Biology of Ringed Seals (*Phoca hispida*): An Overview. NAMMCO Sci. Publ.(1): 9-45. Available from https://pdfs.semanticscholar.org/d2fa/ce1acd69d54fdd4d82a316914feadf5887de.pdf?_ga=2.124329994.1623352659.1585420905-805737118.1583785669.

Reeves, R.R., Wenzel, G.W., and Kingsley, C.S. 1998. Catch history of ringed seals (*Phoca hispida*) in Canada. NAMMCO Scientific Publications 1: 100-129. doi:10.7557/3.2983.

Reist, J.D., Wrona, F.J., Prowse, T.D., Dempson, J.B., Power, M., Köck, G., Carmichael, T.J., Sawatzky, C.D., Lehtonen, H., and Tallman, R.F. 2006. Effects of Climate Change and UV Radiation on Fisheries for Arctic Freshwater and Anadromous Species. Ambio 35(7): 402-410. doi:10.1579/0044-7447(2006)35[402:Eoccau]2.0.Co;2.

Renaud, P.E., Riedel, A., Michel, C., Morata, N., Gosselin, M., Juul-Pedersen, T., and Chiuchiolo, A. 2007. Seasonal Variation in Benthic Community Oxygen Demand: A Response to an Ice Algal Bloom in the Beaufort Sea, Canadian Arctic? Journal of Marine Systems 67(1-2): 1-12. doi:10.1016/j.jmarsys.2006.07.006. Available from https://www.sciencedirect.com/science/article/abs/pii/S092479630600193X

Ricketts, B., and Donaldson, J. 1981. Sedimentary history of the Belcher Group of Hudson Bay. *In* Proterozoic Basins of Canada. *Edited by* F. H. A. Campbell. Geological Survey of Canada, Hull, QC. pp. 235-254.

Ricketts, B.D., and Donaldson, J.A. 1979. Stone rosettes as indicators of ancient shorelines: examples from the Precambrian Belcher Group, Northwest Territories. Can. J. Earth Sci. 16(9): 1887-1891. doi:10.1139/e79-174.

Ridenour, N.A., Hu, X., Sydor, K., Myers, P.G., and Barber, D.G. 2019a. Revisiting the Circulation of Hudson Bay: Evidence for a Seasonal Pattern. Geophysical Research Letters 46(7): 3891-3899. doi:10.1029/2019gl082344.

Ridenour, N.A., Hu, X., Jafarikhasragh, S., Landy, J.C., Lukovich, J.V., Stadnyk, T.A., Sydor, K., Myers, P.G., and Barber, D.G. 2019b. Sensitivity of freshwater dynamics to ocean model resolution and river discharge forcing in the Hudson Bay Complex. Journal of Marine Systems 196: 48-64. doi:10.1016/j.jmarsys.2019.04.002.

Ridenour, N. A., Straneo, F., Holte, J., Gratton, Y., Myers, P. G., Barber, D. G. 2021. Hudson Strait inflow: Structure and variability. Journal of Geophysical Research: Oceans, 126, e2020JC017089. https://doi.org/10.1029/2020JC017089

Riewe, R. 1991. Inuit Use of the Sea Ice. Arct. Antarct. Alp. Res. 23(1): 3-10. doi:10.1080/00040851.1991.12002813.

Rikardsen, A.H., Amundsen P.-A., Bjorn, P.A., and Johansen, M. 2005. Comparison of growth, diet, and food consumption of sea-run and lake-dwelling Arctic charr. Journal of Fish Biology 57: 1172-1188.

Robertson, G.J., and Gilchrist, H.G. 1998. Evidence of Population Declines among Common Eiders Breeding in the Belcher Islands, Northwest Territories. Arctic 51(4): 378-385. doi:10.14430/arctic1081.

Robertson, G.J., Reed, A., and Gilchrist, H.G. 2001. Clutch, egg and body size variation among common eiders breeding in Hudson Bay, Canada. Pol. Res. 20(1): 85-94.

Robillard, A., Lesage, V., and Hammill, M.O. 2005. Distribution and abundance of harbour seals (*Phoca vitulina concolor*) and grey seals (*Halichoerus grypus*) in the Estuary and Gulf of St. Lawrence during 1994-2001. Canadian Technical Report of Fisheries and Aquatic Sciences 2613: 152 p.

Rochet, M., and Grainger, E.H. 1988. Community structure of zooplankton in eastern Hudson Bay. Can J Zool. 66: 1626–1630. doi:10.1139/z88-237.

Rockwell, R.F., Abraham, K.F., Witte, C.R., Matulonis, P., Usai, M., Larsen, D., Cooke, F., Pollak, D., and Jefferies, R.L. 2009. The Birds of Wapusk National Park. Wapusk National Park of Canada Occasional Paper No. 1. Parks Canada, Winnipeg, MB. 47 p.

Ross, P.S., Stern, G.A., and Lebeuf, M. 2007. rouble at the top of the food chain : environmental contaminants and health risks in marine mammals : a white paper on search priorities for Fisheries and Oceans Canada. Can. Tech. Rep. Fish. Aquat. Sci. 2734: viii + 30 p.

Rothe, T.C., Padding, P.I., Naves, L.C., and Robertson, G.J. 2015. Harvest of sea ducks in North America: A Contemporary Summary. *In* Ecology and conservation of North American sea ducks: Studies in Avian Biology. *Edited by* J.-P.L. Savard, D.V. Derksen, D. Esler, and J.M. Eadie. CRC Press, Boca Raton, FL. pp. 419-469.

Roy, V., Iken, K., and Archambault, P. 2014. Environmental Drivers of the Canadian Arctic Megabenthic Communities. PLoS One 9(7): e100900. doi:10.1371/journal.pone.0100900. Available from https://www.ncbi.nlm.nih.gov/pubmed/25019385

Roy, V., Iken, K., and Archambault, P. 2015. Regional Variability of Megabenthic Community Structure across the Canadian Arctic. Arctic. 68(2). doi:10.14430/arctic4486.

Sale, R. 2006. A Complete Guide to Arctic Wildlife. Firefly Books Ltd., Richmond Hill, ON.

Saucier, F.J., Senneville, S., Prinsenberg, S., Roy, F., Smith, G., Gachon, P., Caya, D., and Laprise, R. 2004. Modelling the Sea Ice-Ocean Seasonal Cycle in Hudson Bay, Foxe Basin and Hudson Strait, Canada. Climate Dynamics 23: 303-326. doi:10.1007/s00382-004-0445-6.

Scott, J.B.T., and Marshall, G.J. 2010. A Step-Change in the Date of Sea-Ice Breakup in Western Hudson Bay. Arctic 63(2): 155-164. Available from http://pubs.aina.ucalgary.ca/arctic/Arctic63-2-155.pdf

Sea Duck Joint Venture. 2018. Species Status Summary and Information Needs. U.S. Fish and Wildlife Service, Anchorage, AK. 8 p.

Sheffield, G., & Grebmeier, J. M. 2009. Pacific walrus (*Odobenus rosmarus divergens*): differential prey digestion and diet. *Marine Mammal Science*, *25*(4), 761-777.

Sibert, V., Zakardjian, B., Gosselin, M., Starr, M., Senneville, S., and LeClainche, Y. 2011. 3D bio-physical model of the sympagic and planktonic productions in the Hudson Bay system. Journal of Marine Systems 88(3): 401-422.

Simon, M. May. 2009. Preface in Inuit, Polar Bears, and Sustainable Use: Local, National and International Perspectives. M.M.R. Freeman and L. Foote (editors). Edmonton, Alberta: University of Alberta CCI Press.

Sjare, B., Lebeuf, M., and Veinott, G. 2002. Harbor seals in Newfoundland and Labrador: a preliminary summary of new data on aspects of biology, ecology and contaminant profiles and the contamination profile. DFO Can. Sci. Advis. Sec. Res. Doc.: 2005/030.

Sjare, B., & Stirling, I. 1996. The breeding behavior of Atlantic walruses, *Odobenus rosmarus rosmarus*, in the Canadian High Arctic. Canadian Journal of Zoology, 74(5), 897-911.

Smith, J., W., and Barber, D.G. 2007. Polynyas: Windows to the World. Elsevier Science & Technology, Amsterdam, NL. 458 p. Available from https://www.elsevier.com/books/polynyas-windows-to-the-world/smith-jr/978-0-444-52952-7

Smith, M., and Rigby, B. 1981. Distribution of polynyas in the Canadian Arctic. *In* Polynyas in the Canadian Arctic. *Edited by* I. Stirling and H. Cleator. pp. 7-27.

Smith, A.J., Higdon, J.W., Richard, P., Orr, J., Bernhardt, W., Ferguson, S.H. 2017. Beluga whale summer habitat associations in the Nelson River estuary, western Hudson Bay, Canada. PLoS ONE 12(8): e0181045. https://doi.org/10.1371/journal. pone.0181045

Smith, R.J., Hobson, K.A., Koopman, H.N., and Lavigne, D.M. 1996. Distinguishing Between Populations of Fresh- and Salt-water Harbour Seals (*Phoca vitulina*) using Stable-Isotope Ratios and Fatty Acid Profiles. Canadian Journal of Fisheries and Aquatic Sciences 53(2): 272-279. doi:10.1139/f95-192.

Smith, S.D., Muench, R.D., and Pease, C.H. 1990. Polynyas and Leads: An Overview of Physical Processes and Environment. J. Geophys. Res. 95(C6). doi:10.1029/JC095iC06p09461.

Smith, T.G. 1975. Ringed Seals in James Bay and Hudson Bay: Population Estimates and Catch Statistics. *In* Ringed Seals. *Edited by* T. G. Smith, Ste. Anne de Bellevue, QC. pp. 170-182.

Smith, T.G. 1981. Notes on the Bearded Seal, *Erignathus barbatus*, in the Canadian Arctic. Can. Tech. Rep. Fish. Aquat. Sci. 1042: v + 49 p. Available from https://waves-vagues.dfo-mpo.gc.ca/Library/429.pdf

Snelgrove, P.V.R., Archambault, P., Juniper, S.K., Lawton, P., Metaxas, A., Pepin, P., Rice, J.C., and Tunnicliffe, V. 2012. Canadian Healthy Oceans Network (CHONe): An Academic–Government Partnership to Develop Scientific Guidelines for Conservation and Sustainable Usage of Marine Biodiversity. Fish. 37(7): 296-304. doi:10.1080/03632415.2012.696002. Available from https://www.tandfonline.com/doi/abs/10.1080/03632415.2012.696002

Sonne-Hansen, C., Dietz, R., Leifsson, P.S., Hyldstrup, L., and Riget, F.F. 2002. Cadmium toxicity to ringed seals (*Phoca hispida*): an epidemiological study of possible cadmium-induced nephropathy and osteodystrophy in ringed seals (*Phoca hispida*) from Qaanaaq in Northwest Greenland. Science of the Total Environment 295: 167-181.

Stadnyk, T.A., Déry, S.J., MacDonald, M.K., Koenig, K.A. 2019. Freshwater System. In Barber, D., 24 Kuzyk, Z., Candlish, L. An Integrated Regional Impact Assessment of Hudson Bay: Implications of a 25 Changing Environment. Québec City, QC, Canada.

Stewart, R.E.A., Campana, S.E., Jones, C.M., and Stewart, B.E. 2007. Bomb radiocarbon dating calibrates beluga (Delphinapterus leucas) age estimates. Canadian Journal of Zoology 84: 1840-1852.

St-Laurent, P., Straneo, F., Dumais, J.F., and Barber, D.G. 2011. What is the fate of the river waters of Hudson Bay? Journal of Marine Systems 88(3): 352-361. doi:10.1016/j.jmarsys.2011.02.004.

St-Laurent, P., Saucier, F.J., and Dumais, J.F. 2008. On the Modification of Tides in a Seasonally Ice-Covered Sea. J. Geophys Res Oceans 113(C11014): 1-11. doi:10.1029/2007jc004614.

St-Laurent, P., Straneo, F., and Barber, D.G. 2012. A conceptual model of an Arctic sea. Journal of Geophysical Research: Oceans 117(C6): n/a-n/a. doi:10.1029/2011jc007652.

Steele, M., Ermold, W., and Zhang, J. 2008. Arctic Ocean surface warming trends over the past 100 years. Geophysical Research Letters 35(2). doi:10.1029/2007gl031651. Available from https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1029/2007GL031651

Steiner, N., Azetsu-Scott, K., Galbraith, P., Hamilton, J., Hedges, K., Hu, X., Janjua, M.Y., Lambert, N., Larouche, P., Lavoie, D., Loder, J., Melling, H., Merzouk, A., Myers, P., Perrie, W., Peterson, I., Pettipas, R., Scarratt, M., Sou, T., Starr, M., Tallmann, R.F., and van der Baaren, A. 2013. Climate Change Assessment in the Arctic Basin Part 1: Trends and Projections - A Contribution to the Aquatic Climate Change Adaptation Services Program. Can. Tech. Rep. Fish. Aquat. Sci. 3042: xv + 163 p. Available from http://www.dfo-mpo.gc.ca/library/350169.pdf

Stewart, D.B., and Barber, D.G. 2010. The Ocean-Sea Ice-Atmosphere System of the Hudson Bay Complex. *In* A Little Less Arctic: Top Predators in the World's Largest Northern Inland Sea, Hudson Bay. *Edited by* Steven H. Ferguson, Lisa L. Loseto, and Mark L. Mallory. Springer Netherlands, Dordrecht. pp. 1-38. Available from https://doi.org/10.1007/978-90-481-9121-5_1

Stewart, D.B., and Howland, K.L. 2009. An Ecological and Oceanographical Assessment of the Alternate Ballast Water Exchange Zone in the Hudson Strait Region. DFO Can. Sci. Advis. Sec. Res. Doc.: 2009/008. vi + 96 p. Available from https://waves-vagues.dfo-mpo.gc.ca/Library/337766.pdf

Stewart, D.B., and Lockhart, W.L. 2005. An Overview of the Hudson Bay Marine Ecosystem. Can. Tech. Rep. Fish. Aquat. Sci. 2586: vi + 487 p.

Stewart, T.R., Mäkinen, M., Goulon, C., Guillard, J., Marjomäki, T.J., Lasne, E., Karjalainen, J., and Stockwell, J.D. 2021. Influence of warming temperatures on coregonine embryogenesis within and among species. Hydrobiologia 848(18): 4363-4385. doi:10.1007/s10750-021-04648-0.

Stewart, T.R., Vinson, M.R., and Stockwell, J.D. 2022. Effects of warming winter embryo incubation temperatures on larval cisco (*Coregonus artedi*) survival, growth, and critical thermal maximum. J. Great Lakes Res. 48: 1042-1049. doi:10.1101/2021.07.01.450800.

Stirling, I., and Cleator, H. 1981. Polynyas in the Canadian Arctic. Canadian Wildlife Service Occasional Paper No.: 45. Environment Canada, Ottawa, ON. 70 p. Available from http://publications.gc.ca/site/archivee-archived.html?url=http://publications.gc.ca/collections/collection_2018/eccc/CW69-1-45-eng.pdf

Stirling, I., and Derocher, A.E. 1993. Possible Impacts of Climate Warming on Polar Bears. Arctic. 46(3): 240-245.

Stirling, I., and Derocher, A.E. 2012. Effects of Climate Warming on Polar Bears: a Review of the Evidence. Glob. Chang. Biol. 18(9): 2694-2706. doi:10.1111/j.1365-2486.2012.02753.x. Available from https://www.ncbi.nlm.nih.gov/pubmed/24501049

Stirling, I., and Parkinson, C.L. 2006. Possible Effects of Climate Warming on Selected Populations of Polar Bears (*Ursus maritimus*) in the Canadian Arctic. Arctic. 59(3): 261-265. Available from http://pubs.aina.ucalgary.ca/arctic/Arctic59-3-261.pdf

Stirling, I., Andriashek, D., and Calvert, W. 1993. Habitat Preferences of Polar Bears in the Western Canadian Arctic in Late Winter and Spring. Polar Rec. 29: 13-24. doi:10.1017/S0032247400023172. Available from https://www.cambridge.org/core/journals/polar-record/article/habitat-preferences-of-polar-bears-in-the-western-canadian-arctic-in-late-winter-and-spring/48E4972311141C45B98C28B287128B8D

Stirling, I., Lunn, N.J., and Iacozza, J. 1999. Long-Term Trends in the Population Ecology of Polar Bears in Western Hudson Bay in Relation to Climatic Change. Arctic. 52(3): 294-306. doi:10.14430/arctic935. Available from https://journalhosting.ucalgary.ca/index.php/arctic/article/view/63991/47926

Svenning, M.-A., Sandem, K., Halvorsen, M., Kanstad-Hanssen, Ø., Falkegård, M., and Borgstrøm, R. 2016. Change in relative abundance of Atlantic salmon and Arctic charr in Veidnes River, Northern Norway: a possible effect of climate change? Hydrobiologia 783(1): 145-158. doi:10.1007/s10750-016-2690-1.

Tai, T.C., Steiner, N.S., Hoover, C., Cheung, W.W.L., and Sumaila, U.R. 2019. Evaluating present and future potential of arctic fisheries in Canada, Marine Policy, Volume 108, 103637, https://doi.org/10.1016/j.marpol.2019.103637

The Cornell Lab of Ornithology. 2022. Birds of the World [online]. Available from https://birdsoftheworld.org/bow/home [accessed 13 October 2022].

Thiemann, G.W., Budge, S.M., Iverson, S.J., and Stirling, I. 2007. Unusual Fatty Acid Biomarkers Reveal Age- and Sex-Specific Foraging in Polar Bears (*Ursus maritimus*). Can. J. Zool. 85(4): 505-517. doi:10.1139/z07-028.

Thiemann, G.W., Iverson, S.J., and Stirling, I. 2008. Variation in Blubber Fatty Acid Composition Among Marine Mammals in the Canadian Arctic. Marine Mammal Science 24(1): 91-111. doi:10.1111/j.1748-7692.2007.00165.x.

Thompson, H.A. 1968. The climate of Hudson Bay. *In* Science, history and Hudson Bay, Vol. 1. Department of Energy, Mines and Resources, Ottawa, ON. pp. 263-286.

Timmermans, M.-L., Toole, J., and Krishfield, R. 2018. Warming of the interior Arctic Ocean linked to sea ice losses at the basin margins. Science Advances 4: eaat6773. Available from https://www.science.org/doi/pdf/10.1126/sciadv.aat6773

Tivy, A., Howell, S.E.L., Alt, B., McCourt, S., Chagnon, R., Crocker, G., Carrieres, T., and Yackel, J.J. 2011. Trends and Variability in Summer Sea Ice Cover in the Canadian Arctic Based on the Canadian Ice Service Digital Archive, 1960–2008 and 1968–2008. J. Geophys. Res. 116(C3). doi:10.1029/2009jc005855. Available from https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1029/2009JC005855

Tollit, D.J., Greenstreet, S.P.R., and Thompson, P.M. 1997. Prey Selection by Harbour Seals, *Phoca vitulina*, in Relation to Variations in Prey Abundance. Can. J. Zool. 75: 1508-1518.

Tollit, D.J., Black, A.D., Thompson, P.M., Mackay, A., Corpe, H.M., Wilson, B., Van Parijs, S.M., Grellier, K., and Parlane, S. 1998. Variations in Harbour Seal *Phoca vitulina* Diet and Dive-Depths in Relation to Foraging Habitat. The Zoological Society of London 244: 209-222.

Tremblay, J.-É., Robert, D., Varela, D.E., Lovejoy, C., Darnis, G., Nelson, R.J., and Sastri, A.R. 2012. Current State and Trends in Canadian Arctic Marine Ecosystems: I. Primary Production. Clim. Change. 115(1): 161-178. doi:10.1007/s10584-012-0496-3. Available from https://link.springer.com/content/pdf/10.1007/s10584-012-0496-3.pdf

Tynan, C.T., and DeMaster, D.P. 1997. Observations and Predictions of Arctic Climate Change: Potential effects on marine mammals. Arctic 50(4): 308-322.

Ulrich, K.L. 2013. Trophic Ecology of Arctic char (*Salvelinus alpinus* L.) in the Cumberland Sound Region of the Canadian Arctic. Thesis (M.Sc.), Department of Biological Sciences, University of Manitoba, Winnipeg, MB. 211 p. Available from https://mspace.lib.umanitoba.ca/bitstream/handle/1993/21693/Ulrich_Kendra.pdf?sequence=1

Ulrich, K.L., and Tallman, R.F. 2021. The capelin invasion: evidence for a trophic shift in Arctic char populations from the Cumberland Sound region. Arctic Sci. AS-2020: 20. doi:10.1139/AS-2020-0001. Available from https://browzine.com/articles/450503935

UNEP/CBD. 2008. Decision adopted by the conference of the parties to the convention on biological diversity at its ninth meeting. IX/20 Marine and coastal biodiversity. Sections 14 and 19. (Accessed 14 March, 2023)

Verreault, J., Muir, D.C., Norstrom, R.J., Stirling, I., Fisk, A.T., Gabrielsen, G.W., Derocher, A.E., Evans, T.J., Dietz, R., Sonne, C., Sandala, G.M., Gebbink, W., Riget, F.F., Born, E.W., Taylor, M.K., Nagy, J., and Letcher, R.J. 2005. Chlorinated Hydrocarbon Contaminants and Metabolites in Polar Bears (*Ursus maritimus*) from Alaska, Canada, East Greenland, and Svalbard: 1996-2002. Science of the Total Environment 351-352: 369-390. doi:10.1016/j.scitotenv.2004.10.031. Available from https://www.ncbi.nlm.nih.gov/pubmed/16115663

Wagemann, R., Trebacz, E., Boila, G., and Lockhart, W.L. 2000. Mercury Species in the Liver of Ringed Seals. Science of the Total Environment 261: 21-32.

Wang, J., Mysak, L.A., and Ingram, R.G. 1994. A Three-Dimensional Numerical Simulation of Hudson Bay Summer Ocean Circulation: Topographic Gyres, Separations, and Coastal Jets. J. Phys. Oceanogr. 24: 2496-2514.

Wein, E.E., Freeman, M.M.R., and Makus, J.C. 1996. Use of and Preference for Traditional Foods among the Belcher Island Inuit. Arctic 49(3): 256-264. doi:10.14430/arctic1201.

Wein, E.E., Freeman, M.M., and Makus, J.C. 1998. Preliminary assessment of nutrients in daily diets of a sample of Belcher Island Inuit adults. Int. J. Circumpolar Health 57(1): 205-210.

Welch, H.E., Crawford, R.E., and Hop, H. 1993. Occurrence of Arctic Cod (*Boreogadus saida*) Schools and Their Vulnerability to Predation in the Canadian High Arctic. Arctic. 46(4): 331-339.

Wisz, M.S., Broennimann, O., Grønkjær, P., Møller, P.R., Olsen, S.M., Swingedouw, D., Hedeholm, R.B., Nielsen, E.E., Guisan, A., and Pellissier, L. 2015. Arctic Warming Will Promote Atlantic–Pacific Fish Interchange. Nature Climate Change 5(3): 261-265. doi:10.1038/nclimate2500. Available from https://www.nature.com/articles/nclimate2500

World Meteorological Organization. 1970. Glossary and illustrated glossary. *In* WMO sea-ice nomenclature. Secretariat of the World Meteorological Organization, Geneva, CH. pp. 12, 145-147.

WoRMS. 2022. World Register of Marine Species 2022 [online]. Available from https://www.marinespecies.org/aphia.php?p=search [accessed 16 December 2022].

Wight, K.J., McNicholl, D.G., Dunmall, K.D. In Press. A systematic review of the trophic ecology of eight fish species in North American Arctic and subarctic regions. Polar Biology

Wrona, F.J., Prowse, T.D., Reist, J.D., Hobbie, J.E., Levesque, L.M.J., and Vincent, W.F. 2006. Climate Change Effects on Aquatic Biota, Ecosystem Structure and Function. Ambio 35(7): 359-369.

Young, B.G., Ferguson, S.H., and Lunn, N.J. 2015. Variation in Ringed Seal Density and Abundance in Western Hudson Bay Estimated from Aerial Surveys, 1995 to 2013. Arctic 68(3): 301-309. doi:10.14430/arctic4503.

Yurkowski, D.J., Hussey, N.E., Fisk, A.T., Imrie, K.L., Tallman, R.F., and Ferguson, S.H. 2017. Temporal shifts in intraguild predation pressure between beluga whales and Greenland halibut in a changing Arctic. Biology Letters 13(11). doi:10.1098/rsbl.2017.0433. Available from https://royalsocietypublishing.org/doi/pdf/10.1098/rsbl.2017.0433

Yurkowski, D.J., Brown, T.A., Blanchfield, P.J., and Ferguson, S.H. 2020. Atlantic walrus signal latitudinal differences in the long-term decline of sea ice-derived carbon to benthic fauna in the Canadian Arctic. Proc. Biol. Sci. 287: 20202126. doi:10.1098/rspb.2020.2126. Available from https://www.ncbi.nlm.nih.gov/pubmed/33290685

Zevenhhuizen, J. 1996. Late quaternary and surficial marine geology of southeastern Hudson Bay. Thesis (M.Sc.), Dalhousie University, Halifax, NS. 215 p.

APPENDIX

Table A 1. List of phytoplankton, ice algae, and marine macrophyte species observed in the QSA and other areas of the Hudson Bay Complex.

Scientific Nomenclature [1]	Location [2]	Source [3]
Protozoa		
Choanoflagellatea		
Acanthocorbis unguiculata	GWR	Jacquemot et al. 2021
Diaphanoeca grandis	GWR	Jacquemot et al. 2021
Monosiga ovata	GWR	Jacquemot et al. 2021
Sphaeroeca sp.	GWR	Jacquemot et al. 2021
Stephanoeca cauliculata	GWR	Jacquemot et al. 2021
Euglenoidea		
Eutreptiella sp.	NHB	Harvey et al. 1997
Kinetoplastea		
Bodo sp.	HB, HS	Bursa 1961a
Eubacteria		
Cyanophyceae		
Anabaena sp.	HB, HS	Bursa 1961a
Aphanizomenon sp.	HB, HS	Bursa 1961a
Merismopedia tenuissima	NHB	Roff and Legendre 1986
Stigonema sp.	NHB	Roff and Legendre 1986
Chromista		
Bacillariophyceae		
Achnanthes sp.	HB	Anderson et al. 1981
Achnanthes groenlandica	GWR	Legendre and Simard 1979
Actinocyclus curvatulus	GWR	Jacquemot et al. 2021
Amphipleura spp.	GWR	Legendre and Simard 1979
Amphora spp.	NHB, BI, GWR	Legendre and Simard 1979; Roff and Legendre 1986; Ponton and Fortier 1992; Jacquemot et al. 2021
Amophora ostrearia	NHB	Roff and Legendre 1986
Amophora quadrata	NHB	Roff and Legendre 1986
Amylax triacantha var. buxus	GWR	Jacquemot et al. 2021
Asterionella spp.	BI, GWR	Legendre and Simard 1979
Asterionella formosa	HB, GWR	Anderson et al. 1981; Jacquemot et al. 2021
Asterionella gracillima	HB, HS	Bursa 1961a
Asterionella japonica	HB	Anderson et al. 1981
Asterionella kariana	HB, HS	Bursa 1961a

Scientific Nomenclature [1]	**Location** [2]	**Source** [3]
Caloneis spp.	GWR	Legendre and Simard 1979
Caloneis bacillum	HB	Anderson et al. 1981
Ceratoneis fasciola	NHB	Roff and Legendre 1986
Cocconeis spp.	HB, FB, BI, GWR	Bursa 1961b; Legendre and Simard 1979; Anderson et al. 1981
Cocconeis placentula	HB, HS, FB	Bursa 1961a, b
Ctenophora pulchella	NHB	Roff and Legendre 1986
Cylindrotheca closterium	HB, GWR	Anderson et al. 1981; Harvey et al. 1997; Jacquemot et al. 2021
Cymatopleura solea	GWR	Legendre and Simard 1979
Cymbella spp.	BI, GWR	Legendre and Simard 1979
Diatoma spp.	BI, GWR	Legendre and Simard 1979
Diatoma vulgaris	NHB	Roff and Legendre 1986
Diatoma vulgaris var. ehrenbergii	NHB	Roff and Legendre 1986
Diploneis spp.	BI, GWR	Legendre and Simard 1979
Encyonema auerswaldii	NHB	Roff and Legendre 1986
Entomoneis paludosa var. hyperborea	HB, HS, FB	Bursa 1961a, b
Eunotia spp.	GWR	Legendre and Simard 1979
Fragilaria spp.	NHB, BI, GWR	Legendre and Simard 1979; Ponton and Fortier 1992; Harvey et al. 1997; Jacquemot et al. 2021
Fragilaria capucina	HB	Anderson et al. 1981
Fragilaria crotonensis	HB, HS	Bursa 1961a; Anderson et al. 1981
Fragilaria islandica	HB, HS, FB	Bursa 1961a, b
Fragilaria nana	HB, HS	Bursa 1961a
Fragilaria oceanica f. oceanica	HB, HS	Bursa 1961a
Fragilaria striatula	HB, HS	Bursa 1961a
Fragilariopsis cylindricus	HB, HS, FB, GWR	Bursa 1961a, b; Jacquemot et al. 2021
Fragilariopsis pseudonana	NHB	Harvey et al. 1997
Frustulia ventricosa	NHB	Roff and Legendre 1986
Gomphoneis exiguum	NHB	Roff and Legendre 1986
Gomphonema acuminatum	HB, HS	Bursa 1961a
Gomphonema olivaceum	NHB	Roff and Legendre 1986
Gomphonema tinctum	NHB	Roff and Legendre 1986
Grammatophora spp.	GWR	Legendre and Simard 1979
Grammatophora marina	HB, HS	Bursa 1961a
Gyrosigma spp.	HB, FB, GWR	Bursa 1961b; Legendre and Simard 1979; Anderson et al. 1981
Gyrosigma acuminatum	HB, HS, FB	Bursa 1961a, b
Hippodonta capitata	GWR	Jacquemot et al. 2021
Licmophora spp.	BI, GWR	Legendre and Simard 1979
Licmophora abbreviata	HB, HS	Bursa 1961a

Scientific Nomenclature [1]	Location [2]	Source [3]
Licmophora gracilis	NHB	Roff and Legendre 1986
Licmophora gracilis var. anglica	GWR	Legendre and Simard 1979
Licmophora juergensii	GWR	Jacquemot et al. 2021
Mastogloia exigua	NHB	Roff and Legendre 1986
Mastogloia smithii	NHB	Roff and Legendre 1986
Navicula spp.	HB, FB, BI, GWR	Bursa 1961b; Legendre and Simard 1979; Anderson et al. 1981; Ponton and Fortier 1992; Harvey et al. 1997; Jacquemot et al. 2021
Navicula bacillum	NHB	Roff and Legendre 1986
Navicula brebissonii var. subproducta	NHB	Roff and Legendre 1986
Navicula digitoradiata	NHB	Roff and Legendre 1986
Navicula divergens f. elliptica	NHB	Roff and Legendre 1986
Navicula gregaria	GWR	Jacquemot et al. 2021
Navicula lanceolata	NHB	Roff and Legendre 1986
Navicula opima	NHB	Roff and Legendre 1986
Navicula pusilla f pusilla	NHB	Roff and Legendre 1986
Navicula rhynchocephala	NHB	Roff and Legendre 1986
Navicula semen	NHB	Roff and Legendre 1986
Navicula septentrionalis	FB	Bursa 1961b
Navicula vanhoeffenii	HB, HS, FB	Bursa 1961a, b
Nitzschia spp.	BI, GWR	Legendre and Simard 1979; Ponton and Fortier 1992
Nitzschia affinis	NHB	Roff and Legendre 1986
Nitzschia bilobata	FB	Bursa 1961b
Nitzschia closterium	HB, HS, FB	Bursa 1961a, b
Nitzschia delicatissima	HB, HS	Bursa 1961a
Nitzschia dissipata	GWR	Jacquemot et al. 2021
Nitzschia draveillensis	GWR	Jacquemot et al. 2021
Nitzschia frigida	HB, HS, FB	Bursa 1961a, b
Nitzschia lineola	HB, FB	Bursa 1961b; Anderson et al. 1981
Nitzschia longissima	HB, FB	Bursa 1961b; Anderson et al. 1981; Harvey et al. 1997
Nitzschia palea	HB	Anderson et al. 1981
Nitzschia pungens	FB	Bursa 1961b
Pauliella taeniata	HB, HS, FB	Bursa 1961a, b
Pinnularia spp.	HB, HS, FB, GWR	Bursa 1961a, b; Legendre and Simard 1979
Pinnularia alpina	NHB	Roff and Legendre 1986
Pinnularia distans	HB, HS	Bursa 1961a
Pinnularia nobilis	NHB	Roff and Legendre 1986
Pinnularia viridis	NHB	Roff and Legendre 1986
Pleurosigma sp.	HB, HS	Bursa 1961a

Scientific Nomenclature [1]	**Location [2]**	**Source [3]**
Pleurosigma angulatum	NHB	Roff and Legendre 1986
Pleurosigma macrum	NHB	Roff and Legendre 1986
Pleurosigma spenceri	NHB	Roff and Legendre 1986
Pleurosigma spenceri f. curvula	NHB	Roff and Legendre 1986
Pseudo-nitzschia delicatissima	HB, GWR	Anderson et al. 1981; Harvey et al. 1997; Jacquemot et al. 2021
Pseudo-nitzschia seriata	HB, HS, FB, GWR	Bursa 1961a, b; Anderson et al. 1981; Harvey et al. 1997; Jacquemot et al. 2021
Rhabdonema arcuatum	HB, HS	Bursa 1961a
Rhaphoneis luburnica	NHB	Roff and Legendre 1986
Rhipidophora anglica	HB	Legendre and Simard 1979
Rhoicosphenia abbreviata	GWR	Legendre and Simard 1979
Stauroneis anceps	NHB	Roff and Legendre 1986
Stauroneis granii	FB	Bursa 1961b
Surirella spp.	HB, HS, GWR	Bursa 1961a; Legendre and Simard 1979
Synedra spp.	FB, BI, GWR	Bursa 1961b; Legendre and Simard 1979; Ponton and Fortier 1992
Synedra ulna	HB	Anderson et al. 1981
Tabellaria fenestrata	BI, GWR	Legendre and Simard 1979
Tabellaria flocculosa	HB, BI, GWR	Legendre and Simard 1979; Anderson et al. 1981
Tabularia fasciculata	NHB	Roff and Legendre 1986
Tabularia tabulata	GWR	Jacquemot et al. 2021
Thalassionema sp.	GWR	Jacquemot et al. 2021
Thalassionema frauenfeldii	HB, HS, FB	Bursa 1961a, b; Anderson et al. 1981
Thalassionema nitzschioides	HB, HS	Bursa 1961a; Anderson et al. 1981; Harvey et al. 1997
Thalassiothrix longissima	HB, HS	Bursa 1961a
Bolidophyceae		
Triparma sp.	GWR	Jacquemot et al. 2021
Chrysophyceae		
Chrysophytes spp.	NHB	Harvey et al. 1997
Chrysosaccus sp.	GWR	Jacquemot et al. 2021
Chrysosphaerella sp.	GWR	Jacquemot et al. 2021
Dinobryon balticum	HB	Bursa 1961a; Harvey et al. 1997
Dinobryon bavaricum	NHB	Roff and Legendre 1986
Dinobryon crenulatum	GWR	Jacquemot et al. 2021
Dinobryon faculiferum	NHB, GWR	Harvey et al. 1997; Jacquemot et al. 2021
Dinobryon sociale	GWR	Jacquemot et al. 2021
Epipyxis tabellariae	NHB	Roff and Legendre 1986
Mallomonas sp.	GWR	Jacquemot et al. 2021
Monas sp.	GWR	Jacquemot et al. 2021

Scientific Nomenclature [1]	**Location [2]**	**Source [3]**
Ochromonas sp.	NHB	Harvey et al. 1997
Paraphysomonas sp.	GWR	Jacquemot et al. 2021
Synura petersenii	GWR	Jacquemot et al. 2021
Uroglena americana	GWR	Jacquemot et al. 2021
Ciliatea		
Acanthostomella norvegica	HB, HS	Bursa 1961a
Laboea strobila	GWR	Jacquemot et al. 2021
Ptychocylis sp.	GWR	Jacquemot et al. 2021
Stenosomella ventricosa	HB, HS	Bursa 1961a
Strombidium conicoides	HB, HS	Bursa 1961a
Strombidium conicum	HB, HS	Bursa 1961a
Strombidium reticulatum	HB, HS	Bursa 1961a
Coccolithophyceae		
Chrysochromulina sp.	GWR	Jacquemot et al. 2021
Chrysochromulina leadbeateri	GWR	Jacquemot et al. 2021
Chrysochromulina parva	GWR	Jacquemot et al. 2021
Chrysochromulina scutellum	GWR	Jacquemot et al. 2021
Coscinodiscophyceae		
Actinocyclus curvatulus	GWR	Jacquemot et al. 2021
Actinocyclus ehrenbergii	NHB	Roff and Legendre 1986
Actinoptychus sp.	HB, HS	Bursa 1961a
Asteromphalus heptactis	HB	Anderson et al. 1981
Asteromphalus robustus	HB	Anderson et al. 1981
Aulacoseira ambigua	GWR	Jacquemot et al. 2021
Aulacoseira distans	HB, HS	Bursa 1961a
Aulacoseira granulata	HB	Anderson et al. 1981
Aulacoseira islandica	HB, FB	Bursa 1961b; Anderson et al. 1981; Roff and Legendre 1986
Aulacoseira italica	HB	Anderson et al. 1981
Aulacoseira subarctica	GWR	Jacquemot et al. 2021
Coscinodiscus spp.	BI, GWR	Legendre and Simard 1979
Coscinodiscus centralis	HB	Anderson et al. 1981
Coscinodiscus concinnus	HB, HS	Bursa 1961a
Coscinodiscus curvatulus	HB	Anderson et al. 1981
Coscinodiscus granii	HB, HS	Bursa 1961a
Coscinodiscus marginatus	HB, HS	Bursa 1961a
Coscinodiscus oculus-iridis	HB, HS, FB	Bursa 1961a, b
Coscinodiscus radiatus	NHB	Roff and Legendre 1986

Scientific Nomenclature [1]	Location [2]	Source [3]
Coscinodiscus rothii	HB	Anderson et al. 1981
Dactyliosolen fragilissimus	HB, HS	Bursa 1961a; Anderson et al. 1981
Ellerbeckia arenaria	HB, HS, FB	Bursa 1961a, b
Guinardia delicatula	HB	Anderson et al. 1981
Melosira spp.	HB, HS, FB, BI, GWR	Bursa 1961a, b; Legendre and Simard 1979; Ponton and Fortier 1992
Melosira arctica	NHB, FB	Bursa 1961b; Roff and Legendre 1986
Melosira moniliformis	FB	Bursa 1961b
Melosira nummuloides	HB, HS	Bursa 1961a
Proboscia alata	HB, HS, FB	Bursa 1961a, b; Anderson et al. 1981
Pseudoaulacosira sculpta	HB, HS	Bursa 1961a
Rhizosolenia spp.	BI, GWR	Legendre and Simard 1979
Rhizosolenia hebetata f. subacuta	HB	Anderson et al. 1981
Rhizosolenia hebetata f. semispina	HB	Anderson et al. 1981
Rhizosolenia imbricata	HB, HS	Bursa 1961a
Rhizosolenia styliformis	HB, HS, FB	Bursa 1961a, b; Anderson et al. 1981
Stephanopyxis nipponica	HB, HS	Bursa 1961a
Sundstroemia pungens	HB	Anderson et al. 1981
Sundstroemia setigera	HB	Anderson et al. 1981
Urosolenia eriensis	GWR	Jacquemot et al. 2021
Cryptophyceae		
Cryptomonas curvata	GWR	Jacquemot et al. 2021
Cryptomonas tetrapyrenoidosa	GWR	Jacquemot et al. 2021
Cryptophytes spp.	NHB	Harvey et al. 1997
Falcomonas daucoides	GWR	Jacquemot et al. 2021
Plagioselmis nannoplanctica	GWR	Jacquemot et al. 2021
Plagioselmis prolonga	GWR	Jacquemot et al. 2021
Rhodomonas sp.	GWR	Jacquemot et al. 2021
Teleaulax amphioxeia	GWR	Jacquemot et al. 2021
Teleaulax gracilis	GWR	Jacquemot et al. 2021
Dictyochophyceae		
Apedinella radians	NHB	Harvey et al. 1997
Octatis speculum	HB	Bursa 1961a; Harvey et al. 1997
Pseudopedinella pyriformis	NHB	Harvey et al. 1997
Stephanocha spp.	BI, GWR	Legendre and Simard 1979
Dinophyceae		
Alexandrium sp.	GWR	Jacquemot et al. 2021
Alexandrium ostenfeldii	NHB	Harvey et al. 1997

Scientific Nomenclature [1]	**Location [2]**	**Source [3]**
Amphidinium sp.	HB, HS	Bursa 1961a
Amphidinium crassum	HB	Anderson et al. 1981; Harvey et al. 1997
Amphidinium flexum	NHB	Roff and Legendre 1986
Amphidinium klebsii	HB	Anderson et al. 1981
Amphidinium longum	HB	Anderson et al. 1981
Amphidinium luteum	HB	Anderson et al. 1981
Amphisolenia sp.	NHB	Roff and Legendre 1986
Asulcocephalium miricentonis	GWR	Jacquemot et al. 2021
Balechina gracilis	GWR	Jacquemot et al. 2021
Biecheleria ordinata	HB	Anderson et al. 1981
Ceratium spp.	HB, HS, BI, GWR	Bursa 1961a; Legendre and Simard 1979
Ceratium arcticum	HB	Anderson et al. 1981; Harvey et al. 1997
Ceratium hirundinella	HB	Anderson et al. 1981
Cochlodinium sp.	NHB	Harvey et al. 1997
Cochlodinium brandti	NHB	Roff and Legendre 1986
Cucumeridinium coeruleum	NHB	Roff and Legendre 1986
Dinophysis spp.	BI, GWR	Legendre and Simard 1979; Jacquemot et al. 2021
Dinophysis acuminata	HB, HS	Bursa 1961a; Anderson et al. 1981; Harvey et al. 1997
Dinophysis acuta	HB, HS	Bursa 1961a; Anderson et al. 1981
Dinophysis arctica	HB, HS	Bursa 1961a; Anderson et al. 1981
Dinophysis granii	HB, HS	Bursa 1961a
Dinophysis islandica	HB, HS	Bursa 1961a
Dinophysis norvegica	HB, HS	Bursa 1961a; Anderson et al. 1981
Dinophysis ovum	HB	Anderson et al. 1981
Dinophysis robusta	HB, HS	Bursa 1961a
Dinoflagellate sp.	NHB	Harvey et al. 1997
Diplopsalis lenticula	HB, HS	Bursa 1961a
Glenodinium sp.	HB, HS	Bursa 1961a
Glenodinium obliquum	HB	Anderson et al. 1981
Gonyaulax sp.	HB, HS	Bursa 1961a
Gonyaulax spinifera	NHB	Harvey et al. 1997
Gymnodinium sp.	NHB, GWR	Harvey et al. 1997; Jacquemot et al. 2021
Gymnodinium albulum	HB	Anderson et al. 1981
Gymnodinium arcticum	HB	Anderson et al. 1981
Gymnodinium bohemicum	HB	Anderson et al. 1981
Gymnodinium dorsalisulcum	GWR	Jacquemot et al. 2021
Gymnodinium excavatum	HB	Anderson et al. 1981

Scientific Nomenclature [1]	**Location** [2]	**Source** [3]
Gymnodinium filum	HB	Anderson et al. 1981
Gymnodinium fuscum	NHB	Roff and Legendre 1986
Gymnodinium fusiforme	NHB	Harvey et al. 1997
Gymnodinium hyalinum	NHB	Roff and Legendre 1986
Gymnodinium marinum	NHB	Roff and Legendre 1986
Gymnodinium minor	NHB	Roff and Legendre 1986
Gymnodinium pygmaeum	HB	Anderson et al. 1981
Gymnodinium rhomboides	HB	Anderson et al. 1981
Gymnodinium rubrocinctum	NHB	Roff and Legendre 1986
Gymnodinium uberrimum	HB	Anderson et al. 1981
Gymnodinium varians	HB	Anderson et al. 1981
Gyrodinium arcticum	FB	Bursa 1961b
Gyrodinium britannia	HB	Anderson et al. 1981
Gyrodinium dominans	GWR	Jacquemot et al. 2021
Gyrodinium fusiforme	GWR	Jacquemot et al. 2021
Gyrodinium helveticum	HB, GWR	Anderson et al. 1981; Jacquemot et al. 2021
Gyrodinium heterogrammum	GWR	Jacquemot et al. 2021
Gyrodinium heterostriatum	NHB	Roff and Legendre 1986
Gyrodinium pingue	HB	Anderson et al. 1981
Gyrodinium spirale	HB	Anderson et al. 1981
Hemidinium nasutum	NHB	Roff and Legendre 1986
Heterocapsa rotundata	HB, GWR	Anderson et al. 1981; Harvey et al. 1997; Jacquemot et al. 2021
Kapelodinium vestifici	HB, GWR	Anderson et al. 1981; Jacquemot et al. 2021
Karenia brevis	NHB	Roff and Legendre 1986
Lebouridinium glaucum	NHB	Roff and Legendre 1986; Harvey et al. 1997
Levanderina fissa	NHB	Roff and Legendre 1986
Lingulodinium polyedra	NHB	Roff and Legendre 1986
Margalefidinium fulvescens	GWR	Jacquemot et al. 2021
Nematodinium armatum	NHB	Roff and Legendre 1986
Nusuttodinium latum	NHB	Roff and Legendre 1986
Ornithocercus sp.	GWR	Jacquemot et al. 2021
Oxytoxum sp.	NHB	Harvey et al. 1997
Oxytoxum gladiolus	HB, HS	Bursa 1961a
Oxytoxum sphaeroideum	HB	Anderson et al. 1981
Parvodinium pusillum	HB	Anderson et al. 1981
Pentapharsodinium sp.	GWR	Jacquemot et al. 2021
Peridiniella catenata	HB, HS	Bursa 1961a

Scientific Nomenclature [1]	Location [2]	Source [3]
Peridinium spp.	GWR	Legendre and Simard 1979
Peridinium ovatum	BI, GWR	Legendre and Simard 1979
Peridinium simplex	HB, HS	Bursa 1961a
Phalacroma rotundatum	HB, HS, GWR	Bursa 1961a; Anderson et al. 1981; Jacquemot et al. 2021
Prorocentrum sp.	GWR	Jacquemot et al. 2021
Prorocentrum aporum	NHB	Roff and Legendre 1986
Prorocentrum balticum	HB, HS	Bursa 1961a
Prorocentrum cordatum	NHB	Harvey et al. 1997
Prorocentrum dentatum	NHB	Roff and Legendre 1986
Prorocentrum micans	NHB	Roff and Legendre 1986
Prorocentrum reticulatum	HB, HS	Bursa 1961a
Prorocentrum scutellum	NHB	Roff and Legendre 1986
Prorocentrum lima	NHB	Roff and Legendre 1986
Prosoaulax lacustris	HB	Anderson et al. 1981
Protoceratium reticulatum	GWR	Jacquemot et al. 2021
Protodinium simplex	HB	Anderson et al. 1981
Protoperidinium spp.	NHB, GWR	Harvey et al. 1997; Jacquemot et al. 2021
Protoperidinium avellana	HB, HS	Bursa 1961a
Protoperidinium achromaticum	HB, HS	Bursa 1961a
Protoperidinium bipes	HB, HS, GWR	Bursa 1961a; Harvey et al. 1997; Jacquemot et al. 2021
Protoperidinium brevipes	HB, HS	Bursa 1961a; Anderson et al. 1981; Harvey et al. 1997
Protoperidinium cerasus	HB, HS	Bursa 1961a
Protoperidinium conicum	HB, HS	Bursa 1961a; Roff and Legendre 1986
Protoperidinium crassipes	HB, HS	Bursa 1961a
Protoperidinium curvipes	HB, HS	Bursa 1961a
Protoperidinium denticulatum	HB, HS	Bursa 1961a
Protoperidinium depressum	HB, HS	Bursa 1961a; Anderson et al. 1981
Protoperidinium divergens	HB, HS	Bursa 1961a
Protoperidinium finlandicum	HB, HS	Bursa 1961a
Protoperidinium globulus	HB, HS	Bursa 1961a; Anderson et al. 1981
Protoperidinium granii	HB, HS	Bursa 1961a
Protoperidinium islandicum	HB, HS	Bursa 1961a
Protoperidinium leonis	HB, HS	Bursa 1961a
Protoperidinium mite	HB, HS	Bursa 1961a
Protoperidinium obtusum	HB, HS	Bursa 1961a
Protoperidinium oceanicum	HB, HS	Bursa 1961a
Protoperidinium ovatum	HB, HS	Bursa 1961a; Legendre and Simard 1979

Scientific Nomenclature [1]	**Location** [2]	**Source** [3]
Protoperidinium pallidum	HB, HS	Bursa 1961a; Anderson et al. 1981
Protoperidinium pellucidum	HB	Anderson et al. 1981; Harvey et al. 1997
Protoperidinium pentagonum	HB, HS	Bursa 1961a; Roff and Legendre 1986
Protoperidinium roseum	HB, HS	Bursa 1961a
Protoperidinium steini	HB, HS	Bursa 1961a
Protoperidinium subinerme	HB, HS	Bursa 1961a
Protoperidinium subcurvipes	HB, HS	Bursa 1961a
Protoperidinium thorianum	HB, HS	Bursa 1961a
Protoperidinium triquetrum	HB, HS	Bursa 1961a; Anderson et al. 1981
Pseliodinium fusus	NHB	Roff and Legendre 1986
Scrippsiella acuminata	HB, HS	Bursa 1961a; Anderson et al. 1981; Harvey et al. 1997
Spatulodinium pseudonoctiluca	NHB	Roff and Legendre 1986
Togula britannicum	HB	Anderson et al. 1981
Torodinium robustum	HB, GWR	Anderson et al. 1981; Harvey et al. 1997; Jacquemot et al. 2021
Torquentidium helix	NHB	Roff and Legendre 1986
Triadinium polyedricum	HB, HS	Bursa 1961a
Tripos arietinus	HB, HS	Bursa 1961a
Tripos karstenii	HB, HS	Bursa 1961a
Tripos lineatus	HB, HS	Bursa 1961a
Tripos longipes	HB, HS	Bursa 1961a; Anderson et al. 1981
Tripos macroceros	HB, HS	Bursa 1961a
Tripos muelleri	HB, HS	Bursa 1961a
Tripos tenuis	GWR	Jacquemot et al. 2021
Tryblionella compressa	NHB	Roff and Legendre 1986
Imbricatea		
Peregrinia sp.	GWR	Jacquemot et al. 2021
Spongomonas sp.	GWR	Jacquemot et al. 2021
Katablepharidaceae		
Katablepharis japonica	GWR	Jacquemot et al. 2021
Leucocryptos sp.	GWR	Jacquemot et al. 2021
Leucocryptos marina	NHB	Harvey et al. 1997
Litostomatea		
Askenasia sp.	GWR	Jacquemot et al. 2021
Cyclotrichium sp.	GWR	Jacquemot et al. 2021
Didinium gargantua	HB, HS	Bursa 1961a
Didinium nasutum	GWR	Jacquemot et al. 2021
Loxophyllum perihoplophorum	GWR	Jacquemot et al. 2021

Scientific Nomenclature [1]	**Location [2]**	**Source [3]**
Mesodinium rubrum	GWR	Jacquemot et al. 2021
Phialina salinarum	GWR	Jacquemot et al. 2021
Mamiellophyceae		
Mamiella gilva	GWR	Jacquemot et al. 2021
Micromonas commoda	GWR	Jacquemot et al. 2021
Micromonas polaris	GWR	Jacquemot et al. 2021
Mediophyceae		
Attheya decora	HB, HS	Bursa 1961a
Attheya septentrionalis	GWR	Jacquemot et al. 2021
Arcocellulus cornucervis	NHB	Harvey et al. 1997
Bacterosira bathyomphala	HB, HS, FB	Bursa 1961a, b
Biddulphia sp.	HB	Anderson et al. 1981
Chaetoceros spp.	NHB, BI, GWR	Legendre and Simard 1979; Ponton and Fortier 1992; Harvey et al. 1997; Jacquemot et al. 2021
Chaetoceros affinis	FB	Bursa 1961b
Chaetoceros atlanticus	HB, HS, FB	Bursa 1961a, b; Anderson et al. 1981; Harvey et al. 1997
Chaetoceros borealis	HB, HS, FB	Bursa 1961a, b
Chaetoceros brevis	HB, GWR	Anderson et al. 1981; Jacquemot et al. 2021
Chaetoceros compressus	HB, HS, FB	Bursa 1961a, b; Anderson et al. 1981; Harvey et al. 1997
Chaetoceros concavicornis	HB, HS	Bursa 1961a; Harvey et al. 1997
Chaetoceros convolutus	HB, HS	Bursa 1961a; Anderson et al. 1981; Harvey et al. 1997
Chaetoceros curvisetus	HB, HS, FB	Bursa 1961a, b
Chaetoceros danicus	HB	Anderson et al. 1981
Chaetoceros debilis	HB, HS, FB	Bursa 1961a, b; Anderson et al. 1981; Harvey et al. 1997
Chaetoceros decipiens	HB, HS, FB, GWR	Bursa 1961a, b; Anderson et al. 1981; Harvey et al. 1997; Jacquemot et al. 2021
Chaetoceros diadema	HB, HS	Bursa 1961a; Anderson et al. 1981; Harvey et al. 1997
Chaetoceros eibenii	HB, HS, FB	Bursa 1961a, b
Chaetoceros fragilis	HB	Anderson et al. 1981
Chaetoceros furcellatus	HB, HS, FB	Bursa 1961a, b; Harvey et al. 1997
Chaetoceros gracilis	HB, HS, FB	Bursa 1961a, b
Chaetoceros holsaticus	HB	Anderson et al. 1981
Chaetoceros karianus	HB, HS, FB	Bursa 1961a, b
Chaetoceros laciniosus	HB, HS, FB	Bursa 1961a, b; Anderson et al. 1981; Harvey et al. 1997
Chaetoceros lorenzianus	HB, HS, FB	Bursa 1961a, b; Anderson et al. 1981
Chaetoceros mitra	FB	Bursa 1961b
Chaetoceros neogracilis	HB, GWR	Anderson et al. 1981; Jacquemot et al. 2021
Chaetoceros perpusillus	FB	Bursa 1961b
Chaetoceros peruvianus	GWR	Jacquemot et al. 2021

Scientific Nomenclature [1]	**Location** [2]	**Source** [3]
Chaetoceros septentrionalis	HB, HS, FB, GWR	Bursa 1961a, b; Anderson et al. 1981; Jacquemot et al. 2021
Chaetoceros similis	NHB	Harvey et al. 1997
Chaetoceros simplex	NHB	Roff and Legendre 1986
Chaetoceros socialis	HB, HS, FB	Bursa 1961a, b; Harvey et al. 1997
Chaetoceros subsecundus	FB	Bursa 1961b
Chaetoceros subtilis	NHB	Harvey et al. 1997
Chaetoceros teres	HB, HS, FB	Bursa 1961a, b; Anderson et al. 1981
Chaetoceros wighamii	HB, HS, FB	Bursa 1961a, b; Anderson et al. 1981
Cyclotella spp.	BI, GWR	Legendre and Simard 1979
Detonula confervacea	FB	Bursa 1961b
Eucampia groenlandica	HB	Anderson et al. 1981
Eucampia zodiacus	HB, HS, FB	Bursa 1961a, b
Eunotogramma debile	NHB	Roff and Legendre 1986
Helicotheca tamensis	FB	Bursa 1961b
Isthmia nervosa	HB, HS	Bursa 1961a
Leptocylindrus danicus	HB, HS	Bursa 1961a; Anderson et al. 1981; Harvey et al. 1997
Leptocylindrus minimus	HB, HS, GWR	Bursa 1961a; Anderson et al. 1981; Harvey et al. 1997; Jacquemot et al. 2021
Lindavia comta	HB	Anderson et al. 1981
Minidiscus trioculatus	GWR	Jacquemot et al. 2021
Odontella aurita	HB, HS, FB, GWR	Bursa 1961a, b; Jacquemot et al. 2021
Porosira glacialis	HB, HS, FB, GWR	Bursa 1961a, b; Jacquemot et al. 2021
Skeletonema sp.	GWR	Jacquemot et al. 2021
Skeletonema costatum	HB, HS	Bursa 1961a; Anderson et al. 1981; Harvey et al. 1997
Skeletonema marinoi	GWR	Jacquemot et al. 2021
Stephanodiscus sp.	GWR	Jacquemot et al. 2021
Stephanodiscus astraea	HB, HS	Bursa 1961a
Stephanodiscus hantzschii	HB	Anderson et al. 1981
Thalassiosira spp.	HB, HS, FB, BI, GWR	Bursa 1961a, b; Legendre and Simard 1979; Ponton and Fortier 1992; Harvey et al. 1997; Jacquemot et al. 2021
Thalassiosira aestivalis	GWR	Jacquemot et al. 2021
Thalassiosira angustelineata	HB, HS, FB	Bursa 1961a, b; Anderson et al. 1981
Thalassiosira bioculata	HB, HS	Bursa 1961a; Harvey et al. 1997
Thalassiosira condensata	FB	Bursa 1961b
Thalassiosira decipiens	HB, HS	Bursa 1961a; Anderson et al. 1981
Thalassiosira excentricus	FB	Bursa 1961b
Thalassiosira gravida	HB, HS, FB	Bursa 1961a, b; Anderson et al. 1981; Harvey et al. 1997
Thalassiosira hispida	GWR	Jacquemot et al. 2021
Thalassiosira hyalina	HB, HS	Bursa 1961a; Anderson et al. 1981

Scientific Nomenclature [1]	**Location** [2]	**Source** [3]
Thalassiosira leptopus	HB, HS	Bursa 1961a
Thalassiosira nordenskioeldii	HB, HS, FB	Bursa 1961a, b; Anderson et al. 1981; Harvey et al. 1997
Thalassiosira rotula	HB, HS, FB	Bursa 1961a, b
Thalassiosira subtilis	HB, HS, FB	Bursa 1961a, b
Oligohymenophorea		
Stokesia vernalis	GWR	Jacquemot et al. 2021
Vorticella campanula	GWR	Jacquemot et al. 2021
Vorticella convallaria	GWR	Jacquemot et al. 2021
Vorticella microstoma	GWR	Jacquemot et al. 2021
Oligotrichea		
Ptychocylis arctica	HB, HS	Bursa 1961a
Ptychocylis obtusa	HB, HS	Bursa 1961a
Ptychocylis urnula	HB, HS	Bursa 1961a
Rimostrombidium sp.	GWR	Jacquemot et al. 2021
Spirotontonia sp.	GWR	Jacquemot et al. 2021
Strombidium sp.	GWR	Jacquemot et al. 2021
Strombidium biarmatum	GWR	Jacquemot et al. 2021
Pavlovophyceae		
Diacronema sp.	GWR	Jacquemot et al. 2021
Pelagophyceae		
Ankylochrysis sp.	GWR	Jacquemot et al. 2021
Aureococcus anophagefferens	GWR	Jacquemot et al. 2021
Phaeophyceae		
Agarum clathratum	BI, HB, JB, HS	Government of Nunavut 2010; Lee 1980
Alaria esculenta	BI, HB, HS	Government of Nunavut 2010; Lee 1980
Arcticophycus glacialis	NHB	Lee 1980
Ascophyllum nodosum	HS	Lee 1980
Asperococcus fistulosus	HS	Lee 1980
Battersia arctica	NHB, HS	Lee 1980
Chaetopteris plumosa	GWR, JB, HB, HS	Lee 1980
Chorda filum	GWR, JB, HS	Lee 1980
Chordaria flagelliformis	GWR, JB, HB, HS	Lee 1980
Coilodesme bulligera	HS	Lee 1980
Desmarestia aculeata	BI, NHB, JB, HS	Lee 1980; Government of Nunavut 2010
Desmarestia viridis	HS	Lee 1980
Dictyosiphon foeniculaceus	NHB, JB, HS	Lee 1980
Ectocarpus fasciculatus	HS	Lee 1980

Scientific Nomenclature [1]	Location [2]	Source [3]
Ectocarpus siliculosus	GWR, JB, HS	Lee 1980
Elachista fucicola	GWR, NHB, JB, HS	Lee 1980
Eudesme virescens	GWR, HS	Lee 1980
Fucus distichus	GWR, NHB, JB, HS	Nozais et al. 2021; Lee 1980
Fucus vesiculosus	NHB, JB	Lee 1980
Halosiphon tomentosus	GWR, HS	Lee 1980
Haplospora globosa	GWR	Lee 1980
Hedophyllum nigripes	HS	Lee 1980
Hincksia ovata	HS	Lee 1980
Isthmoplea sphaerophora	HS	Lee 1980
Laminaria digitata	HB, HS	Lee 1980
Laminaria solidungula	NHB, HS	Lee 1980
Laminariocolax aecidioides	NHB, HS	Lee 1980
Laminariocolax tomentosoides	NHB, HS	Lee 1980
Leptonematella fasciculata	NHB, HS	Lee 1980
Lithoderma fatiscens	HS	Lee 1980
Microspongium globosum	NHB, HS	Lee 1980
Microspongium stilophorae	HS	Lee 1980
Myrionema strangulans	JB	Lee 1980
Petalonia fascia	GWR, JB, HS	Lee 1980
Phaeostroma parasiticum	HS	Lee 1980
Phaeostroma pustulosum	NHB, HS	Lee 1980
Pogotrichum filiforme	HS	Lee 1980
Protohalopteris radicans	GWR	Lee 1980
Pseudolithoderma extensum	NHB, HS	Lee 1980
Pseudolithoderma subextensum	HS	Lee 1980
Pseudoralfsia verrucosa	HS	Lee 1980
Punctaria tenuissima	NHB, JB	Lee 1980
Pylaiella littoralis	GWR, NHB, JB, FB, HS	Lee 1980
Ralfsia fungiformis	NHB, JB, HS	Lee 1980
Saccharina latissima	BI, NHB, JB, FB, HS	Government of Nunuvut 2010; Lee 1980
Saccorhiza dermatodea	HS	Lee 1980
Scytosiphon lomentaria	HS	Lee 1980
Sorapion kjellmanii	NHB, HS	Lee 1980

Scientific Nomenclature [1]	**Location** [2]	**Source** [3]
Sphacelaria cirrosa	JB	Lee 1980
Stictyosiphon tortilis	GWR, JB, HB, HS	Lee 1980
Stragularia clavata	HS	Lee 1980
Symphyocarpus strangulans	NHB	Lee 1980
Prostomatea		
Urotricha sp.	GWR	Jacquemot et al. 2021
Prymnesiophyceae		
Chrysochromulina sp.	NHB	Harvey et al. 1997
Coccolithus sp.	HB, HS	Bursa 1961a
Emiliania huxleyi	HB, HS	Bursa 1961a
Phaeocystis pouchetii	GWR	Jacquemot et al. 2021
Spirotrichea		
Codonella sp.	HB, HS	Bursa 1961a
Leegaardiella sp.	GWR	Jacquemot et al. 2021
Leprotintinnus bottnicus	HB, HS	Bursa 1961a
Salpingella acuminata	HB, HS	Bursa 1961a
Tintinnidium sp.	GWR	Jacquemot et al. 2021
Tintinnopsis sp.	GWR	Jacquemot et al. 2021
Tintinnopsis beroidea	HB, HS	Bursa 1961a
Tintinnopsis karajacensis	HB, HS	Bursa 1961a
Tintinnopsis parvula	HB, HS	Bursa 1961a
Thecofilosea		
Cryothecomonas aestivalis	GWR	Jacquemot et al. 2021
Ebria tripartiita	BI, GWR	Legendre and Simard 1979; Jacquemot et al. 2021
Xanthophyceae		
Meringosphaera mediterranea	SFC	Harvey et al. 1997
Plantae		
Bangiophyceae		
Porphyra purpurea	HB, HS	Lee 1980
Wildemania miniata	HS	Lee 1980
Chlorophyceae		
Ankistrodesmus falcatus	NHB	Roff and Legendre 1986
Ankistrodesmus spiralis	NHB	Roff and Legendre 1986
Arthrochaete penetrans	NHB, FB, HS	Lee 1980
Chlorochytrium dermatocolax	NHB, JB, FB, HS	Lee 1980
Chlorochytrium schmitzii	HS	Lee 1980
Coccomonas orbicularis	NHB	Roff and Legendre 1986

Scientific Nomenclature [1]	Location [2]	Source [3]
Diplostauron elegans	NHB	Harvey et al. 1997
Gloeocystis sp.	NHB, HS	Roff and Legendre 1986; Lee 1980
Gloeomonas sp.	NHB	Roff and Legendre 1986
Lobomonas sp.	NHB	Roff and Legendre 1986
Oedogonium sp.	NHB	Roff and Legendre 1986
Pandorina spp.	GWR	Legendre and Simard 1979
Pediastrum duplex	NHB	Roff and Legendre 1986
Pleodorina sp.	NHB	Roff and Legendre 1986
Scenedesmus quadricauda	HB, HS	Bursa 1961a
Thoracomonas phacotoides	NHB	Roff and Legendre 1986
Urococcus sp.	NHB	Roff and Legendre 1986
Vitreochlamys sp.	NHB	Roff and Legendre 1986
Chlorodendrophyceae		
Pachysphaera pelagica	NHB	Harvey et al. 1997
Prasinophytes sp.	NHB	Harvey et al. 1997
Pseudoscourfieldia marina	NHB	Harvey et al. 1997
Pterosperma cristatum	NHB	Harvey et al. 1997
Pyramimonas sp.	NHB	Harvey et al. 1997
Compsopogonophyceae		
Erythrocladia irregularis	NHB	Lee 1980
Erythrotrichia carnea	JB	Lee 1980
Conjugatophyceae		
Staurodesmus incus	HB	Legendre and Simard 1979
Florideophyceae		
Acrochaetium parvulum	NHB	Lee 1980
Acrochaetium secundatum	HS	Lee 1980
Ahnfeltia plicata	GWR, HB, JB, HS	Lee 1980
Champia sp.	BI	Government of Nunavut 2010
Clathromorphum circumscriptum	HS	Lee 1980
Clathromorphum compactum	GWR, NHB	Lee 1980
Coccotylus hartzii	HB, JB, HS	Lee 1980
Coccotylus truncatus	GWR, HB, JB, HS	Lee 1980
Devaleraea ramentacea	NHB, HS	Lee 1980
Dumontia contorta	JB	Lee 1980
Euthora cristata	NHB, HS	Lee 1980
Fimbrifolium dichotomum	HS	Lee 1980
Grania efflorescens	NHB	Lee 1980

Scientific Nomenclature [1]	Location [2]	Source [3]
Harveyella mirabilis	NHB, JB, HS	Lee 1980
Hildenbrandia rubra	HS	Lee 1980
Kallymenia schmitzii	HS	Lee 1980
Leptophytum laeve	GWR	Lee 1980
Leptosiphonia flexicaulis	HS	Lee 1980
Lithothamnion glaciale	GWR, NHB	Lee 1980
Membranoptera alata	HS	Lee 1980
Membranoptera fabricana	HS	Lee 1980
Membranoptera spinulosa	HS, JB	Lee 1980
Neodilsea integra	GWR, NHB, JB, HS	Lee 1980
Odonthalia dentata	GWR, HB, JB, HS	Lee 1980
Palmaria palmata	BI, HB, JB, HS	Government of Nunavut 2010; Lee 1980
Peyssonnelia johanseni	JB	Lee 1980
Phycodrys rubens	GWR, HB, JB, HS	Lee 1980
Phymatolithon laevigatum	GWR	Lee 1980
Polysiphonia stricta	HB, JB, HS	Lee 1980
Ptilota gunneri	HS	Lee 1980
Ptilota serrata	HB, JB, HS	Lee 1980
Rhodomela confervoides	HB, HS	Lee 1980
Rhodomela lycopodioides	GWR, NHB, JB, HS	Lee 1980
Rubrointrusa membranacea	NHB	Lee 1980
Savoiea arctica	GWR, HB, JB, HS	Lee 1980
Scagelia americana	HS	Lee 1980
Scagelia pylaisaei	NHB, HS	Lee 1980
Scagelothamnion pusillum	GWR, NHB, JB, HS	Lee 1980
Turnerella pennyi	GWR, NHB	Lee 1980
Magnoliopsida		
Zostera subg. Zostera marina	HB, JB	Lalumière and Lemieux 2002
Mamiellophyceae		
Bathycoccus prasinos	GWR	Jacquemot et al. 2021
Pyramimonadophyceae		
Halosphaera viridis	BI, GWR	Legendre and Simard 1979
Pyramimonas australis	GWR	Jacquemot et al. 2021
Ulvophyceae		
Acrosiphonia arcta	HB, FB, HS	Lee 1980

Scientific Nomenclature [1]	**Location [2]**	**Source [3]**
Binuclearia sp.	NHB	Roff and Legendre 1986
Blidingia marginata	HB, HS	Lee 1980
Blidingia minima	HS	Lee 1980
Blidingia subsalsa	NHB	Lee 1980
Bolbocoleon piliferum	HB, HS	Lee 1980
Chaetomorpha melagonium	NHB, HS	Lee 1980
Cladophora sericea	HS	Lee 1980
Cladophora sp.	HS	Lee 1980
Codiolum pusillum	HS	Lee 1980
Codium fragile	NHB	Nunavut 2014
Epicladia flustrae	NHB, HS	Lee 1980
Gayralia oxysperma	HB	Lee 1980
Kornmannia leptoderma	HS	Lee 1980
Percursaria percursa	HS	Lee 1980
Pseudothrix groenlandica	HB	Lee 1980
Rhizoclonium riparium	HB, HS	Lee 1980
Spongomorpha aeruginosa	NHB, HS	Lee 1980
Ulothrix flacca	NHB, HS	Lee 1980
Ulothrix subflaccida	HS	Lee 1980
Ulva clathrata	JB, HS	Lee 1980
Ulva compressa	GWR, HB, HS	Lee 1980
Ulva intestinalis	HB, JB, HS	Lee 1980
Ulva lactuca	NHB, JB, HS	Lee 1980
Ulva paradoxa	HB, HS, JB	Lee 1980
Ulva prolifera	NHB, JB, HS	Lee 1980
Ulva rigida	HB, HS	Lee 1980
Ulvaria obscura	HS	Lee 1980
Ulvella scutata	HS	Lee 1980
Ulvella viridis	HB	Lee 1980
Urospora penicilliformis	HS	Lee 1980
Urospora wormskjoldii	NHB	Lee 1980
Trebouxiophyceae		
Rosenvingiella polyrhiza	HS	Lee 1980
Zygnematophyceae		
Closterium spp.	BI, GWR	Legendre and Simard 1979
Euastrum elegans	NHB	Roff and Legendre 1986
Spondylosium planum	NHB	Roff and Legendre 1986

Scientific Nomenclature [1]	Location [2]	Source [3]
Staurastrum paradoxum	NHB	Roff and Legendre 1986
Staurodesmus megacanthus	BI, GWR	Legendre and Simard 1979

1 - Each lower level taxon (Family, Genus, or species) organized by Phylum and Class; updated to latest accepted taxonomy (Algae Base 2022).

2 - BI = Belcher Islands, FB = Foxe Basin, GWR = Great Whale River estuary and adjacent coast, HB = Hudson Bay (non-specific), HS = Hudson Strait, NHB = Northern Hudson Bay.

3 - Jacquemot et al. (2021) taxa identified from rRNA and rDNA sequences present in samples.

Table A 2. List of zooplankton and ice-associated fauna observed in the QSA and other areas of the Hudson Bay Complex.

Scientific Nomenclature [1]	Location [2]	Source(s)
Ctenophora		
Nuda		
Beroida		
Beroe cucumis	HS, FB	Grainger 1962
Tentaculata		
Cydippida		
Mertensia ovum	HS, FB	Grainger 1962
Cnidaria		
Hydrozoa		
Anthoathecata		
Bougainvillia superciliaris	NHB, FB	Grainger 1962
Sarsia tubulosa	FB	Grainger 1962
Leptothecata		
Tiaropsis multicirrata	FB	Grainger 1959, 1962
Narcomedusae		
Aeginopsis laurentii	HB, BI, GWR	Grainger 1988; Rochet and Grainger 1988; Estrada et al. 2012
Trachymedusae		
Aglantha digitale	NHB, FB, BI, GWR, NQC	Grainger 1959, 1962; Rochet and Grainger 1988; Lalande and Fortier 2011
Mollusca		
Gastropoda		
Pteropoda		
Clione limacina	NHB, BI, GWR, NQC	Grainger 1962; Rochet and Grainger 1988; Harvey et al. 2001; Government of Nunavut 2010
Limacina helicina	NHB, FB, BI, GWR, NQC	Grainger 1962, 1988; Rochet and Grainger 1988; Harvey et al. 2001

Scientific Nomenclature [1]	Location [2]	Source(s)
Annelida		
Polychaeta	HB	Harvey et al. 2001; Estrada et al. 2012
Phyllodocida		
Tomopteris sp.	HB	Estrada et al. 2012
Arthropoda		
Arachnida		
Acari unidentified	BI	Rochet and Grainger 1988
Copepoda		
Calanoida		
Calanoid nauplii	NHB, FB	Grainger 1959, 1962; Thomas 1999
Acartia longiremis	HB, FB, BI, GWR, NQC	Grainger 1962, 1988; Rochet and Grainger 1988; Drolet et al. 1991; Ponton and Fortier 1992; Harvey et al. 2001; Harvey et al. 2001
Calanus finmarchicus	NHB, FB	Grainger 1962; Harvey et al. 2001
Calanus glacialis	NHB, FB, BI, GWR, NQC	Grainger 1962; Rochet and Grainger 1988; Drolet et al. 1991; Ponton and Fortier 1992; Thomas 1999; Harvey et al. 2001
Calanus hyperboreus	NHB, FB, BI, GWR, NQC	Grainger 1962; Rochet and Grainger 1988; Harvey et al. 2001
Centropages abdominalis	LT	Rochet and Grainger 1988
Centropages hamatus	NHB	Harvey et al. 2001
Eurtytemora herdmani	LT	Rochet and Grainger 1988
Paraeuchaeta norvegica	HB	Estrada et al. 2012
Metridia longa	NHB, FB, BI, GWR, NQC	Grainger 1962; Rochet and Grainger 1988; Drolet et al. 1991; Ponton and Fortier 1992; Harvey et al. 2001
Microcalanus sp.	HB	Estrada et al. 2012
Microcalanus pygmaeus	NHB, FB, BI, GWR, NQC	Grainger 1962, 1988; Rochet and Grainger 1988; Drolet et al. 1991; Ponton and Fortier 1992
Pseudocalanus spp.	HB, BI, GWR, NQC	Grainger 1988; Rochet and Grainger 1988; Drolet et al. 1991; Ponton and Fortier 1992; Harvey et al. 2001; Estrada et al. 2012
Pseudocalanus minutus	NHB, FB	Grainger 1959, 1962; Thomas 1999
Cyclopoida		
Oithona similis	NHB, FB, BI, GWR, NQC	Grainger 1962, 1988; Rochet and Grainger 1988; Drolet et al. 1991; Ponton and Fortier 1992
Triconia borealis	NHB, FB, BI, GWR, NQC	Grainger 1962, 1988; Rochet and Grainger 1988; Drolet et al. 1991; Ponton and Fortier 1992; Estrada et al. 2012
Harpacticoida		
Halectinosoma sp.	GWR	Grainger 1988
Harpacticus superflexus	GWR	Grainger 1988
Tisbe furcata	GWR	Grainger 1988

Scientific Nomenclature [1]	Location [2]	Source(s)
Malacostraca		
Amphipoda		
Hyperia sp.	HB	Estrada et al. 2012
Hyperia galba	NHB	Harvey et al. 2001
Hyperoche medusarum	FB	Grainger 1959
Onisimus glacialis	FB	Grainger 1962
Onisimus nanseni	NHB, FB	Grainger 1962
Themisto abyssorum	HB	Grainger 1962; Harvey et al. 2001; Estrada et al. 2012
Themisto compressa	HB	Estrada et al. 2012
Themisto gaudichaudii	NHB	Grainger 1962
Themisto libellula	NHB, BI	Rochet and Grainger 1988; Harvey et al. 2001
Decapoda		
Decapod sp. larvae	NHB	Harvey et al. 2001; Estrada et al. 2012
Pagurus sp.	FB	Grainger 1959
Euphausiacea		
Euphausiacean sp.	NHB	Harvey et al. 2001
Thysanoessa raschii	NHB, FB	Grainger 1962; Harvey et al. 2001
Isopoda		
Isopod sp.	NHB, GWR	Grainger 1988; Harvey et al. 2001
Mysida		
Mysis sp.	NHB	Harvey et al. 2001
Mysis oculata	GWR	Grainger 1988
Ostracoda	NHB	Harvey et al. 2001
Myodocopida		
Philomedes globosus	GWR	Grainger 1988
Thecostraca		
Cirripedia sp. larvae	NHB, FB	Grainger 1962; Harvey et al. 2001
Balanomorpha		
Balanus sp.	BI	Rochet and Grainger 1988
Chaetognatha		
Sagittoidea		
Aphragmophora		
Parasagitta elegans	HB, FB, BI, GWR, NQC	Grainger 1959, 1962, 1988; Rochet and Grainger 1988; Drolet et al. 1991; Ponton and Fortier 1992; Thomas 1999; Harvey et al. 2001; Lapoussière et al. 2009
Chordata		
Tunicata		
Tunicate sp. Larvae	NHB	Grainger 1962

Scientific Nomenclature [1]	**Location** [2]	**Source(s)**
Copelata		
Fritillaria sp.	HB	Estrada et al. 2012
Fritillaria borealis	GWR	Grainger 1988
Oikopleura sp.	NHB	Ponton and Fortier 1992; Harvey et al. 2001
Oikopleura labradoiriensis	GWR	Grainger 1988
Oikopleura vanhoeffeni	NHB, BI	Grainger 1959, 1962; Rochet and Grainger 1988

1 - Each lower level taxon (Family, Genus, or species) organized by Phylum, Class, and Order; updated to latest accepted taxonomy (WoRMS 2022).

2 - BI = Belcher Islands, FB = Foxe Basin, GWR = Great Whale River estuary and adjacent coast, HB = Hudson Bay (non-specific), HS = Hudson Strait, LT = Lake Tasiujaq (a large brackish bay north of the Little Whale River), NHB = Northern Hudson Bay, NQC = northern Quebec coast (near Inukjuak).

Table A 3. List of zooplankton, ice-associated fauna, and benthic invertebrate infauna and epifauna observed in the QSA and other areas of the Hudson Bay Complex.

Scientific Nomenclature [1]	**Location** [2]	**Source(s)**
Porifera	GWR, LT, NJB, NQC, OS	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Cnidaria		
Anthozoa	GWR	Pierrejean Unpublished Data
Actinaria	GWR, OS	Pierrejean et al. 2020
Allantactis parasitica	BI, LWR	Atkinson and Wacasey 1989
Bolocera tuediae	GWR	Pierrejean et al. 2020
Urticina felina	NQC	Atkinson and Wacasey 1989
Malacalcyonacea		
Duva florida	OS	M. Pierrejean et al. 2020
Hydrozoa	GWR, HB	Atkinson and Wacasey 1989; M. Pierrejean et al. 2020
Anthoathecata		
Coryne hincksi	BI	Atkinson and Wacasey 1989
Eudendrium rameum	BI	Atkinson and Wacasey 1989
Rhizorhagium roseum	NJB	Atkinson and Wacasey 1989
Leptothecata		
Abietinaria pulchra	NJB	Atkinson and Wacasey 1989
Calycella syringa	BI, NJB	Atkinson and Wacasey 1989
Campanularia volubilis	BI, NJB	Atkinson and Wacasey 1989
Cuspidella humilis	SI	Atkinson and Wacasey 1989
Filellum serpens	NJB	Atkinson and Wacasey 1989
Gonothyraea loveni	BI	Atkinson and Wacasey 1989
Halecium minutum	BI	Atkinson and Wacasey 1989

Scientific Nomenclature [1]	Location [2]	Source(s)
Halecium undulatum	BI, NJB	Atkinson and Wacasey 1989
Orthopyxis integra	BI	Atkinson and Wacasey 1989
Sertularella polyzonias	BI, NJB	Atkinson and Wacasey 1989
Sertularia schmidti	BI	Atkinson and Wacasey 1989
Sertularia similis	BI, NJB	Atkinson and Wacasey 1989
Symplectoscyphus tricuspidatus	BI, NJB	Atkinson and Wacasey 1989
Thuiaria articulata	OS	Atkinson and Wacasey 1989
Nematoda		
Nematode sp.	BI	Atkinson and Wacasey 1989
Mollusca		
Bivalvia		
Adapedonta		
Hiatella arctica	BI, LT, LWR, SI	Atkinson and Wacasey 1989; Government of Nunavut 2010
Anomalodesmata		
Cuspidaria subtorta	LWR	Atkinson and Wacasey 1989
Lyonsia arenosa	SI	Atkinson and Wacasey 1989
Pandora glacialis	BI	Atkinson and Wacasey 1989
Periploma aleuticum	BI, SI	Atkinson and Wacasey 1989
Thracia myopsis	BI	Atkinson and Wacasey 1989
Arcida		
Bathyarca glacialis	GWR	Atkinson and Wacasey 1989
Carditida		
Astarte sp.	NQC	Pierrejean et al. 2020
Astarte borealis	BI	Atkinson and Wacasey 1989
Astarte crenata	BI, LT, NQC	Atkinson and Wacasey 1989
Astarte montagui	BI, NQC, OS	Atkinson and Wacasey 1989
Cardiida		
Ciliatocardium ciliatum	BI, LWR, NQC, OS, SI	Atkinson and Wacasey 1989; Government of Nunavut 2010; Pierrejean et al. 2020
Macoma balthica	BI, LT, NQC	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Macoma calcarea	BI, NJB, LT, NQC, OS, SI	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Macoma loveni	NQC	Atkinson and Wacasey 1989
Macoma moesta	BI, OS	Atkinson and Wacasey 1989
Macoma torelli	BI, OS	Atkinson and Wacasey 1989
Serripes groenlandicus	BI, NQC	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Lucinida		
Axinopsida orbiculata	BI	Atkinson and Wacasey 1989

Scientific Nomenclature [1]	**Location** [2]	**Source(s)**
Parathyasira equalis	BI	Atkinson and Wacasey 1989
Thyasiridae	GWR	Pierrejean et al. 2020
Thyasira sp.	OS	Pierrejean et al. 2020
Thyasira gouldi	BI, OS, SI	Atkinson and Wacasey 1989
Myida		
Mya pseudoarenaria	BI, NQC	Atkinson and Wacasey 1989
Mya truncata	BI, LWR, NQC	Atkinson and Wacasey 1989; Government of Nunavut 2010; M. Pierrejean et al. 2020
Mytilida		
Arvella faba	BI, LT	Atkinson and Wacasey 1989
Musculus discors	BI, LT, OS	Atkinson and Wacasey 1989
Musculus glacialis	OS	Atkinson and Wacasey 1989
Musculus niger	NQC, OS	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Mytilus edulis	BI, LT, LWR, NQC	Atkinson and Wacasey 1989; Government of Nunavut 2010; Pierrejean et al. 2020
Pectinida		
Chlamys islandica	BI, LWR, NQC, OS	Atkinson and Wacasey 1989; Government of Nunavut 2010
Similipecten greenlandicus	BI, GWR, NJB, LT, LWR, NQC	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Nuculida		
Ennucula tenuis	BI, GWR, NJB, LT, NQC, OS, SI	Atkinson and Wacasey 1989; Pierrejean et al. 2020 and Unpublished Data
Nuculanida		
Nuculana minuta	NQC, OS	Atkinson and Wacasey 1989
Nuculana pernula	GWR, BI, NJB, NQC, OS, SI	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Portlandia arctica	BI, GWR, LT, LWR, NQC	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Yoldia hyperborea	BI, GWR, LT, NJB, NQC, OS, SI	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Yoldiella sp.	GWR, OS	Pierrejean et al. 2020
Yoldiella lenticula	BI, GWR, LT, OS	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Cephalopoda		
Oegopsida		
Gonatus fabricii	BI	Government of Nunavut 2010
Gastropoda		
Caenogastropoda		
Tachyrhynchus reticulatus	NQC	Atkinson and Wacasey 1989
Cephalaspidea		

Scientific Nomenclature [1]	Location [2]	Source(s)
Cylichna alba	BI, GWR LT, NQC, OS	Atkinson and Wacasey 1989; Pierrejean et al. 2020 and Unpublished Data
Cylichnoides occultus	LT, OS	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Philine sp.	NQC	Pierrejean et al. 2020
Pseudocylichna magna	LT	Atkinson and Wacasey 1989
Littorinimorpha		
Ariadnaria borealis	BI, LT, NQC, OS	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Cryptonatica affinis	BI	Government of Nunavut 2010
Euspira pallida	BI, LT, LWR	Atkinson and Wacasey 1989
Littorina saxatilis	BI, LT, LWR	Atkinson and Wacasey 1989
Velutina undata	GWR	Atkinson and Wacasey 1989
Velutina velutina	BI	Atkinson and Wacasey 1989
Neogastropoda		
Admete viridula	BI, LT, NQC, OS	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Boreotrophon truncatus	BI	Atkinson and Wacasey 1989
Buccinidae	BI, OS	Government of Nunavut 2010; Pierrejean et al. 2020
Buccinum sp.	GWR	M. Pierrejean Unpublished Data
Buccinum hydrophanum	GWR, LT	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Buccinum scalariforme	BI, GWR, LT, LWR, NQC, OS	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Buccinum tottenii	BI, GWR	Atkinson and Wacasey 1989
Colus sp.	BI, OS	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Colus islandicus	LT	Atkinson and Wacasey 1989
Curtitoma sp.	NQC	Pierrejean et al. 2020
Curtitoma incisula	BI	Atkinson and Wacasey 1989
Curtitoma trevelliana	BI	Atkinson and Wacasey 1989
Oenopota sp.	NQC	Pierrejean et al. 2020
Plicifusus kroyeri	BI	Atkinson and Wacasey 1989
Turridae	OS	Pierrejean et al. 2020
Nudibranchia		
Dendronotus sp.	GWR	Pierrejean et al. 2020
Patellogastropoda		
Lepeta caeca	BI, LT, NQC, OS	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Testudinalia testudinalis	BI	Atkinson and Wacasey 1989; Government of Nunavut 2010
Trochida		
Margarites costalis	LT, LWR, NQC, OS, SI	Atkinson and Wacasey 1989
Margarites groenlandicus umbilicalis	BI	Atkinson and Wacasey 1989
Margarites helicinus	SI	Atkinson and Wacasey 1989

Scientific Nomenclature [1]	Location [2]	Source(s)
Margarites olivaceus	BI, NQC	Atkinson and Wacasey 1989
Polyplacophora		
Chitonida		
Stenosemus albus	BI	Atkinson and Wacasey 1989
Tonicella marmorea	BI, SI	Atkinson and Wacasey 1989
Annelida		
Sipuncula	OS	Pierrejean et al. 2020
Sipunculidae	GWR	Pierrejean et al. 2020
Phascolion strombus strombus	GWR, LT	Atkinson and Wacasey 1989
Oligochaeta		
Oligochaete sp.	BI	Atkinson and Wacasey 1989
Polychaeta		
Polychaete sp	BI	Atkinson and Wacasey 1989
Eunicida		
Lumbrineridae	OS	Pierrejean et al. 2020
Lumbrineris mixochaeta	OS	Pierrejean et al. 2020
Scoletoma fragilis	GWR, NQC, OS	Pierrejean et al. 2020 and Unpublished Data
Phyllodocida		
Bylgides sp.	OS	Pierrejean et al. 2020
Bylgides sarsi	NQC	Pierrejean et al. 2020
Capitellidae	OS	Pierrejean et al. 2020 and Unpublished Data
Ceratocephale loveni	GWR	Pierrejean et al. 2020
Gattyana amondseni	NQC	Pierrejean et al. 2020
Gattyana cirrhosa	NQC	Pierrejean et al. 2020
Harmothoe sp.	NQC	Pierrejean et al. 2020
Micronephthys minuta	GWR, NQC	Pierrejean et al. 2020 and Unpublished Data
Myrianida sp.	GWR	Atkinson and Wacasey 1989
Nereididae	OS	Pierrejean et al. 2020
Phyllodocidae	NQC, OS	Pierrejean et al. 2020
Polynoidae	GWR, OS	Pierrejean et al. 2020
Sphaerodoridae	OS	Pierrejean et al. 2020
Sabellida		
Sabellidae	GWR	Pierrejean et al. 2020
Scolecida		
Aricidea sp.	GWR	Pierrejean et al. 2020
Maldanidae	OS	Pierrejean et al. 2020
Maldane sarsi	GWR, OS	Pierrejean et al. 2020

Scientific Nomenclature [1]	Location [2]	Source(s)
Orbiniidae	NQC	Pierrejean et al. 2020
Petaloproctus tenuis	BI	Atkinson and Wacasey 1989
Scoloplos sp.	GWR	Pierrejean et al. 2020
Spionida		
Polydora sp.	OS	Pierrejean et al. 2020
Prionospio sp.	GWR, OS	Pierrejean et al. 2020
Spionidae	OS	Pierrejean et al. 2020
Terebellida		
Ampharete finmarchica	NQC, OS	Pierrejean et al. 2020
Amphicteis ninonae	NQC, OS	Pierrejean et al. 2020
Axionice flexuosa	NQC	Pierrejean et al. 2020
Cirratulidae	GWR, OS	Pierrejean et al. 2020
Cistenides granulata	NQC	Pierrejean et al. 2020
Eteone flava	OS	Pierrejean et al. 2020
Eteone longa	GWR	Pierrejean et al. 2020
Terebellidae	OS	Pierrejean et al. 2020
Nemertea		
Nemertea sp.	GWR, NJB, LWR, NQC, OS	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Arthropoda		
Arachnida		
Acari unidentified	BI	Atkinson and Wacasey 1989
Malacostraca		
Amphipoda		
Acanthonotozoma sp.	LT	Atkinson and Wacasey 1989
Acanthonotozoma inflatum	NJB	Atkinson and Wacasey 1989
Acanthostepheia malmgreni	GWR, LT, OS	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Ampelisca sp.	NQC	Pierrejean et al. 2020
Ampelisca eschrichti	BI	Atkinson and Wacasey 1989
Amphithopsis longicaudata	BI	Atkinson and Wacasey 1989
Anonyx sp.	NQC, OS	Pierrejean et al. 2020
Anonyx nugax	NJB, NQC	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Anonyx sarsi	NJB	Atkinson and Wacasey 1989
Arrhis phyllonyx	GWR, LT, NQC	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Atylus carinatus	LT	Atkinson and Wacasey 1989
Byblis gaimardii	NJB	Atkinson and Wacasey 1989
Calliopius laeviusculus	BI	Atkinson and Wacasey 1989
Calliopius rathkii	BI	Atkinson and Wacasey 1989

Scientific Nomenclature [1]	Location [2]	Source(s)
Caprella septentrionalis	BI	Atkinson and Wacasey 1989
Dyopedos monacanthus	BI	Atkinson and Wacasey 1989
Dyopedos porrectus	BI	Atkinson and Wacasey 1989
Ericthonius tolli	LT	Atkinson and Wacasey 1989
Eusiridae	OS	Pierrejean et al. 2020
Eusirus cuspidatus	OS	Atkinson and Wacasey 1989
Gammarus oceanicus	BI, LWR	Atkinson and Wacasey 1989
Gammarus setosus	BI, LT, LWR	Atkinson and Wacasey 1989
Halirages nilssoni	NJB	Atkinson and Wacasey 1989
Haploops laevis	BI, NJB, LT	Atkinson and Wacasey 1989
Haploops setosa	BI, GWR, NJB	Atkinson and Wacasey 1989
Haploops tubicola	LT, NQC	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Ischyrocerus anguipes	BI	Atkinson and Wacasey 1989
Ischyrocerus commensalis	BI	Atkinson and Wacasey 1989
Ischyrocerus latipes	BI, NJB	Atkinson and Wacasey 1989
Ischyrocerus megalops	BI	Atkinson and Wacasey 1989
Lepidepecreum serraculum	GWR	Pierrejean et al. 2020
Lepidepecreum umbo	GWR	Pierrejean et al. 2020
Lysianassidae	GWR, OS	Pierrejean et al. 2020
Megamoera dentata	GWR, NQC	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Metopa bruzelii	BI	Atkinson and Wacasey 1989
Monoculodes sp.	NJB	Atkinson and Wacasey 1989
Oediceros saginatus	NJB	Atkinson and Wacasey 1989
Oedicerotidae	GWR, NQC, OS	Pierrejean et al. 2020
Onisimus sp.	LT	Atkinson and Wacasey 1989
Onisimus edwardsii	BI	Atkinson and Wacasey 1989
Onisimus glacialis	BI	Atkinson and Wacasey 1989
Onisimus litoralis	BI	Atkinson and Wacasey 1989
Onisimus plautus	NQC	Pierrejean et al. 2020
Orchomene minuta	BI	Atkinson and Wacasey 1989
Orchomene pinguis	BI	Atkinson and Wacasey 1989
Parapleustes assimilis	BI	Atkinson and Wacasey 1989
Paratryphosites abyssi	OS	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Pardalisca cuspidata	BI	Atkinson and Wacasey 1989
Paroediceros sp.	NJB	Atkinson and Wacasey 1989
Paroediceros lynceus	GWR, NQC	Pierrejean et al. 2020
Pleustidae	GWR	Pierrejean et al. 2020

Scientific Nomenclature [1]	Location [2]	Source(s)
Pontogeneia inermis	BI	Atkinson and Wacasey 1989
Pontoporeia femorata	OS	Pierrejean et al. 2020
Quasimelita formosa	NJB	Atkinson and Wacasey 1989
Rhachotropis aculeata	GWR, NJB, NQC	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Rhachotropis oculata	BI	Atkinson and Wacasey 1989
Rozinante fragilis	GWR	Pierrejean et al. 2020
Stegocephalus inflatus	GWR, LWR, OS	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Stenula invalida	BI	Atkinson and Wacasey 1989
Syrrhoe crenulata	NJB, NQC	Atkinson and Wacasey 1989
Tmetonyx cicada	GWR	Atkinson and Wacasey 1989
Unciola leucopis	NJB	Atkinson and Wacasey 1989
Cumacea		
Brachydiastylis resima	BI, LT	Atkinson and Wacasey 1989
Diastylis goodsiri	NQC, OS	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Diastylis rathkei	GWR, BI, LT, NQC, OS	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Diastylis scorpioides	NQC, OS	Atkinson and Wacasey 1989
Diastylis spinulosa	LT	Atkinson and Wacasey 1989
Eudorella emarginata	BI	Atkinson and Wacasey 1989
Leucon (Leucon) nasica	BI	Atkinson and Wacasey 1989
Decapoda		
Argis dentata	BI, LT, LWR, NQC, SI	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Eualus fabricii	BI, LWR, SI	Atkinson and Wacasey 1989
Eualus gaimardi	BI, GWR, NJB, LT, OS	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Eualus gaimardi belcheri	GWR	Pierrejean et al. 2020
Eualus macilentus	BI, GWR, LT, NQC, OS, SI	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Hyas coarctatus	BI, GWR, NJB, LWR, NQC, OS	Atkinson and Wacasey 1989; Government of Nunavut 2010; Pierrejean et al. 2020
Lebbeus groenlandicus	BI	Atkinson and Wacasey 1989
Lebbeus polaris	BI	Atkinson and Wacasey 1989
Pagurus sp.	BI	Government of Nunavut 2010
Pagurus pubescens	BI	Atkinson and Wacasey 1989
Pandalus montagui	BI, GWR, LT, NQC	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Sabinea septemcarinata	BI, GWR, LT, NQC, OS, SI	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Sclerocrangon boreas	OS	Atkinson and Wacasey 1989
Spirontocaris phippsi	BI	Atkinson and Wacasey 1989
Spirontocaris spinus	BI, LWR, NQC	Atkinson and Wacasey 1989
Isopoda		

Scientific Nomenclature [1]	**Location [2]**	**Source(s)**
Arcturus baffini	OS	Atkinson and Wacasey 1989
Munnopsis typica	BI	Atkinson and Wacasey 1989
Munnopsurus giganteus	LWR, OS	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Saduria sabini	GWR, NJB, OS	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Saduria sibirica	GWR	Pierrejean et al. 2020
Leptostraca		
Nebalia bipes	BI	Atkinson and Wacasey 1989
Tanaidacea		
Akanthophoreus gracilis	OS	Pierrejean et al. 2020
Pycnogonida		
Pantopoda		
Nymphon brevitarse	NJB	Atkinson and Wacasey 1989
Thecostraca		
Balanomorpha		
Balanus sp.	BI	Government of Nunavut 2010
Balanus balanus	BI, NJB, SI	Atkinson and Wacasey 1989
Balanus crenatus	BI, NJB, LWR	Atkinson and Wacasey 1989
Semibalanus balanoides	BI, LWR	Atkinson and Wacasey 1989
Bryozoa		
Gymnolaemata		
Cheilostomatida		
Aquiloniella scabra	BI, SI	Atkinson and Wacasey 1989
Cylindroporella tubulosa	BI	Atkinson and Wacasey 1989
Cystisella saccata	NQC, OS, SI	Atkinson and Wacasey 1989
Hippoporella hippopus	BI	Atkinson and Wacasey 1989
Leieschara subgracilis	OS	Atkinson and Wacasey 1989
Securiflustra securifrons	OS	Atkinson and Wacasey 1989
Smittoidea propinqua	BI	Atkinson and Wacasey 1989
Stomacrustula cruenta	BI	Atkinson and Wacasey 1989
Ctenostomatida		
Alcyonidium disciforme	GWR	Pierrejean et al. 2020
Alcyonidium gelatinosum	LT	Atkinson and Wacasey 1989
Alcyonidium pseudosciforme	GWR	Pierrejean et al. 2020
Brachiopoda		
Rhynchonellata		
Rhynchonellida		
Hemithiris psittacea	BI, NJB, NQC, OS	Atkinson and Wacasey 1989

Scientific Nomenclature [1]	Location [2]	Source(s)
Echinodermata		
Asteroidea		
Forcipulatida		
Icasterias panopla	BI, GWR	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Leptasterias groenlandica	BI, LWR	Atkinson and Wacasey 1989
Leptasterias (Hexasterias) polaris	BI, SI	Atkinson and Wacasey 1989; Government of Nunavut 2010
Urasterias lincki	BI, GWR, LT	Atkinson and Wacasey 1989
Paxillosida		
Ctenodiscus crispatus	BI, GWR, LT, OS	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Spinulosida		
Henricia eschrichti	BI	Atkinson and Wacasey 1989
Valvatida		
Crossaster papposus	BI, LWR, OS	Atkinson and Wacasey 1989
Velatida		
Pteraster sp.	OS	Pierrejean et al. 2020
Crinoidea		
Comatulida		
Heliometra glacialis	OS	Atkinson and Wacasey 1989
Echinoidea		
Camarodonta		
Strongylocentrotus sp.	NQC	Pierrejean et al. 2020
Strongylocentrotus droebachiensis	BI, LT, LWR, OS, SI	Atkinson and Wacasey 1989; Government of Nunavut 2010
Holothuroidea		
Holothuroidea	BI	Government of Nunavut 2010
Apodida		
Myriotrochus rinkii	BI, GWR, NQC	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Dendrochirotida		
Cucumaria frondosa	BI	Atkinson and Wacasey 1989
Pentamera calcigera	BI, GWR, LT	Atkinson and Wacasey 1989
Psolus phantapus	NQC	Atkinson and Wacasey 1989
Molpadida		
Eupyrgus scaber	GWR	Pierrejean et al. 2020
Ophiuroidea		
Amphilepidida		
Amphiura sundevalli	OS	Pierrejean et al. 2020
Ophiopholis aculeata	BI, LT, NQC, OS	Atkinson and Wacasey 1989
Euryalida		

Scientific Nomenclature [1]	**Location** [2]	**Source(s)**
Gorgonocephalus sp.	BI	Government of Nunavut 2010
Gorgonocephalus arcticus	BI, GWR, LT, LWR	Atkinson and Wacasey 1989
Gorgonocephalus eucnemis	LT	Atkinson and Wacasey 1989
Ophiacanthida		
Ophiacantha bidentata	BI, GWR, NJB, LT, LWR, NQC, OS	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Ophiurida		
Ophiocten sericeum	BI, GWR, NJB, LT, LWR, NQC, OS, SI	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Ophiura robusta	BI, LT, NQC, OS	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Ophiura sarsii	BI, GWR, NJB, LWR, NQC, OS, SI	Atkinson and Wacasey 1989; Pierrejean et al. 2020
Stegophiura nodosa	BI	Atkinson and Wacasey 1989
Chordata		
Ascidiacea		
Phlebobranchia		
Ascidia sp.	SI	Atkinson and Wacasey 1989
Ascidia callosa	BI	Atkinson and Wacasey 1989
Ascidia obliqua	GWR	Atkinson and Wacasey 1989
Ciona intestinalis	LT	Atkinson and Wacasey 1989
Stolidobranchia		
Boltenia echinata	BI	Atkinson and Wacasey 1989
Boltenia ovifera	BI, LWR	Atkinson and Wacasey 1989
Dendrodoa aggregata	BI	Atkinson and Wacasey 1989
Molgula griffithsii	LT	Atkinson and Wacasey 1989
Molgula siphonalis	NNJB	Atkinson and Wacasey 1989
Styela coriacea	BI, NNJB	Atkinson and Wacasey 1989
Styela rustica	BI, LWR	Atkinson and Wacasey 1989

1 - Each lower level taxon (Family, Genus, or species) organized by Phylum, Class, and Order; updated to latest accepted taxonomy (WoRMS 2022).

2 - BI = Belcher Islands, GWR = Great Whale River estuary and adjacent coast, HB = Hudson Bay (non-specific), NJB = near northwest entrance to James Bay, LT = Lake Tasiujaq (a large brackish bay north of the Little Whale River), LWR = Little Whale River estuary and adjacent coast, NQC = northern Quebec coast (near Inukjuak and within QSA), OS = offshore west of Belcher Islands, SI = Sleeper Islands

Table A 4. List of fish species observed in the QSA and other areas of the Hudson Bay Complex.

Family	Scientific Name	Common Name	Location [1]	Source(s)
Myxinidae	*Myxine glutinosa*	Atlantic Hagfish	BI	Government of Nunavut 2010
Somniosidae	*Somniosus microcephalus*	Greenland Shark	HB, JB	Coad and Reist 2018
Rajidae	*Amblyraja radiata*	Thorny Skate[4]	BI, NHB	Government of Nunavut 2010; Coad and Reist 2018
Acipenseridae	*Acipenser fulvescens*	Lake Sturgeon	HB, JB	Coad and Reist 2018
Clupeidae	*Clupea harengus*	Atlantic Herring	BI, GWR, HB, JB, NQC	Government of Nunavut 2010; Coad and Reist 2018
Osmeridae	*Mallotus villosus*	Capelin	BI, GWR, HB, JB, LWR, NQC	Drolet et al. 1991; Ponton and Fortier 1992; Ponton et al. 1993; Government of Nunavut 2010; Coad and Reist 2018
	Osmerus mordax	Rainbow Smelt	BI, HB, JB	Government of Nunavut 2010; Coad and Reist 2018
Salmonidae	*Coregonus artedi*	Cisco	BI, GWR, HB, JB, LWR, NQC	Kemp et al. 1989; Drolet et al. 1991; Ponton et al. 1993; Government of Nunavut 2010; Coad and Reist 2018
	Coregonus clupeaformis	Lake Whitefish	BI, GWR, HB, JB, LWR, NQC	Kemp et al. 1989; Drolet et al. 1991; Ponton et al. 1993; Coad and Reist 2018
	Prosopium cylindraceum	Round Whitefish	BI, GWR, HB, JB, LWR, NQC	Kemp et al. 1989; Government of Nunavut 2010; Coad and Reist 2018
	Salmo salar	Atlantic Salmon	HB, LWR, NQC	Coad and Reist 2018; Bilous and Dunmall 2020
	Oncorhynchus gorbuscha	Pink Salmon	HB	McNicholl et al. 2021
	Salvelinus alpinus	Arctic Char	BI, GWR, HB, JB, LWR, NQC	Kemp et al. 1989; Coad and Reist 2018
	Salvelinus fontinalis	Brook Trout	GWR, HB, JB, LWR, NQC	Kemp et al. 1989; Coad and Reist 2018
	Salvelinus namaycush	Lake Trout	BI, GWR, HB, JB, LWR, NQC	Kemp et al. 1989; Government of Nunavut 2010; Coad and Reist 2018
Gadidae	*Arctogadus glacialis*	Polar Cod	BI, NHB	Government of Nunavut 2010; Coad and Reist 2018
	Boreogadus saida	Arctic Cod	BI, GWR, HB, JB, LWR	Drolet et al. 1991; Ponton and Fortier 1992; Ponton et al. 1993; Government of Nunavut 2010; Coad and Reist 2018
	Gadus morhua	Atlantic Cod		

Family	Scientific Name	Common Name	Location [1]	Source(s)
	Gadus ogac	Greenland Cod	BI, GWR, HB, JB, LWR, NQC	Ponton et al. 1993; Government of Nunavut 2010; Coad and Reist 2018
	Lota lota	Burbot	BI, GWR, HB, JB	Drolet et al. 1991; Ponton et al. 1993; Coad and Reist 2018
Gasterosteidae	*Gasterosteus aculeatus*	Three-spined Stickleback	BI, GWR, HB, JB, LWR, NQC	Government of Nunavut 2010; Coad and Reist 2018
	Pungitius pungitius	Ninespine Stickleback	BI, GWR, HB, JB, LWR, NQC	Coad and Reist 2018
Cottidae	*Artediellus atlanticus*	Atlantic Hookear Sculpin	NHB	Coad and Reist 2018
	Artediellus uncinatus	Arctic Hookear Sculpin	NHB	Coad and Reist 2018
	Gymnocanthus tricuspis	Arctic Staghorn Sculpin	BI, GWR, HB, JB, LWR	Drolet et al. 1991; Ponton et al. 1993; Coad and Reist 2018
	Icelus sp.		GWR	Drolet et al. 1991; Ponton et al. 1993
	Icelus bicornis	Twohorn Sculpin	BI, HB	Government of Nunavut 2010; Coad and Reist 2018
	Icelus spatula	Spatulate Sculpin	LWR, SI	Coad and Reist 2018
	Myoxocephalus aenaeus	Grubby	NHB	Coad and Reist 2018
	Myoxocephalus octodecemspinosus	Longhorn Sculpin	GWR	Coad and Reist 2018
	Myoxocephalus quadricornis	Fourhorn Sculpin	BI, GWR, HB, JB, LWR, NQC	Drolet et al. 1991; Ponton et al. 1993; Coad and Reist 2018
	Myoxocephalus scorpioides	Arctic Sculpin	BI, GWR, HB, JB, LWR, NQC	Drolet et al. 1991; Ponton et al. 1993; Coad and Reist 2018
	Myoxocephalus scorpius	Shorthorn Sculpin	BI, GWR, HB, JB, LWR, NQC	Ponton et al. 1993; Government of Nunavut 2010; Coad and Reist 2018
	Triglops sp.		GWR	Drolet et al. 1991; Ponton et al. 1993
	Triglops murrayi	Moustache Sculpin	BI, GWR, HB, JB	Coad and Reist 2018
	Triglops nybelini	Bigeye Sculpin	NHB	Coad and Reist 2018
	Triglops pingelii	Ribbed Sculpin	HB, JB	Coad and Reist 2018
Agonidae	*Aspidophoroides olrikii*	Arctic Alligatorfish	BI, GWR, HB, JB, LWR, NQC, SI	Ponton et al. 1993; Coad and Reist 2018
	Leptagonus decagonus	Atlantic Poacher	BI, NHB, LWR	Coad and Reist 2018
Psychrolutidae	*Cottunculus microps*	Polar Sculpin	NHB	Coad and Reist 2018
Cyclopteridae	*Cyclopterus lumpus*	Lumpfish	BI, GWR, HB, JB, LWR	Government of Nunavut 2010; Coad and Reist 2018
	Eumicrotremus derjugini	Leatherfin Lumpsucker	HB	Coad and Reist 2018

Family	Scientific Name	Common Name	Location [1]	Source(s)
	Eumicrotremus spinosus	Spiny Lumpsucker	HB, LWR	Coad and Reist 2018
Liparidae	*Careproctus reinhardti*	Sea Tadpole	HB, LT	Coad and Reist 2018
	Liparis sp.	Snailfish	GWR	Ponton and Fortier 1992; Ponton et al. 1993
	Liparis fabricii	Gelatinous Seasnail	GWR, NHB	Drolet et al. 1991; Coad and Reist 2018
	Liparis gibbus	Variegated Snailfish	BI, HB, JB, LWR	Coad and Reist 2018
	Liparis tunicatus	Greenland Seasnail	NHB, JB	Coad and Reist 2018
Zoarcidae	*Gymnelus retrodorsalis*	Aurora Pout	NHB	Coad and Reist 2018
	Gymnelus viridis	Fish Doctor	NHB	Coad and Reist 2018
	Lycodes pallidus	Pale Eelpout	NHB, JB	Coad and Reist 2018
	Lycodes reticulatus	Arctic Eelpout	BI, HB, LT	Government of Nunavut 2010; Coad and Reist 2018
Stichaeidae	*Anisarchus medius*	Stout Eelblenny	NHB, LT	Coad and Reist 2018
	Eumesogrammus praecisus	Fourline Snakeblenny	HB	Coad and Reist 2018
	Leptoclinus maculatus	Daubed Shanny	NHB, JB, LWR	Coad and Reist 2018
	Lumpenus fabricii	Slender Eelblenny	GWR, HB, JB, LWR, NQC	Drolet et al. 1991; Coad and Reist 2018
	Stichaeus punctatus	Arctic Shanny	BI, GWR, HB, JB, NQC	Drolet et al. 1991; Coad and Reist 2018
Pholidae	*Pholis fasciata*	Banded Gunnel	BI, GWR, HB, JB, NQC	Government of Nunavut 2010; Coad and Reist 2018
Ammodytidae	*Ammodytes* sp.	Sand Lance	GWR	Drolet et al. 1991; Ponton and Fortier 1992; Ponton et al. 1993
	Ammodytes dubius	Northern Sand Lance	GWR, HB, JB	Coad and Reist 2018
	Ammodytes hexapterus	Pacific Sand Lance	BI, GWR, HB, JB, LWR, NQC	Coad and Reist 2018
Pleuronectidae	*Hippoglossoides platessoides*	American Plaice	BI, GWR, LWR	Ponton et al. 1993; Government of Nunavut 2010; Coad and Reist 2018
	Reinhardtius hippoglossoides	Greenland Halibut	NHB	Coad and Reist 2018

1 - BI = Belcher Islands, GWR = Great Whale River estuary and adjacent coast, HB = Hudson Bay (non-specific), JB = James Bay, LT = Lake Tasiujaq (a large brackish bay north of the Little Whale River), LWR = Little Whale River estuary and adjacent coast, NHB = northern Hudson Bay, NQC = northern Quebec coast (near Inukjuak and within QSA), SI = Sleeper Islands

Table A 5. List of waterbird species observed in the QSA and surrounding waters.

Common Name	Scientific Name	Use of the QSA	COSEWIC Status	SARA Status	Source
Sandhill Crane	*Grus canadensis*	*Migrant*	-	-	Manning 1976; Government of Nunavut 2010
Canada Goose	*Branta canadensis*	*Breeding*	-	-	Manning 1976; Government of Nunavut 2010
Cackling Goose	*Branta hutchinsii*	*Breeding*	-	-	Government of Nunavut 2010
White Fronted Goose	*Anser albifrons*	*Unknown*	-	-	Manning 1976; Government of Nunavut 2010
Snow Goose	*Anser caerulescens*	*Breeding*	-	-	Manning 1976; Government of Nunavut 2010
Ross's Goose	*Rhodostethia rosea*	*Unknown*	-	-	Government of Nunavut 2010
Brant	*Branta bernicla*	*Unknown*	-	-	Manning 1976; Government of Nunavut 2010
Tundra Swan	*Cygnus columbianus*	*Breeding*	-	-	Manning 1976; Government of Nunavut 2010
Mallard	*Anas platyrhynchos*	*Unknown*	-	-	Government of Nunavut 2010
Northern Pintail	*Anas acuta*	*Breeding*	-	-	Manning 1976; Government of Nunavut 2010
Green-winged Teal	*Anas crecca*	*Breeding*	-	-	Government of Nunavut 2010
Greater Scaup	*Aythya marila*	*Unknown*	-	-	Government of Nunavut 2010
Lesser Scaup	*Aythya affinis*	*Unknown*	-	-	Government of Nunavut 2010
King Eider	*Somateria spectabilis*	*Breeding / Overwintering*	-	-	Manning 1976; Government of Nunavut 2010; Robertson and Gilchrist 1998
Common Eider	*Somateria mollissima*	*Breeding / Overwintering*	-	-	Manning 1976; Government of Nunavut 2010; Robertson and Gilchrist 1998
Harlequin Duck	*Histrionicus histrionicus*	*Breeding*	Special Concern	Special Concern	Manning 1976; Government of Nunavut 2010
Surf Scoter	*Melanitta perspicillata*	*Breeding*	-	-	Manning 1976; Government of Nunavut 2010
White-winged Scoter	*Melanitta fusca*	*Breeding*	-	-	Manning 1976; Government of Nunavut 2010
Black Scoter	*Melanitta americana*	*Breeding*	-	-	Manning 1976; Government of Nunavut 2010
American Black Duck	*Anas rubripes*	*Breeding*	-	-	Manning 1976; Government of Nunavut 2010
Long Tailed Duck	*Clangula hyemalis*	*Breeding / Overwintering*	-	-	Manning 1976; Government of Nunavut 2010; Robertson and Gilchrist 1998
Common Merganser	*Mergus merganser americanus*	*Breeding*	-	-	Manning 1976; Government of Nunavut 2010
Red-breasted Merganser	*Mergus serrator*	*Breeding*	-	-	Manning 1976; Government of Nunavut 2010
Hooded Merganser	*Lophodytes cucullatus*	*Unknown*	-	-	Manning 1976; Government of Nunavut 2010
Common Goldeneye	*Bucephala clangula*	*Breeding*	-	-	Manning 1976; Government of Nunavut 2010

Common Name	Scientific Name	Use of the QSA	COSEWIC Status	SARA Status	Source
Red-throated Loon	*Gavia stellata*	*Breeding*	-	-	Manning 1976; Government of Nunavut 2010
Common Loon	*Gavia immer*	*Breeding*	-	-	Manning 1976; Government of Nunavut 2010
Arctic Loon	*Gavia arctica*	*Breeding*	-	-	Government of Nunavut 2010
Pacific Loon	*Gavia pacifica*	*Unknown*	-	-	Manning 1976; Government of Nunavut 2010
Double-crested Cormorant	*Nannopterum auritum*	*Unknown*	-	-	Government of Nunavut 2010
Semipalmated Plover	*Charadrius semipalmatus*	*Breeding*	-	-	Manning 1976; Government of Nunavut 2010
Golden Plover	*Pluvialis dominica*	*Breeding*	-	-	Manning 1976; Government of Nunavut 2010
Piping Plover Melodus	*Charadrius melodus*	*Unknown*	-	-	Government of Nunavut 2010
Black-bellied Plover	*Pluvialis squatarola*	*Unknown*	-	-	Manning 1976; Government of Nunavut 2010
Ruddy Turnstone	*Arenaria interpres*	*Unknown*	-	-	Manning 1976; Government of Nunavut 2010
Lesser Yellowlegs	*Tringa flavipes*	*Migrant*	Threatened	No Status	NCRI 2010
Greater Yellowlegs	*Tringa melanoleuca*	*Migrant*	-	-	Manning 1976; Government of Nunavut 2010
Whimbrel	*Numenius phaeopus*	*Unknown*	-	-	Manning 1976; Government of Nunavut 2010
Hudsonian Godwit	*Limosa haemastica*	*Unknown*	Threatened	No Status	Government of Nunavut 2010
Ruddy Turnstone	*Arenaria interpres*	*Unknown*	-	-	Government of Nunavut 2010
Red Knot (islandica subspecies)	*Calidris canutus islandica*	*Subspecies observed not specified*	Not at Risk	Special Concern	Manning 1976; Government of Nunavut 2010
Red Knot (rufa subspecies)	*Calidris canutus rufa*	*Subspecies observed not specified*	Endangered or Special Concern, depending on overwintering location	Endangered or No Status, depending on overwintering location	Manning 1976; Government of Nunavut 2010
Sanderling	*Calidris alba*	*Unknown*	-	-	Manning 1976; Government of Nunavut 2010
Short-billed Dowitcher	*Limnodromus griseus*	*Unknown*	-	-	Government of Nunavut 2010
Spotted Sandpiper	*Actitis macularius*	*Unknown*	-	-	Government of Nunavut 2010
Purple Sandpiper	*Calidris maritima*	*Breeding*	-	-	Manning 1976; Government of Nunavut 2010
Pectoral Sandpiper	*Calidris melanotos*	*Migrant*	-	-	Manning 1976; Government of Nunavut 2010
White-rumped Sandpiper	*Calidris fusicolis*	*Breeding*	-	-	Manning 1976; Government of Nunavut 2010
Baird's Sandpiper	*Calidris bairdii*	*Migrant*	-	-	Manning 1976; Government of Nunavut 2010
Least Sandpiper	*Calidris minutilla*	*Breeding*	-	-	Manning 1976; Government of Nunavut 2010
Dunlin	*Calidris alpina*	*Unknown*	-	-	Manning 1976; Government of Nunavut 2010

Common Name	Scientific Name	Use of the QSA	COSEWIC Status	SARA Status	Source
Semipalmated Sandpiper	*Calidris pusilla*	*Unknown*	-	-	Manning 1976; Government of Nunavut 2010
Stilt Sandpiper	*Calidris himantopus*	*Unknown*	-	-	Government of Nunavut 2010
Buff-breasted Sandpiper	*Calidris subruficollis*	*Unknown*	Special Concern	Special Concern	Government of Nunavut 2010
Wilson's Snipe	*Gallinago delicata*	*Unknown*	-	-	Government of Nunavut 2010
Red-necked Phalarope	*Phalaropus lobatus*	*Breeding*	Special Concern	Special Concern	Manning 1976; Government of Nunavut 2010
Red Phalarope	*Phalaropus fulicarius*	*Unknown*	-	-	Government of Nunavut 2010
Black Guillemot	*Cepphus Grylle*	*Breeding / Overwintering*	-	-	Manning 1976; Robertson and Gilchrist 1998
Ivory Gull	*Pagophila eburnea*	*Observation suspect*	Endangered	Endangered	Government of Nunavut 2010
Bonaparte's Gull	*Chroicocephalus philadelphia*	*Observation suspect*	-	-	Government of Nunavut 2010
Herring Gull	*Larus argentatus*	*Breeding / Overwintering*	-	-	Manning 1976; NCRI 2010; Robertson and Gilchrist 1998
Iceland Gull	*Larus glaucoides*	*Unknown*	-	-	Government of Nunavut 2010
Glaucous Gull	*Larus hyperboreus*	*Breeding / Overwintering*	-	-	Manning 1976; NCRI 2010; Robertson and Gilchrist 1998
Ring-billed Gull	*Larus delawarensis*	*Breeding*	-	-	Government of Nunavut 2010
Lesser Black-backed Gull	*Larus fuscus*	*Unknown*	-	-	Government of Nunavut 2010
Great Black-backed Gull	*Larus marinus*	*Unknown*	-	-	Government of Nunavut 2010
Arctic Tern	*Sterna paradisaea*	*Breeding*	-	-	Manning 1976; Government of Nunavut 2010
Pomarine Jaeger	*Stercorarius pomarinus*	*Breeding*	-	-	Government of Nunavut 2010
Parasitic Jaeger	*Stercorarius parasiticus*	*Breeding*	-	-	Manning 1976; Government of Nunavut 2010
Long-tailed Jaeger	*Stercorarius parasiticus*	*Breeding*	-	-	Manning 1976; Government of Nunavut 2010
Thick billed Murre	*Uria lomvia*	*Unknown*	-	-	Manning 1976; Government of Nunavut 2010