Atlantic walrus (*Odobenus rosmarus rosmarus*) in northern Hudson Bay — status, research needs, and monitoring opportunities

Jeff W. Higdon,[1] D. Bruce Stewart[2] and Robert E.A. Stewart[3]

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1 Higdon Wildlife Consulting, Winnipeg, MB
2 Arctic Biological Consultants, Winnipeg, MB
3 Sila Consulting, Howden, MB

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Abstract

The Atlantic walrus (*Odobenus rosmarus rosmarus*) is a species of cultural, ecological, and socioeconomic importance around Hudson Bay. This technical report summarizes relevant information on walruses in northern Hudson Bay, including western and Inuit scientific and traditional knowledge. We summarize available information on the walrus population in northern Hudson Bay and adjacent areas (e.g., Foxe Basin), including population size and trends, habitat, ecology, and environmental changes. Threats to walruses are highlighted, as are the legislation and the management structures that apply to walrus conservation in Canada. We also discuss habitat protection as it applies to walrus, describe current research, and provide a summary of information gaps and recommendations for additional research and monitoring.

1.0 Introduction

Walruses (*Odobenus rosmarus*) are large gregarious pinnipeds with upper canine teeth that grow into long tusks. The species has a discontinuous circumpolar Arctic and sub-Arctic distribution (Figure 1). It is the only living member of its family, and two existing subspecies are recognized — the Atlantic walrus, *O. r. rosmarus*, and the Pacific walrus, *O. r. divergens*, which includes walruses in the Laptev Sea that have sometimes been considered a distinct subspecies. Atlantic walruses were historically an important component of the subsistence economy of the eastern Canadian Arctic and Greenland. Hunts are still of socioeconomic and cultural importance, despite declining harvest effort often related to changes in local needs, such as a decline in dog teams and associated food requirements.

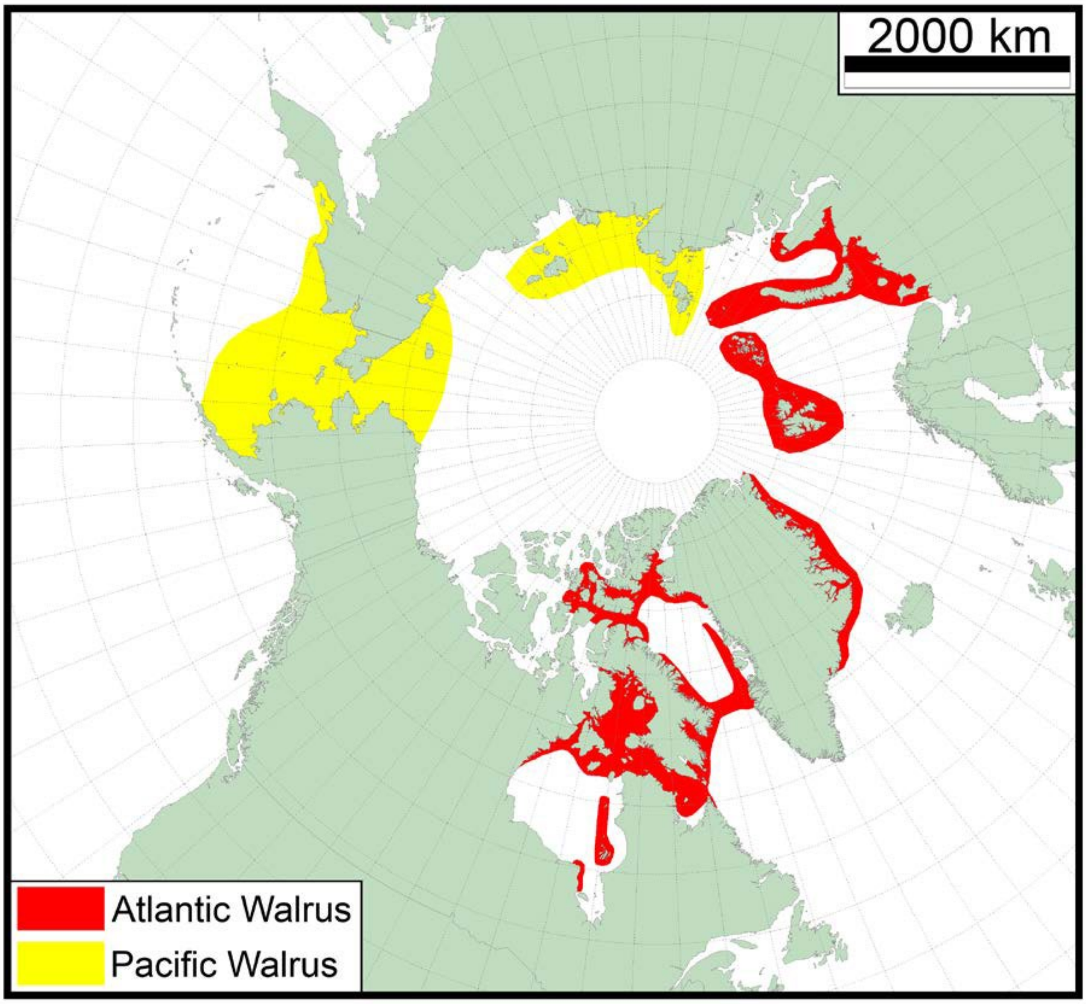


Figure 1. Approximate present distribution of Atlantic (in red) and Pacific (in yellow) walrus (map from COSEWIC 2017)

As industrial and commercial development continues in the Arctic, it is of paramount importance to manage these activities using the best available knowledge of the ecosystems being affected. One specific concern is potential gaps in our current knowledge and understanding of walruses in northern Hudson

Bay. This report summarizes relevant information on walruses in the region from western science and Inuit traditional knowledge, which is a component of *Inuit Qaujimajatuqangit* [IQ], or Inuit societal values. Inuit in the region are concerned about impacts on walruses caused by noise from vessels and other disruptions during breeding, feeding and migration, and about socioeconomic impacts on Inuit harvesters through associated lost revenue (e.g., from sale of tusks) and increased expenses (e.g., having to travel farther to harvest walruses) (Carter et al. 2019).

This report summarizes what is known about walrus abundance, distribution, and ecology in northern Hudson Bay and adjacent areas (section 2), human activities, threats, and limiting factors (s. 3), legislation and management as it pertains to walruses and their habitats (s. 4), marine protection in the region that addresses walruses (s. 5), and current research on walruses in the region (s. 6), and it finishes with a summary of information gaps and recommendations for further research (s. 7). As a comprehensive summary of available knowledge, it provides relevant information for walrus conservation at local and larger scales (e.g., at the population level) and will help guide work to advance community-led monitoring, management, and protected areas in northern Hudson Bay.

2.0 Walrus populations in the Hudson Bay region

Three walrus stocks (DFO 2002; Stewart 2008a) are found in the Hudson Bay region. The Hudson Bay–Davis Strait stock, or a portion thereof, is the main focus of this report, with detailed information presented throughout. A high-level overview of the two adjacent stocks, one in Foxe Basin the other in south and east Hudson Bay, is provided at the end of this section. All three of these stocks (management units) are included in the Committee on the Status of Endangered Wildlife in Canada's (COSEWIC 2017) central/low Arctic designatable unit (DU), with slightly different management stocks identified (Figures 2 and 3). COSEWIC (2017) treated the central and low Arctic (i.e., south and east Hudson Bay stock) DU as one unit for assessment but acknowledged uncertainty in regards to connectivity (see Figure 2). In contrast, Higdon and Stewart (2018) treated these two groups as separate populations, given the uncertainty. Data on geographical distributions, lead isotope ratios, and growth patterns suggest that the walruses in northern Foxe Basin, central Foxe Basin, and northern Hudson Bay–Davis Strait should be treated as separate management stocks (Stewart 2008a), although genetic analyses have not been able to differentiate between these animals (de March et al. 2002; Shafer et al. 2014). Walruses are also found in the High Arctic (see Figures 1, 2, 3) but are not discussed further here as the report focuses on the central/low Arctic population. Furthermore, the central/low Arctic population (as defined by COSEWIC 2017) is shared with western Greenland, but information on the walruses in those waters is not within the scope of this report.

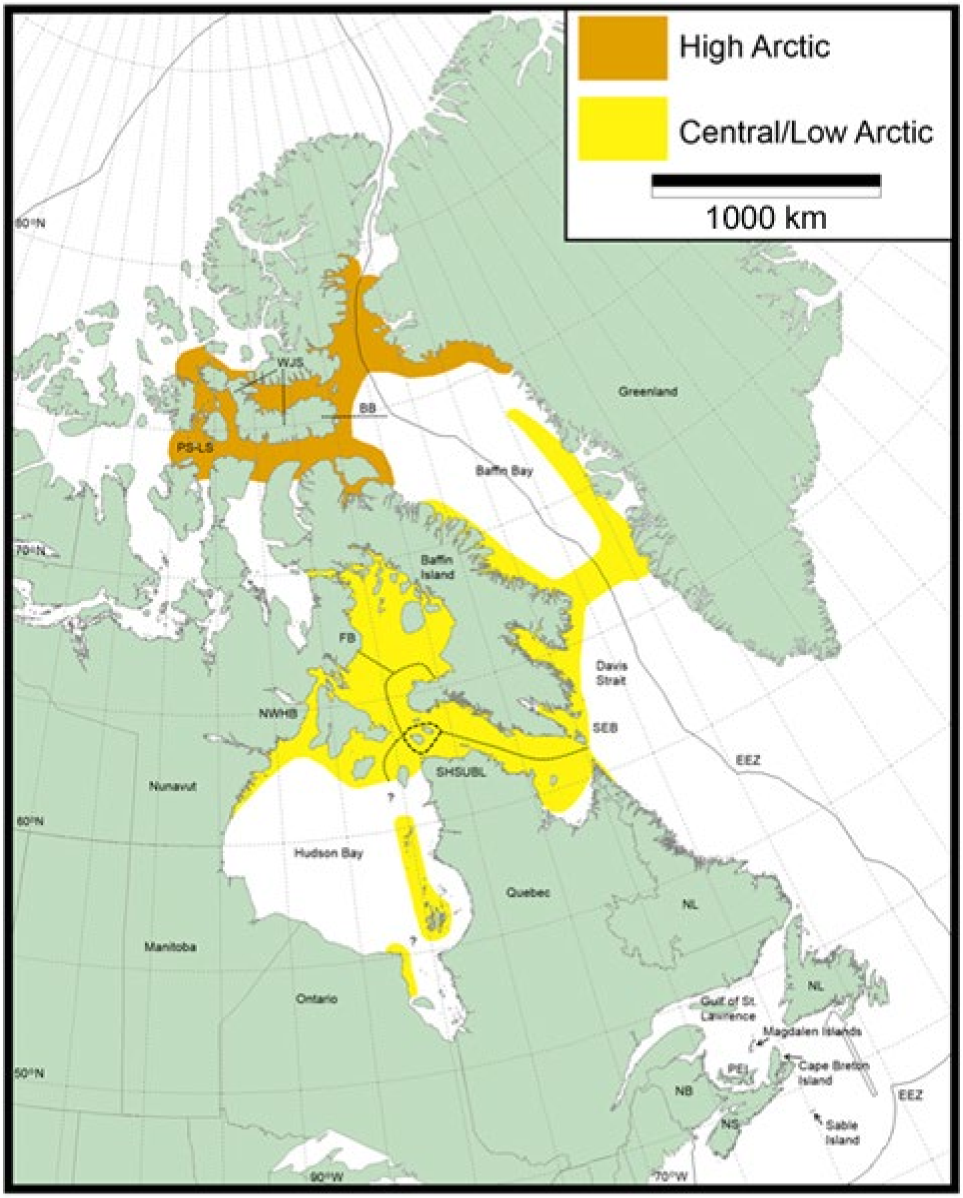


Figure 2. Distribution of Atlantic walruses in the eastern Canadian Arctic, with two populations ("designatable units") as recognized by COSEWIC (map from COSEWIC 2017). See COSEWIC (2017) for acronym definitions of regions used for summary of walrus historic exploitation and current status.

Figure 3. Map of Fisheries and Oceans Canada (DFO) recognized walrus stocks in the eastern Canadian Arctic. Three stocks are in the High Arctic population (Baffin Bay; West Jones Sound; Penny Strait–Lancaster Sound, but see Heide-Jørgensen et al. 2017), which are not considered in this report. The Hudson Bay–Davis Strait, south and east Hudson Bay, and Foxe Basin stocks comprise the central/low Arctic population as defined by COSEWIC (map from Hammill et al. 2016a).

2.1 Hudson Bay–Davis Strait population

The Hudson Bay–Davis Strait walrus population has a wide distribution in Canadian waters, ranging from northwest Hudson Bay (e.g., the Naujaat and Coral Harbour (Salliq) areas) through Hudson Strait and north along the eastern coast of Baffin Island (Born et al. 1995; Hammill et al. 2016a; COSEWIC 2017; Higdon and Stewart 2018) (Figure 3). It is a component of the central/low Arctic population/DU as defined and assessed by COSEWIC (2017). Walruses from this population are hunted by Inuit in communities in both Nunavut and Nunavik (Stewart et al. 2014).

2.1.1 Population size and trends

In the late 1800s, declining abundance of bowhead whales (*Balaena mysticetus*) led to commercial whalers and traders diversifying their activities and increasing their hunting of walruses and other valuable species (Stewart et al. 2014). Many animals were killed before commercial walrus hunting was banned in Canada, in 1928 (COSEWIC 2017). Northwest Hudson Bay is one area where commercial whalers harvested large numbers of walruses, and the population was much reduced by the early 1900s (Stewart et al. 2014; COSEWIC 2017).

The first counts of walrus numbers in the northwest Hudson Bay region occurred in the mid-1950s, with aerial surveys of the Walrus Island–Coats Island–Southampton Island area (Loughrey 1959). Aerial and boat-based surveys were conducted in the region in 1961 (Fisher 1962), followed by additional aerial counts in 1976, 1977 (Mansfield and St. Aubin 1991), and 1988–1990 (Richard 1993). These earlier surveys provide counts of the minimum number of walruses in the area but are not corrected for animals that were not seen. The walrus is a difficult species to survey for population estimation. Most recent surveys count animals at traditional haulout sites (*uglit* in Inuktitut, singular *ugli*) and correct for haulout dynamics using various methods, including concurrent satellite tagging data. A large-scale survey was conducted in September 2014, which used visual and photo counts of walruses at haulouts in northwest Hudson Bay and Hudson Strait, with corrections for haulout dynamics (Hammill et al. 2016a). The 2014 survey covered Hudson Strait, south Baffin Island, and the Southampton Island area, and a total of 2,144 hauled-out animals was counted in the Hudson Bay–Davis Strait stock area. The counts were adjusted for the proportion of animals hauled out at the time of the survey using haulout data from other studies (i.e., no concurrent tagging), which resulted in a corrected abundance estimate of 7,100 (95% Confidence Limits (CL) = 2,500 - 20,400) (rounded to the nearest 100) in the Hudson Bay–Davis Strait stock (Hammill et al. 2016a). A recent walrus status assessment (COSEWIC 2017) reported a population estimate for the northwest Hudson Bay portion of the survey as 5,500 (95% Confidence Intervals (CI) = 2,000 - 15,900), using the proportion of the total animals counted (78% of the simple count) in that area.

An aerial strip-transect survey was conducted in Hudson Strait in March–April 2012 (Elliott et al. 2013). Two replicates were flown, and both were corrected for availability and perception biases. The first estimated 4,675 walruses (Coefficient of Variation (CV) 0.45, 95% CI 1,845 - 11,842), and the second (with incomplete coverage due to inclement weather) 6,020 walruses (CV 0.40, 95% CI 2,485 - 14,585). The stock composition of walruses wintering in this area is unknown, and most animals were seen in central and western Hudson Strait, along both coasts (i.e., Baffin Island and Nunavik) (Elliott et al. 2013).

It is difficult to assess trends in walrus populations. It can be inferred from past commercial exploitation that numbers were historically depleted (Stewart et al. 2014; COSEWIC 2017), but assessment of recent population trends is hampered by infrequent surveys, incomplete survey coverage, differences in methods used, and poorly described methods. The most quantitative attempt at trend analysis (Hammill et al. 2016b) noted these caveats in fitting a surplus production model to aerial survey data using Bayesian methods. These authors estimated that walruses in the northern Hudson Bay region declined from around 10,400 animals (rounded to the nearest 100) in 1954 to a nadir of 3,900 animals in 1986 but have since increased to 7,000 (95% credibility intervals = 4,100 - 10,800) animals in 2014. Given the caveats noted and the high within year and between year usage of haulout sites, these values are highly uncertain.

2.1.2 Ecosystem

Walruses occupy a large range but have a relatively narrow ecological niche and specialized habitat needs (Born et al. 1995). They require areas of shallow water with productive bivalve communities and access to both open water (to breathe) and suitable ice or nearby land to haul out on (Davis et al. 1978). They are associated with moving pack ice for much of the year, and polynyas and floe edges are important during the winter. The Hudson Bay, Hudson Strait, and Foxe Basin areas all provide high-quality walrus habitat.

2.1.2.1 Habitat

Suitable haulout locations are a key determinant of walrus habitat, and this includes both sea ice and terrestrial haulouts (Mansfield 1973). There is little scientific information available on the seasonal movement patterns of walruses in northwest Hudson Bay or on the influences of environmental conditions such as sea ice on those movements (see below for a summary of the extensive local knowledge available).

Satellite-tagging studies in other areas suggest that selection of wintering habitat may be little affected by ice conditions. Walruses breed in winter, and in Svalbard, Norway, tagged males wintered in the same locations with high inter-annual seasonal site fidelity, into heavy pack ice (>90% cover) (Freitas et al. 2009) (note that only male animals were included in this study). The influence of different environmental variables on habitat use by male Svalbard walruses varied seasonally (Freitas et al. 2009). Similarly, Dietz et al. (2014) found both males and females wintered over at Store Hellefiske Banke, central western Greenland, regardless of ice coverage. In Svalbard, water depth and distance to coastline did not affect winter distribution but were important determinants of walrus habitat use during the summer period of intensive foraging. During the non-breeding season, male walruses made intense use of shallow areas (≤ 40 metres) close to the coast (≤ 20 kilometres) (Freitas et al. 2009). Dietz et al. (2014) also found that both males and females were found over deeper water in winter than in summer.

The distribution of walrus in northern Hudson Bay varies seasonally, but movement of specific walrus from one area to another has not been documented. Tagging studies were conducted in the mid-1950s at Bencas Island, Coats Island, and Southampton Island, using harpoon-head tags (147 tagged, four recaptured), but revealed only local movements (Mansfield 1958; Loughrey 1959).

Inuit observations indicate that walruses remain in northern Hudson Bay and Hudson Strait all year, moving inshore and offshore in response to changes in the ice (Orr and Rebizant 1987; MacDonald et al. 1997; Stewart 2002). Sea ice has a significant influence on walrus movements and distribution and, subsequently, on their availability for hunters (MacDonald et al. 1997). Walruses occur off the floe edge along the south and east coasts of Southampton Island and west and southwest coasts of Foxe Peninsula in winter. They favour the pack ice of Evans Strait and Hudson Strait in late spring and summer and move ashore to haulouts as pack ice dissipates (Orr and Rebizant 1987). In the fall, walruses are concentrated at or near haulouts on Bencas, Walrus, Coats, Mills, Nottingham, and Salisbury islands and on western Foxe Peninsula (Orr and Rebizant 1987). Hunters from Kinngait (formerly Cape Dorset) have observed walrus herds of between 500 and 1,000 animals on the ice or at haulouts along western Foxe Peninsula in summer, particularly between Kinngait and Cape Dorchester, with similar numbers in the area between Salisbury and Nottingham islands (Orr and Rebizant 1987). They also reported an increase in the number of walruses near the community over the 30 years prior to 2000 (DFO 2002). Inuit from Akulivik and Ivujivik have seen walruses moving northward from Hudson Bay into Hudson Strait in the fall (Reeves 1995; Fleming and Newton 2003). Walruses remain in the Ivujivik area year-round but are seldom seen near Akulivik in summer (Fleming and Newton 2003). Some walruses are present year-round near Nottingham and Salisbury islands, where strong currents maintain polynyas through the winter (Kemp 1976; Orr and Rebizant 1987).

In western Hudson Bay, walruses occupy the north side of Chesterfield Inlet in the spring, are absent near the community in summer, and are present in the Chesterfield Inlet–Roes Welcome Sound area in winter (Brice-Bennett 1976; Fleming and Newton 2003). They occur in Wager Bay when ice is minimal, and Inuit indicate that they prefer areas with strong currents. Walruses are common in the Repulse Bay area but less so when summer ice concentrations remain high. Walruses were historically more common and numerous along the west coast of Hudson Bay between Arviat and Chesterfield Inlet (Loughrey 1959; Born et al. 1995) but have not occupied various haulouts in western Hudson Bay since the 1950s (Born et al. 1995; DFO 2002; Fleming and Newton 2003; COSEWIC

2017). They are now found mostly north of Chesterfield Inlet, where Inuit reported they were more numerous in the early 1990s than they had been in the past (Fleming and Newton 2003).

An aerial survey of walrus abundance and distribution was conducted in Hudson Strait in March–April 2012 (Elliott et al. 2013). Walrus observations were most frequent in areas of open water with adjacent ice cover (<50%) and peaked in areas within the 100-metre depth contour (Elliott et al. 2013). About half (56%) of the animals observed during the two survey replicates were hauled out on the ice. In winter, Inuit hunters from Coral Harbour and Kinngait see walruses near the floe edge, swimming or hauled out on ice floes (Orr and Rebizant 1987). Information on walrus winter habitat use farther offshore in the region is limited, as there are no observations. Research in western Greenland shows a similar affinity for sea ice habitats during spring. March–April aerial surveys showed a habitat preference for dense pack ice, with most walruses seen in in >60% ice cover (Born et al. 1994). During April and May, tagged walruses selected for 50–60% ice cover, with males showing preference for significantly greater ice cover than females (64% versus 52%) (Dietz et al. 2014).

When sea ice coverage is minimal, walruses require terrestrial haulout sites. Terrestrial haulouts (*uglit*) are often situated on low shores with steep or shelving sub-tidal zones that provide easy access to the water (Mansfield 1959; Salter 1979a, b; Trent University and Makivik Corporation 2015). Higdon (2016) summarized haulout locations throughout the eastern Canadian Arctic, for inclusion in the Nunavut Land Use Plan (NLUP) (see Figure 4).

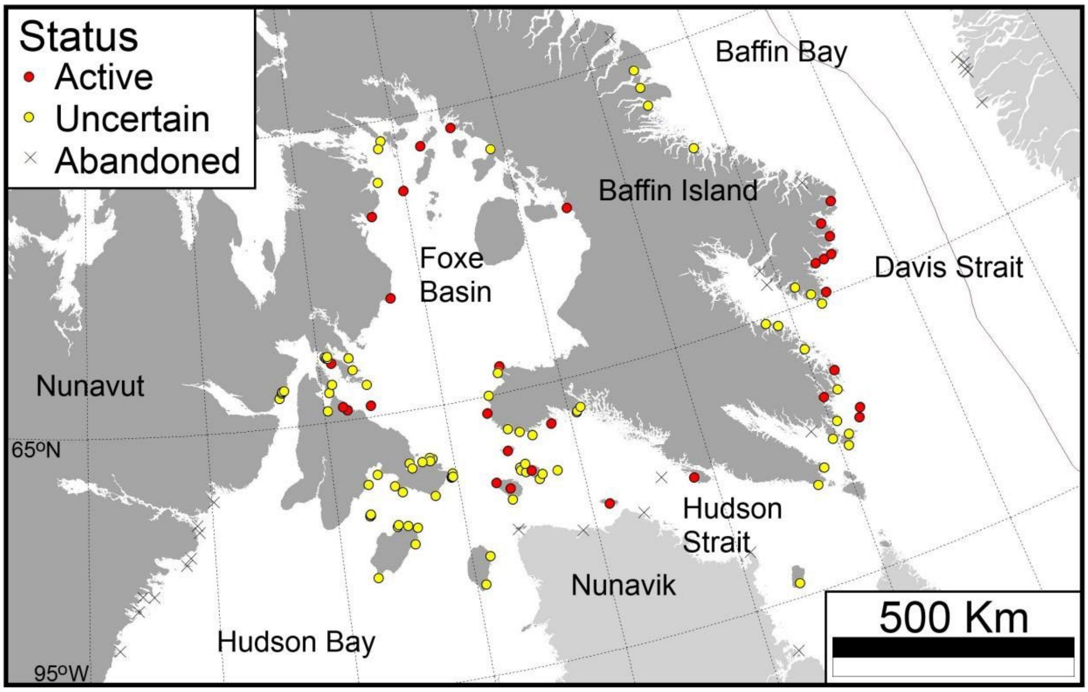


Figure 4. Locations of walrus haulouts in the study area (from Higdon 2016). Note that DFO-led aerial surveys have since confirmed that some of the "uncertain" status sites are still active (Hammill et al. 2016a). Sites that Higdon (2016) presumed to be abandoned could become re-occupied at some point in the future.

There have been extensive efforts to compile Inuit knowledge on walrus distribution in northwest Hudson Bay. The first major compilation was the Inuit Land-use and Occupancy Study (Brody 1976a; Freeman 1976), a major effort to compile and map Inuit land use and wildlife distribution across what is now Nunavut (Figures 5, 6 and 7). The land-use study provides important data on the historical harvesting areas for walruses for comparison with more recent data. Orr and Rebizant (1987) compiled Inuit knowledge from interviews with hunters in Coral Harbour and Kinngait and presented seasonal maps of walrus distribution (Figure 8). Reeves (1995) mapped data for Nunavik waters adjacent to the Coral Harbour area (Figure 9). More recent Inuit observations on walrus distribution and movements are mapped in the Nunavut Coastal Resource Inventory for Coral Harbour (GN 2014; Ghazal 2014, Figures 10 and 11). Community meetings in Coral Harbour to discuss the draft NLUP have included mapping exercises and provided relevant spatial data (Figure 12) (NPC 2014). Carter et al. (2019) also mapped important walrus habitats in the Coral Harbour area (Figure 13).

Ultimately, the key determinants for walrus distribution, movements, and habitat use relate to availability of benthic prey (shallow waters, abundance of prey items) and haulout locations on land or sea ice. Walruses are also sensitive to disturbance (see section 3.2.1.2), which influences distribution. Stewart et al. (2020) conducted preliminary habitat suitability modelling for walruses in Hudson Bay, Hudson Strait, and Foxe Basin. Habitat suitability was modelled for two seasons — September ("summer," sea ice minima) and March ("winter," ice maxima). The models included four environmental variables that are related to walrus life history requirements, hence habitat use: water depth, seasonal ice cover, distance to the coast or ice, and proximity to a terrestrial haulout. Winter and summer habitat scores were highly correlated (Figure 14), indicating similarities in the seasonal habitat rankings for the two models (Stewart et al. 2020). The authors recommended that future modelling activities should explore alternate (finer-scale) environmental data. The model results could also be compared to Inuit observations of important walrus habitat areas (e.g., compare Figures 5–8 and 10–13 with Figure 14).

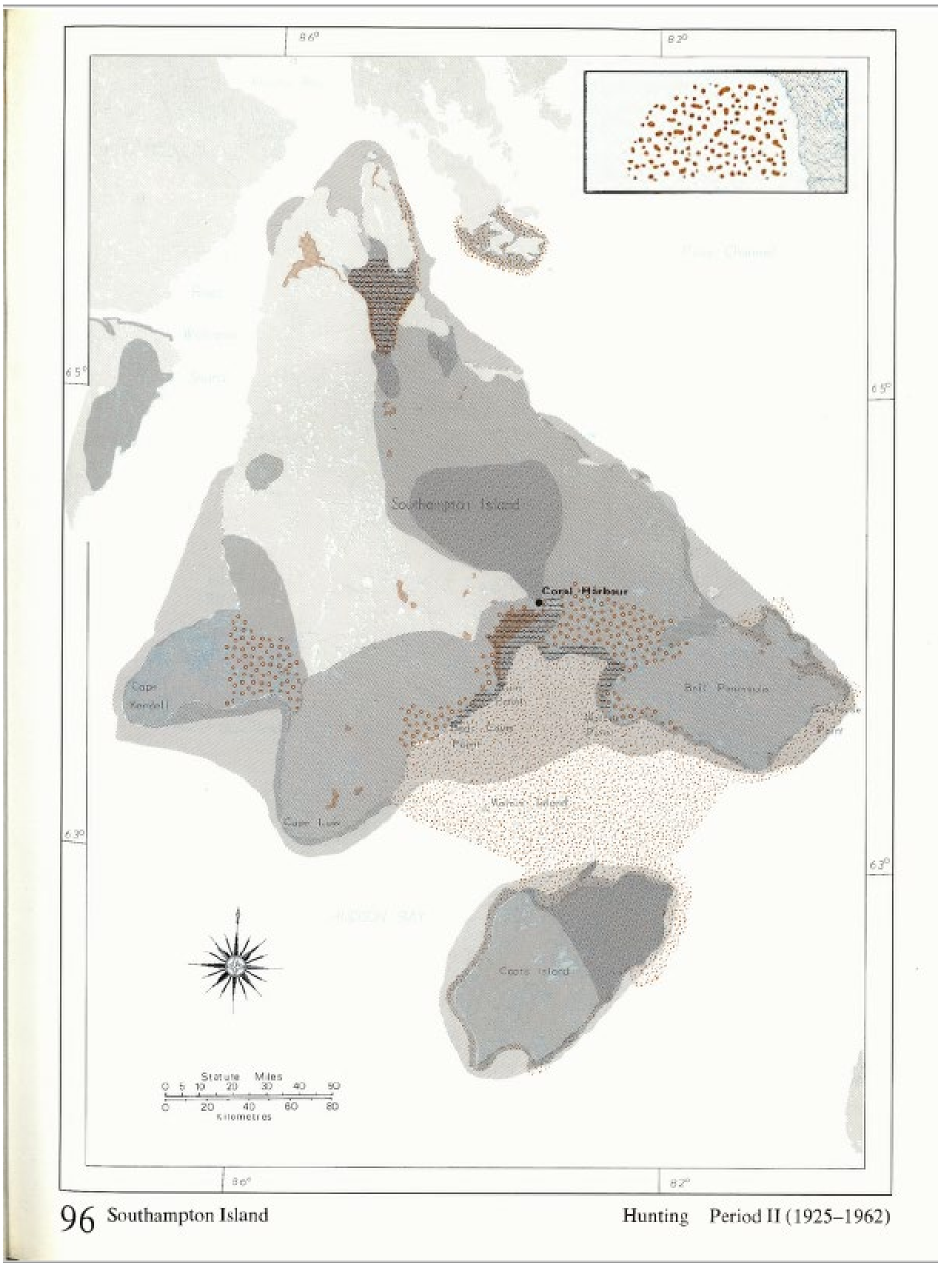


Figure 5. Harvesting areas for walruses (and other marine species) used by Coral Harbour Inuit for the period 1925–1962 (Map 96 in Freeman 1976, Vol. 3). See top right for legend key for walrus harvesting areas.

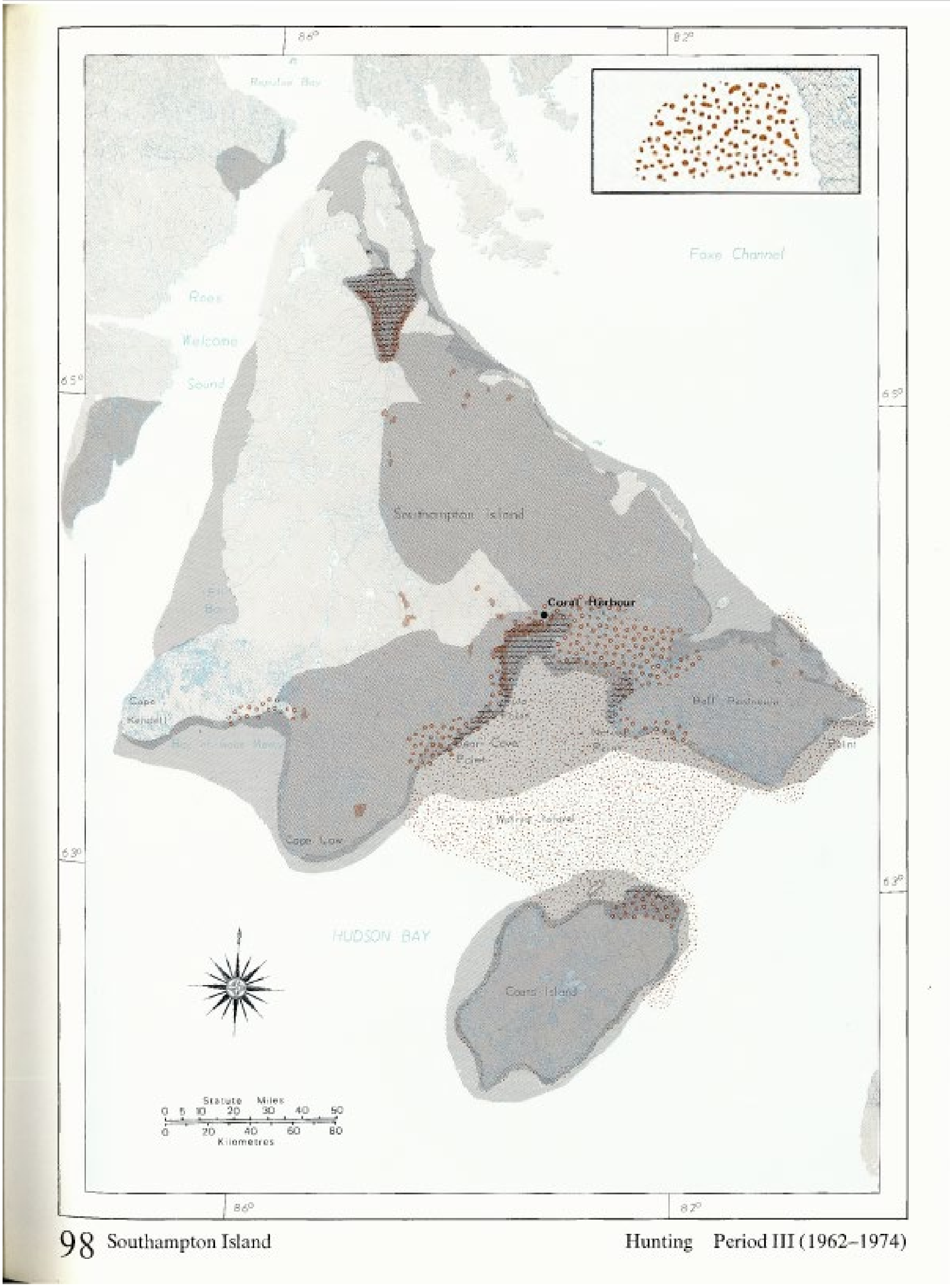


Figure 6. Harvesting areas for walruses (and other marine species) used by Coral Harbour Inuit for the period 1962–1974 (Map 98 in Freeman 1976, Vol. 3). See top right for legend key for walrus harvesting areas.

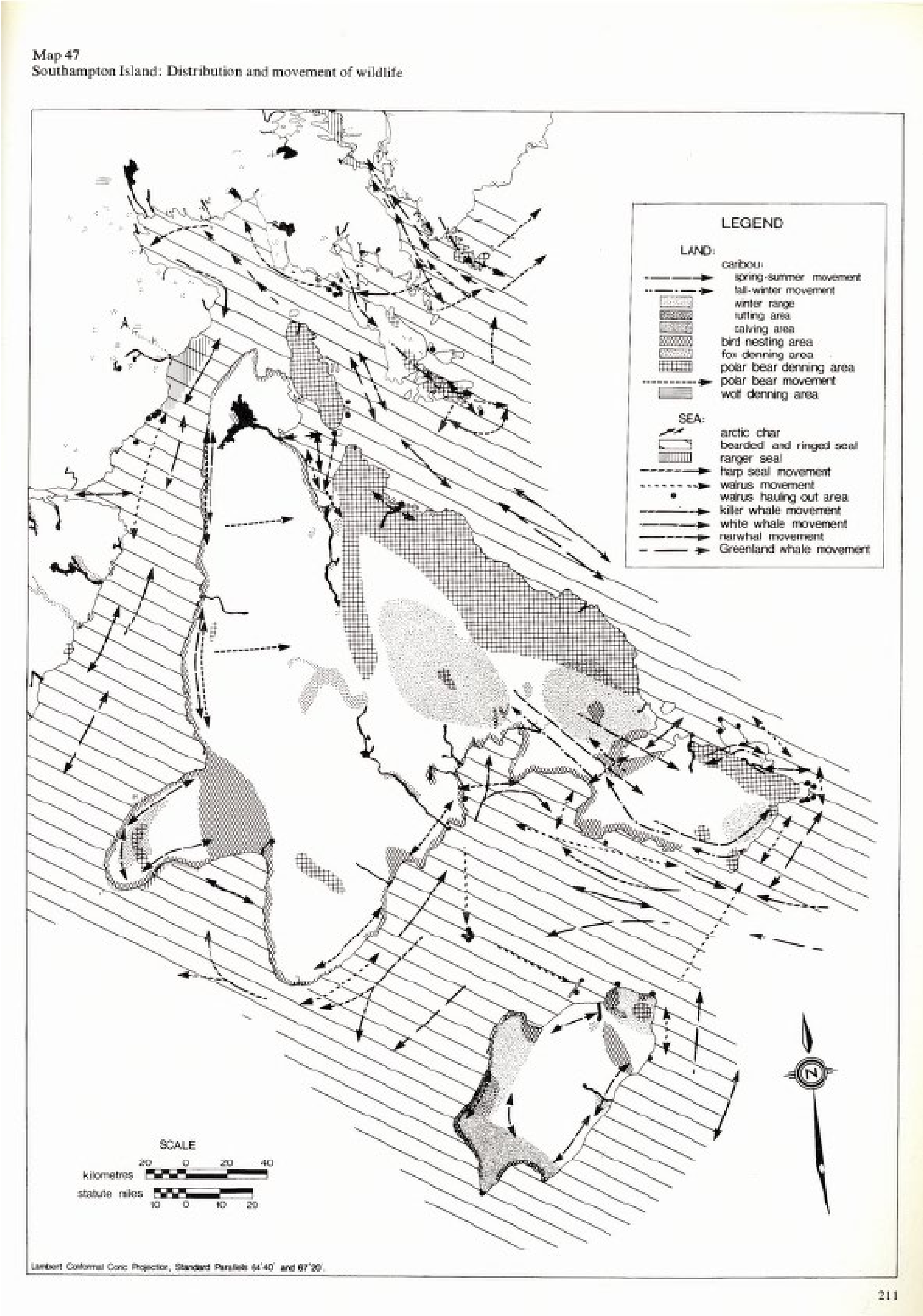


Figure 7. Walrus movements and haulout locations near Southampton Island, as identified during land-use mapping for the Inuit land-use and occupancy study (Brody 1976a)

Figure 8. Seasonal distribution of Atlantic walruses in northern Hudson Bay and western Hudson Strait as reported by Inuit hunters. Top left, winter; top right, spring; bottom left, summer; bottom right, fall (from Orr and Rebizant 1987)

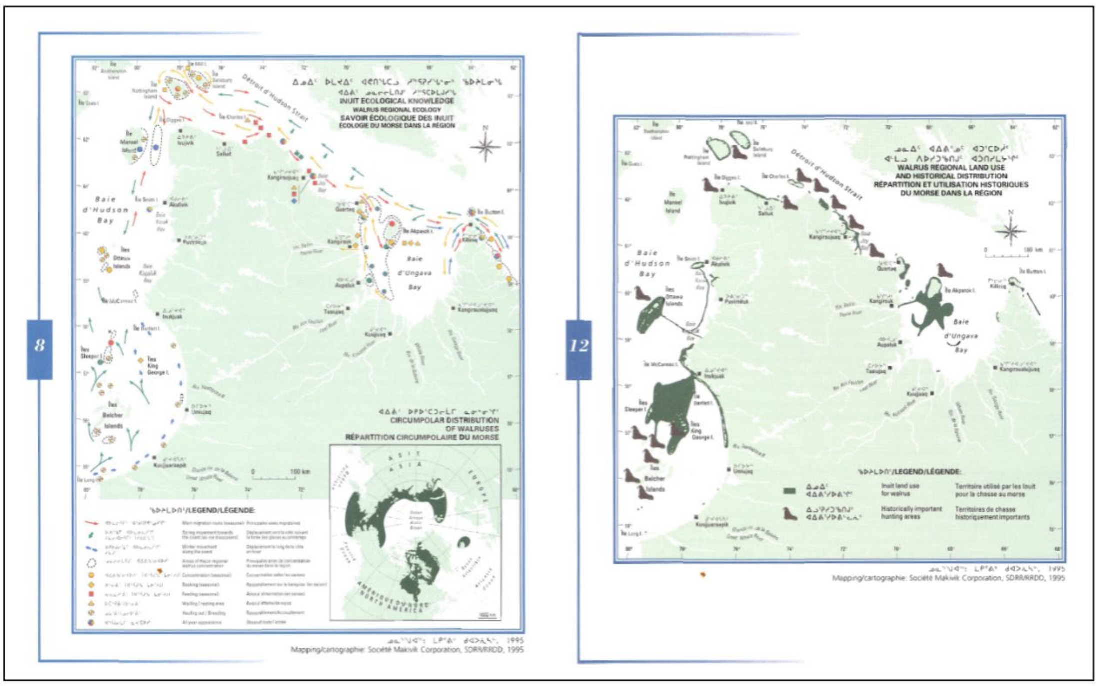


Figure 9. Left: Inuit knowledge of walrus regional ecology in Nunavik. Right: Inuit land use for walrus harvesting in Nunavik (from Reeves 1995)

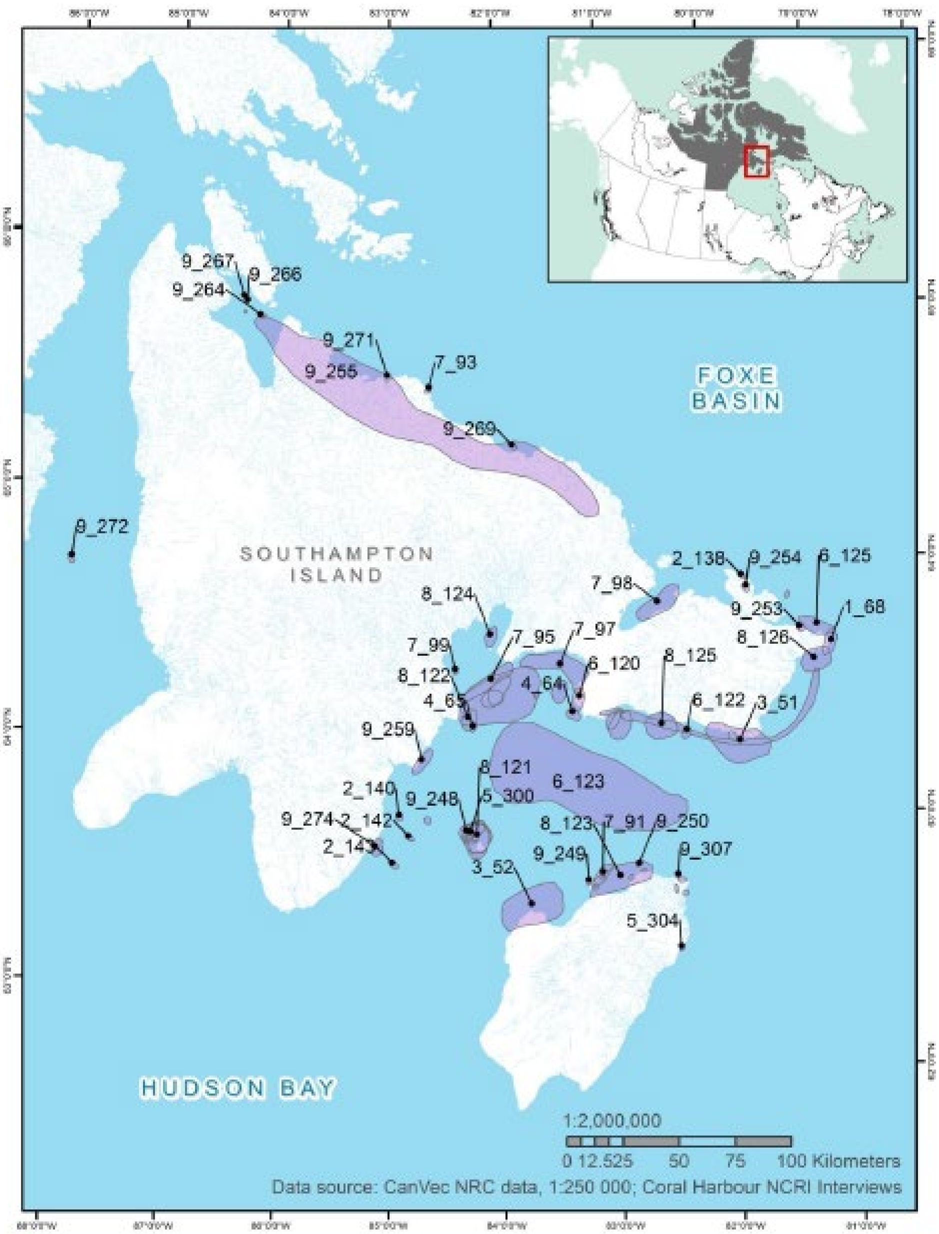


Figure 10. Coral Harbour walrus distribution as identified during the mapping for the Nunavut Coastal Resources Inventory (from Ghazal 2014). Numbers correspond to tabular information summary in the original source.

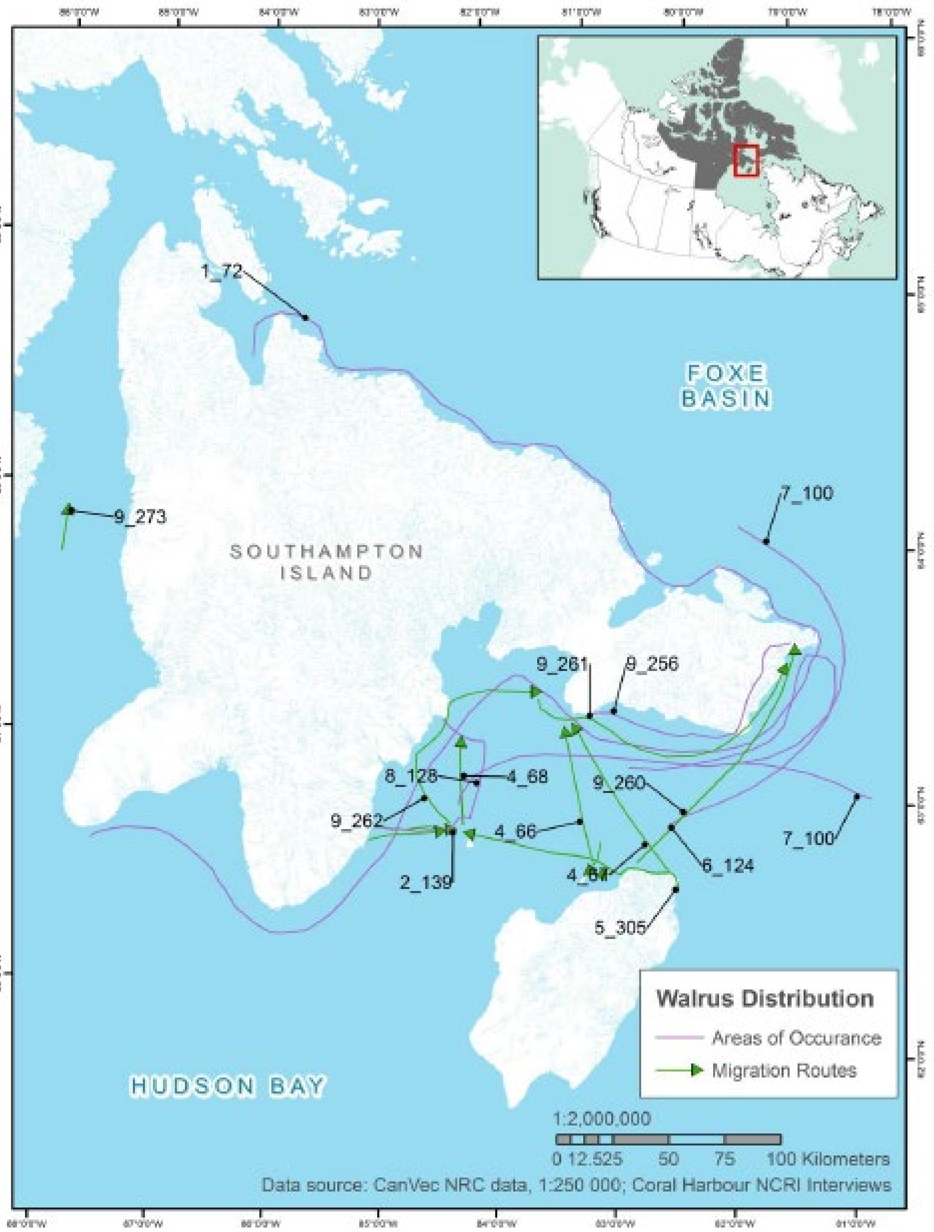
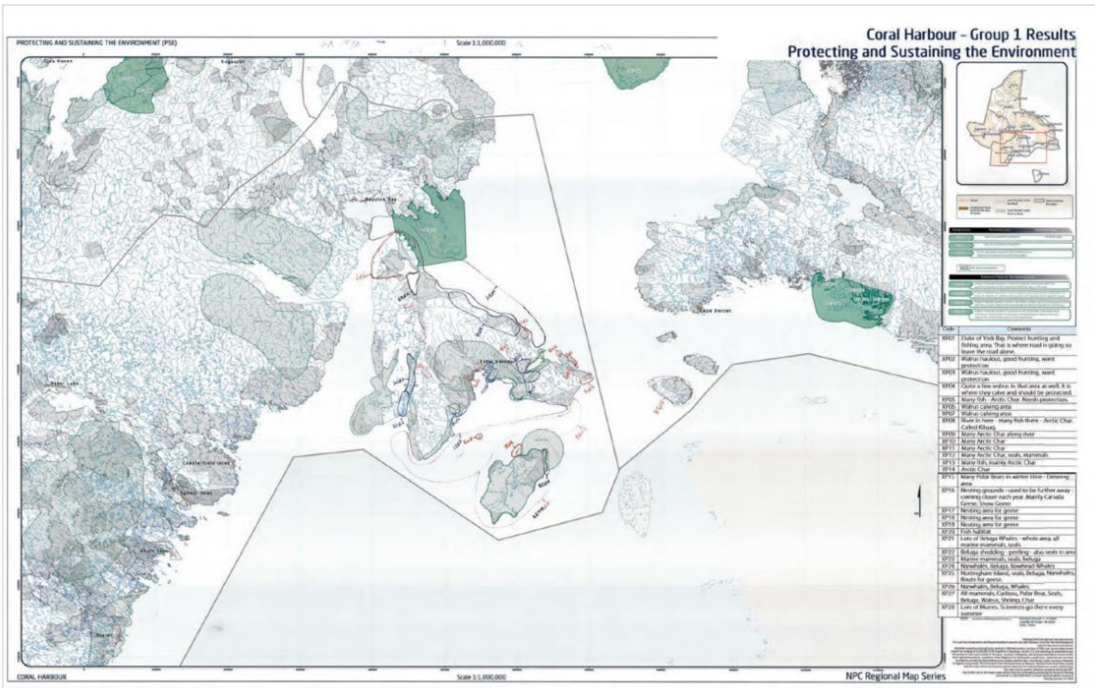


Figure 11. Coral Harbour walrus migration routes as identified during the mapping for the Nunavut Coastal Resources Inventory (from Ghazal 2014). Numbers correspond to tabular information summary in the original source.



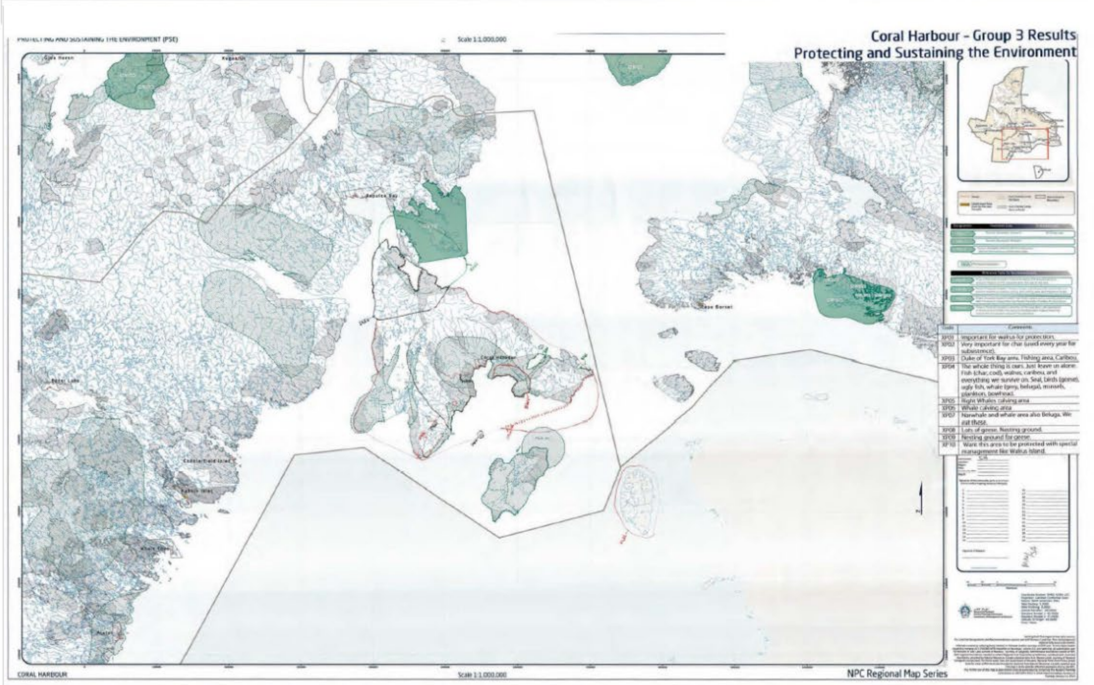


Figure 12. Walrus information provided by Coral Harbour residents during community mapping exercises related to the draft NLUP. Top: walrus haulouts and important habitats, including calving areas. Bottom: important areas to protect for walruses and areas where special management is needed (e.g., Walrus Island) (from NPC 2014)

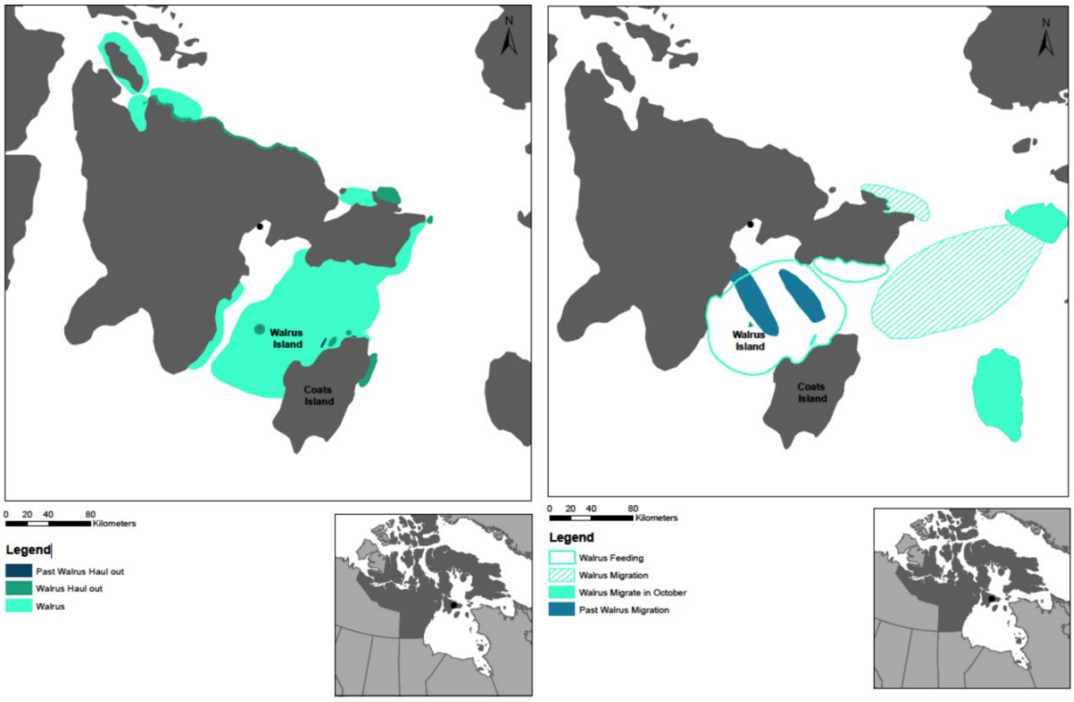


Figure 13. Left: Locations where walruses are observed during the open-water season. Right: Location of walrus feeding and migration during the open-water season (from Carter et al. 2019)

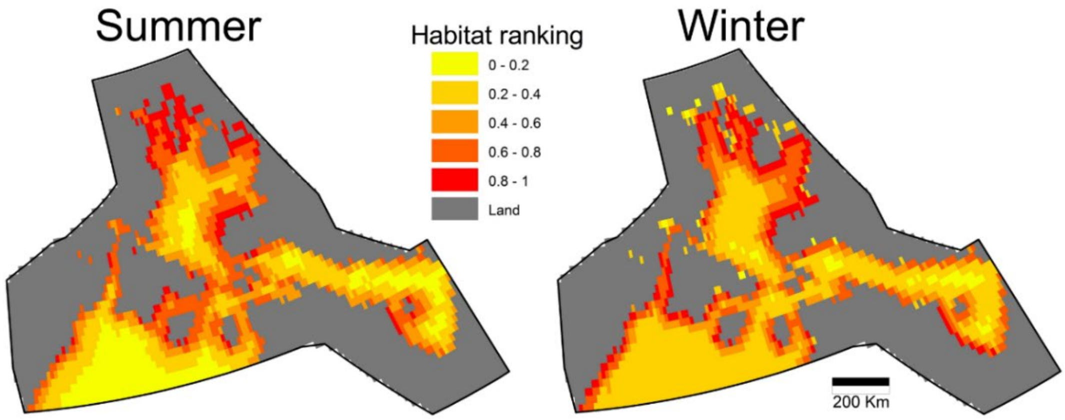


Figure 14. Habitat suitability for walrus, modelled during the seasons of minimum (left panel) and maximum (right panel) sea ice cover using four environmental variables: water depth, seasonal ice cover, distance to the coast or ice, and proximity to a terrestrial haulout. Values are normalized to a 0–1 scale and divided into five equal intervals (from Stewart et al. 2020).

2.1.2.1.1 Recent habitat changes and predicted future changes

Climate-change impacts, including declines in sea ice concentration throughout much of Northern Canada, are well documented in Arctic regions (AMAP 2017; Mudryk et al. 2018). Much of the research on climate change in the Canadian Arctic has focused on the High Arctic region (Hamilton 2013), but there are data specific to Hudson Bay. Hudson Bay is a seasonal ice zone that undergoes a complete cryogenic cycle each year, with ice beginning to form in late October and typically ice-free conditions by early August (Maxwell 1986; Gagnon and Gough 2005; Stewart and Barber 2010; CIS 2011; Hochheim and Barber 2014; Andrews et al. 2018). Ice formation usually begins in the northern part of Hudson Bay and becomes consolidated during mid-November (Maxwell 1986; Gagnon and Gough 2005; Stewart and Barber 2010). Breakup occurs in early July in northwest Hudson Bay, where the ice is removed by strong prevailing northwesterly winds and ocean currents (Gagnon and Gough 2005). The area of open water in this region expands to the south and east throughout July (Gagnon and Gough 2005).

While breakup and freeze-up dates are highly variable, Gagnon and Gough (2005) identified a statistically significant trend towards earlier breakup in western Hudson Bay and towards later freeze-up in northern Hudson Bay. More recent studies have confirmed these trends, and the length of the open-water season has, on average, increased by 3.1 (± 0.6) weeks in Hudson Bay (and 4.9 ± 0.8 and 3.5 ± 0.9 weeks in Hudson Strait and Foxe Basin, respectively) over the past four to five decades (Hochheim and Barber 2014; Kowal et al. 2017; also see Andrews et al. 2018). The rate of summer ice decline in the Hudson Bay region was −11.3% ± 2.6% per decade between 1968 and 2008 (Tivy et al. 2011). Other studies have also shown statistically significant trends for earlier breakup in western Hudson Bay, Hudson Strait, and Foxe Basin (Stirling and Parkinson 2006; Hochheim et al. 2010; Galbraith and LaRoche 2011). A multi-model consensus for the period 2020–2050 predicts reductions in winter sea ice concentration of 5–10% per decade (or 15–30% in total) for Hudson Bay (Mudryk et al. 2018). The seasonal ice cover of Hudson Bay is a major influence on the ecology of the marine system (Hamilton 2013), and additional research on the ecological impacts of sea ice declines in northwest Hudson Bay is needed.

Walruses depend on benthic invertebrates for food (see below), and there has been little research on benthic communities in the northwest Hudson Bay region. Research conducted elsewhere, and modelling within the region, does provide relevant information. One important factor in understanding climate change impacts on walruses is the role that ice algae has played and will continue to play in the Hudson Bay marine ecosystem (Hamilton 2013). Ice algae contribute up to 57% of primary production in some Arctic regions (Gosselin et al. 1997), and around 25% of total production in some areas of Hudson Bay (Legendre et al. 1996). These small plants form the base of the ice-associated food web (Poulin et al. 2011; Post et al. 2013; Tedesco et al. 2019), and reductions in ice cover will shift more of the primary production to pelagic phytoplankton living in the water column (Hoover 2010; Hoover et al. 2013a, b; Post et al. 2013; 2019; Tedesco et al. 2019). Changes in the sources of production (i.e., from sympagic [ice associated] to pelagic) will likely have effects that cascade throughout the food webs of the Hudson Bay region (Hamilton 2013). Plankton cells are frozen within the ice each autumn and released back into the water column during the spring melt, and cells that sink through the water column to the benthos are a major contributor to the diets of benthic species (Wassmann 1998; McMahon et al. 2006; Lavoie et al. 2009; Hoover et al. 2013a, b). The minimum export of ice algae to the benthic community has been estimated at 20% in southeastern parts of Hudson Bay (Tremblay et al. 1989).

Hoover et al. (2013a, b) used an ecosystem model to reconstruct past changes and simulate potential future changes to Hudson Bay marine food webs under various climate change scenarios (also see Hoover 2010; Hoover et al. 2012). The model was first used to simulate the ecosystem's changes from 1970 to 2009, driven by environmental variables (sea-surface temperature and sea ice) and catches of different wildlife species (Hoover et al. 2013a). The model was then used to develop a suite of future scenarios with a variety of climate change and harvest levels to forecast future changes to 2069 (Hoover et al. 2013b). In the fitted historic model, declines in sea ice and increases in the spring bloom facilitate a shift from benthic to pelagic pathways in lower trophic levels (Hoover et al. 2013a). As sea ice declined, declines in ice algae and ice detritus in the model led to declines in the biomass of bivalves and other benthos functional groups considered (marine worms, echinoderms, other benthos) (Hoover et al. 2013a). The consequences of such shifts to the current status and trends in Hudson Bay walrus populations have not been studied in detail. Under future climate scenarios, ecosystem shifts favouring pelagic species over benthic species are further exaggerated (Hoover et al. 2013b). These results, while uncertain due to model and data limitations, highlight the need for additional research on climate change, benthic habitats, and walruses.

2.1.2.2 Food web and ecosystem interactions

Atlantic walruses primarily consume benthic invertebrates, bivalve molluscs such as *Mya truncata*, *Macoma calcarea*, and *Serripes* species in particular (Mansfield 1958; Fisher 1989; Fisher and Stewart 1997). Other benthic prey include polychaetes, echiurids, and sipunculids. When foraging, walruses use their sensitive whiskers to identify prey and expose them using a flipper or a jet of water from their mouth (Loughrey 1959; Kastelein et al. 1990; Levermann et al. 2003). Most foraging occurs at depths from 10 to 80 metres (Mansfield 1958; Born et al. 2003; Born and Acquarone 2007) although adult males can dive to depths of at least 250 metres (Born et al. 2005). The depth range of most foraging corresponds closely to the depth distribution of important clam prey species. Seasonal feeding patterns are not well studied, although walruses may feed most intensively in the fall (Fisher and Stewart 1997). In Svalbard, Norway, strong inter-annual fidelity to summering areas may be explained by the predictable availability of benthic food resources in key habitat areas (Freitas 2008; Freitas et al. 2009). The diets of males and females are similar, but females have a more efficient digestion (Fisher 1989; Fisher et al. 1992). Walruses will also occasionally eat ringed (*Pusa hispida*) and bearded (*Erignathus barbatus*) seals, fishes, and squids (Mansfield 1958; Hantzsch 1977) and will also prey upon seabirds (Mallory et al. 2004). Most seal eating is predation rather than scavenging (Lowry and Fay 1984 – Pacific walruses), and Inuit note that seal predation is most prevalent in areas where deep water makes it harder for walruses to access benthic resources (Gunn et al. 1988; Piugattuk 1990; Kappianaq 1992, 1997).

The only significant predator of walruses in the eastern Canadian Arctic, besides humans, is the polar bear (*Ursus maritimus*) (Loughrey 1959; Killian and Stirling 1978; Thiemann et al. 2008; Galicia et al. 2016). Walruses are most vulnerable to polar bear predation when they are frozen out of their breathing holes or reliant on a very limited area of open water for breathing and hauling out, especially in areas where rough ice provides cover for stalking (Calvert and Stirling 1990). Predation rates could also be high if the open-water period lengthens, forcing walruses to make greater use of terrestrial sites (Garlich-Miller et al. 2011). Sub-adults are more vulnerable to polar bear attacks, as adults can be aggressive and possess large tusks for defence. Polar bear predation on walruses varies by area, with the highest rates in Foxe Basin (Thiemann et al. 2008; Galicia et al. 2016). The degree of walrus predation also varies with bear sex and age — consumption was greatest among large adult male bears and increased with age for both males and females (Thiemann et al. 2008; Galicia et al. 2016). Rates of mortality from polar bear predation are unknown and should be studied. Killer whales (*Orcinus orca*) are a significant predator on some marine mammal species in the eastern Canadian Arctic but they do not appear to regularly hunt Atlantic walrus (Ferguson et al. 2012).

2.2 Other Hudson Bay region populations

2.2.1 Foxe Basin

Walruses are widely distributed in northern Foxe Basin, although their distribution in southern Foxe Basin, closer to northwest Hudson Bay, is less well understood (COSEWIC 2017). Inuit Elders in Foxe Basin recognize two groups of walruses on the basis of differences in body size, colour, meat flavour, and distribution (DFO 2002). There are also differences in dental lead isotope ratios of animals landed by hunters from Igloolik and Sanirajak (formerly Hall Beach), which suggest that hunters from the two communities take animals from different local stocks (Outridge et al. 2003; Stewart et al. 2003). Due to difficulties in distinguishing between them during surveys, both stocks are managed as a single Foxe Basin stock (Stewart 2008a; Hammill et al. 2016c).

The combined Foxe Basin (i.e., northern Foxe Basin and southern Foxe Basin) population was surveyed using haulout counts in September 2011, with counts adjusted for behaviour using satellite-tagged animals. The minimum counted population (MCP) was 6,043 animals, with corrected estimates ranging from 8,152 (CV 0.02) to 13,452 (CV 0.43) depending on adjustment method (Stewart et al. 2013). The “best” estimate was 10,379 walruses. These data were re-analyzed by Hammill et al. (2016c) along with 1980s surveys (Orr et al 1986;

Richard 1993) to look for evidence of population trends, with broadly similar results for 2011 abundance. Population trend is uncertain, but there is no evidence for a decline in numbers (COSEWIC 2017). A Bayesian surplus production model fitted to Foxe Basin aerial survey data estimated a current population abundance of 12,500 (95% credibility interval = 8,600 - 18,500, rounded to the nearest 100), and the population appears to have remained stable over the last 60 years (Hammill et al. (2016b). The walrus is an important species for harvest by the Foxe Basin communities of Igloolik and Sanirajak, with landed catches of 80–310 per year for both combined in recent decades (Stewart et al. 2014).

2.2.2 South and east Hudson Bay

The south and east Hudson Bay walrus population (the low Arctic portion of a combined population with the central Arctic stocks in COSEWIC 2017) is found along the eastern Hudson Bay coast from the Ottawa Islands south to western James Bay (Figures 2 and 3). There is a lack of data on abundance and movements of these walruses, in addition to gaps in our knowledge of the genetic relationships between these animals and adjacent groups. Organochlorine signatures, metal concentrations in tissues, and dental lead isotope ratios all indicate some differences between these animals and those in Foxe Basin and Hudson Strait (Wagemann and Stewart 1994; Muir et al. 1995; Outridge and Stewart 1999; Outridge et al. 2003). During traditional knowledge interviews in 2013–2014, Inukjuak (Nunavik) Elders reported that walruses in the Sleeper Islands belong to a different stock than those found at Nottingham and Salisbury islands in Hudson Strait (Trent University and Makivik Corporation 2015). Additional sample data are needed to determine if these animals are from a genetically distinct population (COSEWIC 2017).

The south and east Hudson Bay population is thought to be reduced from historic abundance (COSEWIC 2017). An aerial survey of haulouts in September 2014 estimated 200 animals (95% CL = 70 - 570), rounded to the nearest 10 animals (Simple Count (SC) = 58; Minimum Counted Population (MCP) = 101; Bounded Count (BC) = 196) (Hammill et al. 2016a). This is the only systematic survey to have been conducted in the area (there are opportunistic counts by Ontario Ministry of Natural Resources staff near Cape Henrietta Maria), and no trend data are available (COSEWIC 2017). Annual reported harvests from this population or stock average around 10 animals per year over the period 1980–2010 (Stewart et al. 2014), with annual harvests ranging from zero to 28 walruses.

3.0 Human activities, threats, and limiting factors

Walrus are gregarious and valuable, with a narrow trophic niche and restricted seasonal distribution that makes them relatively easy for hunters to locate and vulnerable to environmental changes (Born et al. 1995). Hunting continues to be an important factor for Atlantic walrus management in Canada, but industrial development and climate change are becoming increasingly important as conservation concerns (COSEWIC 2017). Hauser et al. (2018) considered walruses more vulnerable to impacts from shipping via the Northwest Passage than other pinniped species, largely because of their higher climate change sensitivity and exposure along the route. Shipping of iron ore may soon disrupt walrus habitats in Hudson Strait and Foxe Basin year-round (BIMC 2018).

At recent workshops and hearings, local Inuit and scientists have expressed concern about the potential impacts from non-renewable resource exploration and development as well as disturbance by tourism (e.g., Megannety 2011; Qikiqtani Inuit Association 2011, 2012; DFO 2012, 2013; NTI and KIA 2015; Stewart et al. 2012, 2017; COSEWIC 2017; NIRB 2019). Human disturbances can cause walruses to stampede into the water, can interfere with feeding, can cause walrus to increase energy expenditures, can mask walrus communications, can impair walruses' ability to thermoregulate, and can increase stress levels in walruses (COSEWIC 2017). Prolonged or repeated disturbances may cause them to abandon their haulouts. The ability of walrus to recolonize areas and to adapt to disturbances is unknown.

The COSEWIC (2017) threats assessment for walruses in the central/low Arctic DU (designatable unit), which includes animals that summer in northwest Hudson Bay, produced an overall threat impact score of "high" to "very high." The potential increase in commercial shipping related to industrial development in the Arctic was identified as a particular concern, because the species is sensitive to human disturbance and proposed routes run through core habitat. Medium- to high-impact threats included transportation and service corridors, such as shipping lanes and flight paths. Medium-impact threats were biological-resource use (i.e., harvesting) and natural system modifications (e.g., from water-management activities), and medium- to low-impact threats were human intrusions and disturbances, such as recreation activities. Pollution was considered a low-impact threat, and unknown-impact threats included energy production and mining, invasive and other problematic species, and climate change. However, it is important to note that these threats are not evenly spread, so walruses that inhabit the Coral Harbour area, seasonally or year-round, are subject to a somewhat different mix and level of threats than those elsewhere in the central/low Arctic DU.

3.1 Energy production and mining

Southampton Island and other islands in northern Hudson Bay and western Hudson Strait have not been subject to large-scale non-renewable resource development, such as mining or hydrocarbon extraction. But walruses that summer in the Coral Harbour area may be affected by shipping activities related to mines in the Kivalliq region, Nunavik, and on northern Baffin Island.

Current risks from non-renewable resource exploration and development to walruses that are hunted by Coral Harbour are low. There is no exploratory drilling for oil or natural gas ongoing and there are no active oil or natural gas wells within walrus range in northern Hudson Bay (Figure 15; Hanna et al. 2018;

CIRNAC 2018, 2019). No exploration, significant discovery, or production licences have been in force for Hudson Bay since Aug. 8, 2017, when eight offshore-exploration permits in the Hudson Bay were surrendered in their entirety in accordance with the Canada Oil and Gas Land Regulations (CIRNAC 2018, 2019). The moratorium on oil and gas exploration and other activities in Arctic waters, which was to expire on December 31, 2021, has been extended to December 31, 2022. (Government of Canada 2019a, 2022).

The closest mining developments are situated inland from the Kivalliq coast (Meliadine gold mine and Meadowbank gold mine) and well inland from the Hudson Strait coast of Nunavik (Raglan Mine and Nunavik Nickel Project). Agnico Eagle's mine-servicing vessels have started to use a route south of Coats Island that avoids haulouts in Fisher and Evans Straits, unless bad weather forces them to take an alternate route north of Coats Island (Agnico Eagle Nunavut 2020). Despite some efforts to reduce vessel traffic through sensitive areas, there is significant traffic on the route between Coats and Southampton islands as vessels service Kivalliq communities and mine sites (Maerospace 2020). Future risks to walruses, particularly related to hydrocarbon exploration and development, are unknown but deserve consideration.

Hudson Bay is situated in the only large intracratonic basin in North America without proven hydrocarbon reserves (Lavoie et al. 2015). From 1964 to 1985, extensive linear seismic surveys were conducted in Ungava Bay, Hudson Strait, and southwestern Hudson Bay, and four onshore and five offshore exploration wells were drilled (Figure 15; Lavoie et al. 2013, 2015; Hanna et al. 2018). Evidence of hydrocarbons was found in well log data and seismic reflection profiles, but exploration was stopped due to pessimistic conclusions about source rocks and the thermal rank of the basin (Lavoie et al. 2015). Recent discoveries of pockmarks on the sea floor and possible evidence of oil slicks in satellite imagery support the likelihood of an active petroleum system. While the offshore petroleum potential of Hudson Bay, Repulse Bay, and Foxe Channel is considered low to moderate (Hanna et al. 2018), the available information suggests that the Hudson Bay basin has higher petroleum potential than previously considered and is, at least locally, prospective for oil accumulations (Lavoie et al. 2015). Outcrops of petroliferous Ordovician shales on Southampton Island (Heywood and Sandford 1976; Lavoie et al. 2018) are not considered prospective as, despite being organic rich, the rock has not reached the stage where it has generated and expelled much oil.

Additional seismic work has been identified as the next step in proving hydrocarbon resources in the Hudson Bay basin (Lavoie et al. 2015). The potential for hydrocarbon exploration is a concern with respect to walruses as their sensitivity to behavioural disturbances from seismic testing and drilling, threshold for noise-related injury, and vulnerability to spill-related impacts are unknown (COSEWIC 2017; Stewart et al. 2017). The Nunavut Impact Review Board (NIRB) has recommended that these information gaps on disturbance effects be filled should the current moratorium on oil and gas exploration in the Canadian Arctic waters be lifted (NIRB 2019: vol. 3, Sec. 10.2, pgs. 426-451). In western

Greenland, protection zones have been established around key walrus summering habitats wherein seismic activities are to be avoided from Oct. 1 to May 31 or limited to a few widely spaced (>10 kilometres) lines that are subject to approval and impact studies (Kyhn et al. 2011). Sea ice typically prevents seismic activities on the species' wintering grounds.

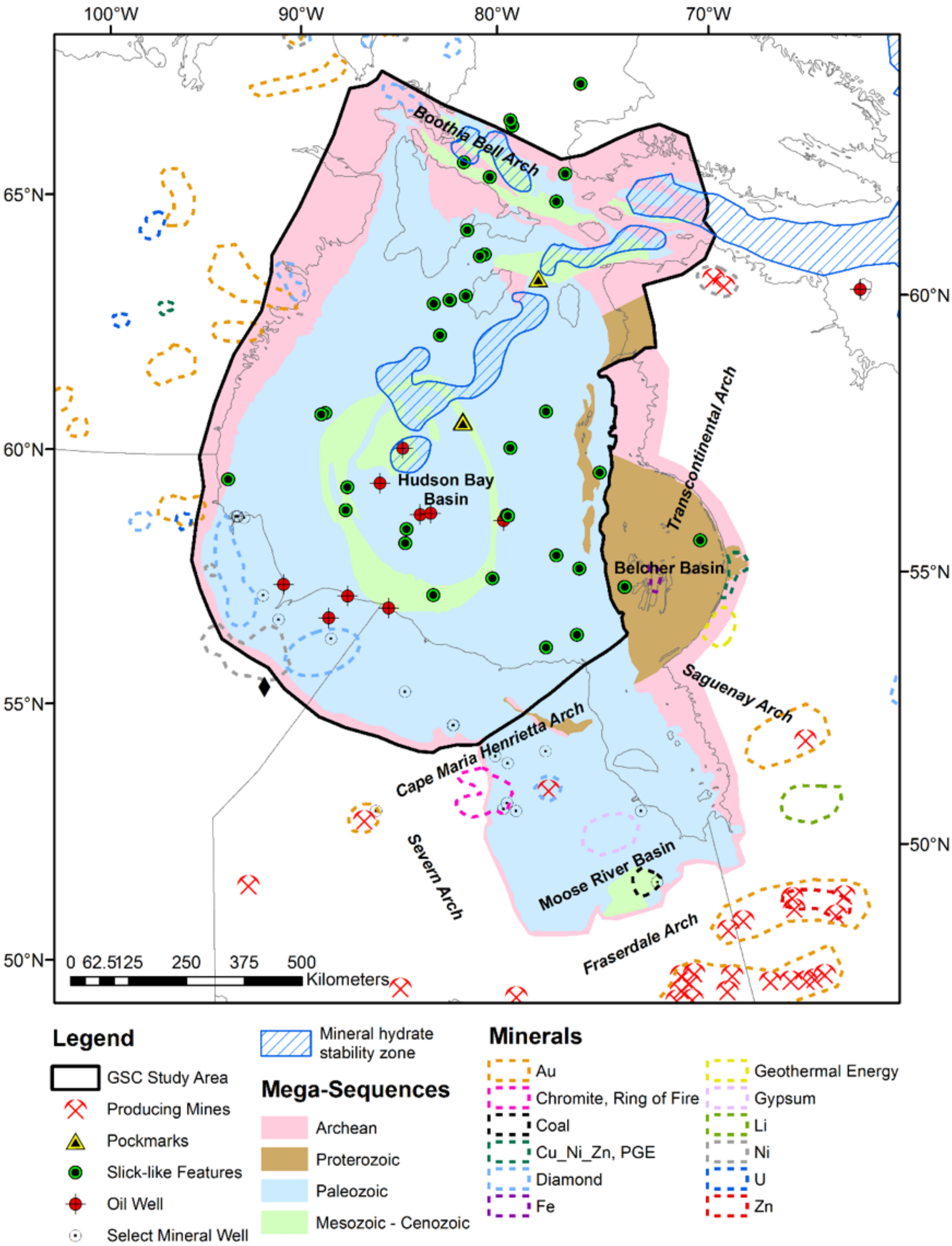


Figure 15. Geological map of the Hudson Bay area, showing Hudson Bay and James Bay geologic mega-sequences, select petroleum system indicators (sea surface slick-like features, sea floor pockmarks), and well locations. Wells shown are both petroleum and mineral wells drilled in the Hudson Bay basin and surrounding onshore areas (from Hanna et al. 2018, Figure 3, pg. 7)

A variety of mineral deposits have been identified near the mainland coasts of Hudson Bay and Hudson Strait but none on Southampton Island or Coats Island

(Figure 15; Hanna et al. 2018). Resource extraction from these deposits is unlikely to have direct effects on walruses, but animals that summer in the Coats Island area may be vulnerable to project-related shipping disturbances and spills. Any offshore mining development would require establishment of a new regulatory framework (Hanna et al. 2018).

3.2 Shipping, transportation, and service corridors

Walruses are sensitive to disturbances caused by shipping activities and aircraft overflights and often exhibit an escape response. An animal's previous experiences with disturbance, the type and strength of sound, olfactory and visual cues, and access to escape routes are some of the factors that affect their responses (Loughrey 1959; Fay et al. 1984; Born et al. 1995; COSEWIC 2017). Their eyes appear to be specialized anatomically for short-range vision in the water and on land (Kastelein 1993). Above water, Atlantic walruses can probably distinguish large moving objects, such as boats, visually at a distance of approximately 60 metres, but seem to be unable to identify a stationary person who was not silhouetted within six metres (Loughrey 1959). Walruses have fairly acute hearing and will reply to hunters imitating their vocalizations from a distance of approximately one kilometre. However, they probably rely primarily on their acute sense of smell to sense danger on land and while swimming at the surface (Loughrey 1959; Fay et al. 1984). Wind direction is important for detecting odours, and an approach from downwind, that is moving upwind or into the wind, generally allows for closer approach than approaching from the direction of the wind (moving downwind). On land, Atlantic walruses can be approached closer than six metres from downwind, provided the threat cannot be identified visually or by sound, but when approached from upwind, they will stampede into the water before the threat (e.g., person) can be seen.

Pacific walruses also react much later when approached from downwind (facing into the wind) than when the wind carries scent towards the animals. Depending on the source of the intrusion (ship, boat, helicopter) reaction distances were 64% (helicopter) to 94% (inflatable boat) shorter (Fay et al. 1984):

- ship: 1,500–2,000 metres vs. 100–650 metres
- 30-foot survey boat: 600 metres vs. 40–60 metres
- inflatable boat: 200–300 metres vs. 10–20 metres
- helicopter: 1,000–1,800 metres vs. 400–600 metres

Disturbance may affect population dynamics by causing stampedes, interfering with feeding, causing walruses to increase energy expenditures - particularly on the part of calves, masking walrus communications, impairing walruses' ability to thermoregulate, and increasing walrus stress levels (Stewart et al. 1993; COSEWIC 2017). Young walruses and those in poor condition are vulnerable to trampling if herds are stampeded onshore or offshore (Salter 1979a; Born et al. 1995). High-mortality stampede events have been reported at Pacific walrus haulouts but not for Atlantic walruses, possibly due in part to the very large aggregations of Pacific walruses and remoteness of large walrus haulouts in

Canada (Higdon and Stewart 2018). But, Atlantic walrus stampedes do cause some mortality (Loughrey 1959) and tusk breakage (B. Sjare, DFO, pers. comm. 2005). The reactions of Pacific walruses at Round Island, Alaska, to disturbance have remained similar over a 20-plus-year monitoring period, for both boats and aircraft, suggesting that the walruses have not habituated to these disturbances (DFO 2019a).

Multi-decade avoidance, or abandonment, of haulouts has been observed, particularly in areas that are readily accessible from communities (COSEWIC 2017). Factors leading to abandonment have not been studied systematically but disturbance caused by human activities and hunting are contributing factors (Salter 1979a; Kopaq 1987; Born et al. 1995; Immaroitok 1996; Kupaaq 1996; Paniaq 2005). Inuit Elders in Hudson Bay and elsewhere caution against hunting at feeding areas and leaving remains at haulouts, as this leads to abandonment.

> *"When I was growing up, I remember, my father and the others used to say never try to kill a Walrus where you think it will sink right into the feeding areas, or never cut up the Walrus where they usually bask or rest. The elders used to say never to leave the guts near the islands where they bask. If you do that the Walrus will move away from there."*
> (Zach Novalinga, Sanikiluaq, in Fleming and Newton 2003:16)

Once walruses stop using a haulout, it may not be reoccupied for many years, changing Inuit access to walrus.

3.2.1.1 Shipping activities

Walruses that summer in northwest Hudson Bay and winter there or in Hudson Strait may be exposed to merchant vessels loaded with cargo or fuel (e.g., sealift) for communities and other developments (e.g., mines), tourist cruise ships, fishing vessels, and government vessels (scientific, coast guard, navy) (Stewart and Howland 2009; Chan et al. 2012; Dawson et al. 2018; Carter et al. 2019; Stewart et al. 2020). Key stressors from interactions with ship traffic can include underwater shipping noise, ice-habitat alteration, haulout disturbance, sediment mobilization, introduction of non-indigenous species, accidental oil spills, and ship strikes (COSEWIC 2017; Stewart et al. 2020; Figure 16). Their effects on walrus distribution and abundance are not well understood.

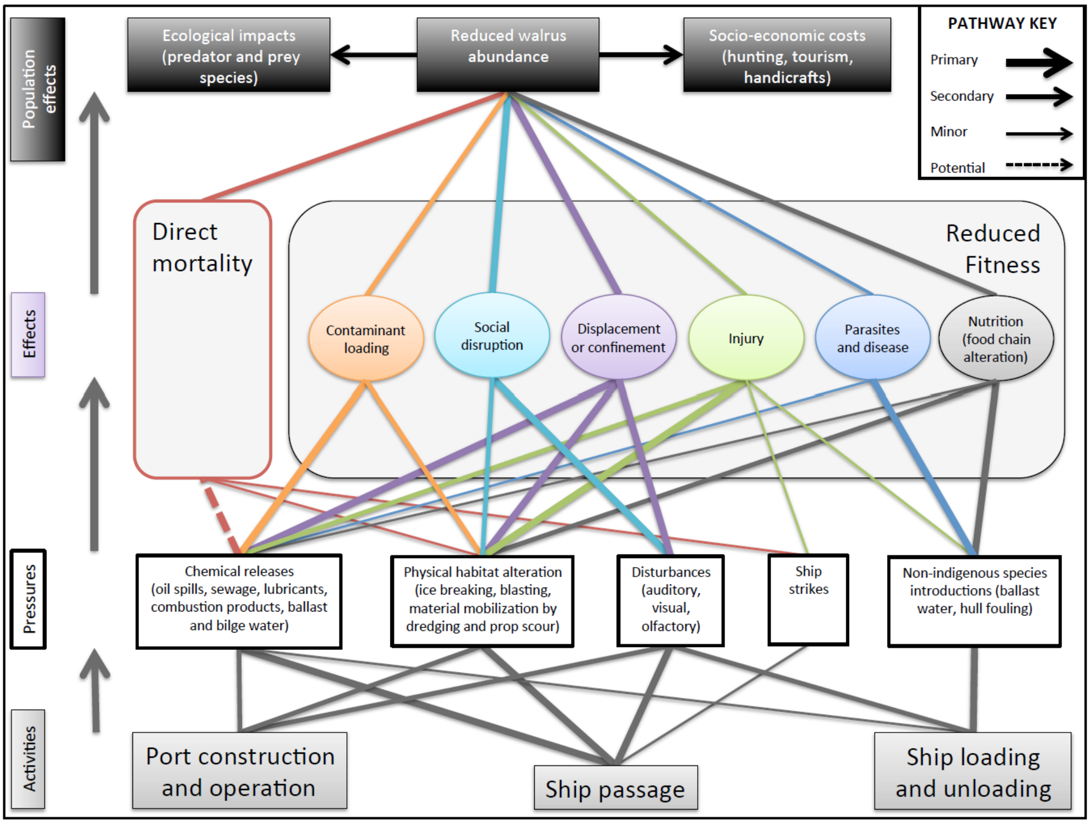


Figure 16. Effects pathways from ore shipment and related activities on Atlantic walruses in Hudson Strait and Foxe Basin (from Stewart et al. 2020)

Between 1980 and 2014, significant trends towards earlier breakup, later freeze-up, and longer open-water seasons increased the offshore shipping accessibility (ice concentrations ≤15%) to communities and resource projects in Hudson Strait and Hudson Bay (Andrews et al. 2018). Shipping (km/yr) within 50 kilometres of Coral Harbour nearly doubled between 1990–2000 and 2011–2015 (Dawson et al. 2018; Carter et al. 2019). The magnitude of this increase was moderate in the grand scheme of things (Dawson et al. 2018) but may underestimate changes in vessel traffic near the important walrus haulouts on Coats and Walrus islands, which are nearer the track used by mining and resupply vessels. Hauser et al. (2018) considered walruses to have a high sensitivity to climate change relative to most other marine mammals but ranked their vulnerability to shipping in Hudson Strait and northern Hudson Bay as low based on current shipping levels. This is likely to be an underestimate of future shipping risk.

Significant increases in shipping via northern Hudson Bay and Hudson Strait are planned in the coming decade (2021–2030) (BIMC 2018). The Mary River Mine, which has government approval to export 18 Mt of iron ore to market annually from Steensby Inlet on northern Baffin Island via Foxe Basin and Hudson Strait (BIMC 2012, 2018; NIRB 2012), is expected to contribute significantly to this increase. Its shipping via this route is planned to begin in 2024 and to continue for at least 21 years. During each year of operation, purpose-built capesize ore carriers (180,000 deadweight tonnage) will make about 102 round trips via Hudson Strait to transport the ore. These ice-strengthened vessels will transit important walrus habitat year-round. In late winter 2012, the highest densities of walrus in Hudson Strait were observed within three kilometres of the planned year-round shipping route; densities decreased steadily with distance from the route (Elliott et al. 2013). The proportion of these animals that summer in northwest Hudson Bay is unknown but potentially substantial.

Other shipping to and from Hudson Bay may increase in response to resupply requirements, resumption of regular grain shipments from Churchill (Franz-Warkentin 2019), mining developments, and tourism. Plans to transport oil by rail to Churchill were suspended in 2014 due to safety concerns and political opposition (Jones 2013; McNeill 2014; Hansen 2018), but export bottlenecks have prompted interest in building a pipeline to Churchill (Lambert 2020). If this plan is realized, it would increase risk of oil spills affecting walruses in northern Hudson Bay and Hudson Strait.

Low-impact shipping corridors are being developed by the Government of Canada to address safety and sustainability concerns related to climate change (The PEW Charitable Trusts 2016; Carter et al. 2019; Dawson et al. 2020). Use of these proposed shipping routes is voluntary, and Inuit input on the development of these routes has been limited. Work is ongoing with Coral Harbour however, to identify 1) preferred corridors, 2) areas to avoid, 3) restrictions by season, 4) modification of vessel operation, and 5) areas where charting is needed (Figures 17, 18; Carter et al. 2019; Dawson et al. 2020). This input is important to inform planners and regulators of the need to conserve walruses. Inuit have recommended avoidance of the route between Coats and Walrus islands by ships other than resupply vessels enroute to and from the community. Vessels enroute to other communities and mines in the Kivalliq region were suggested to be rerouted south of Coats Island to avoid disturbing these important walrus habitats. Government corridors must incorporate information on these and other sensitive marine mammal habitats into corridor selection if sustainability concerns are to be properly addressed.

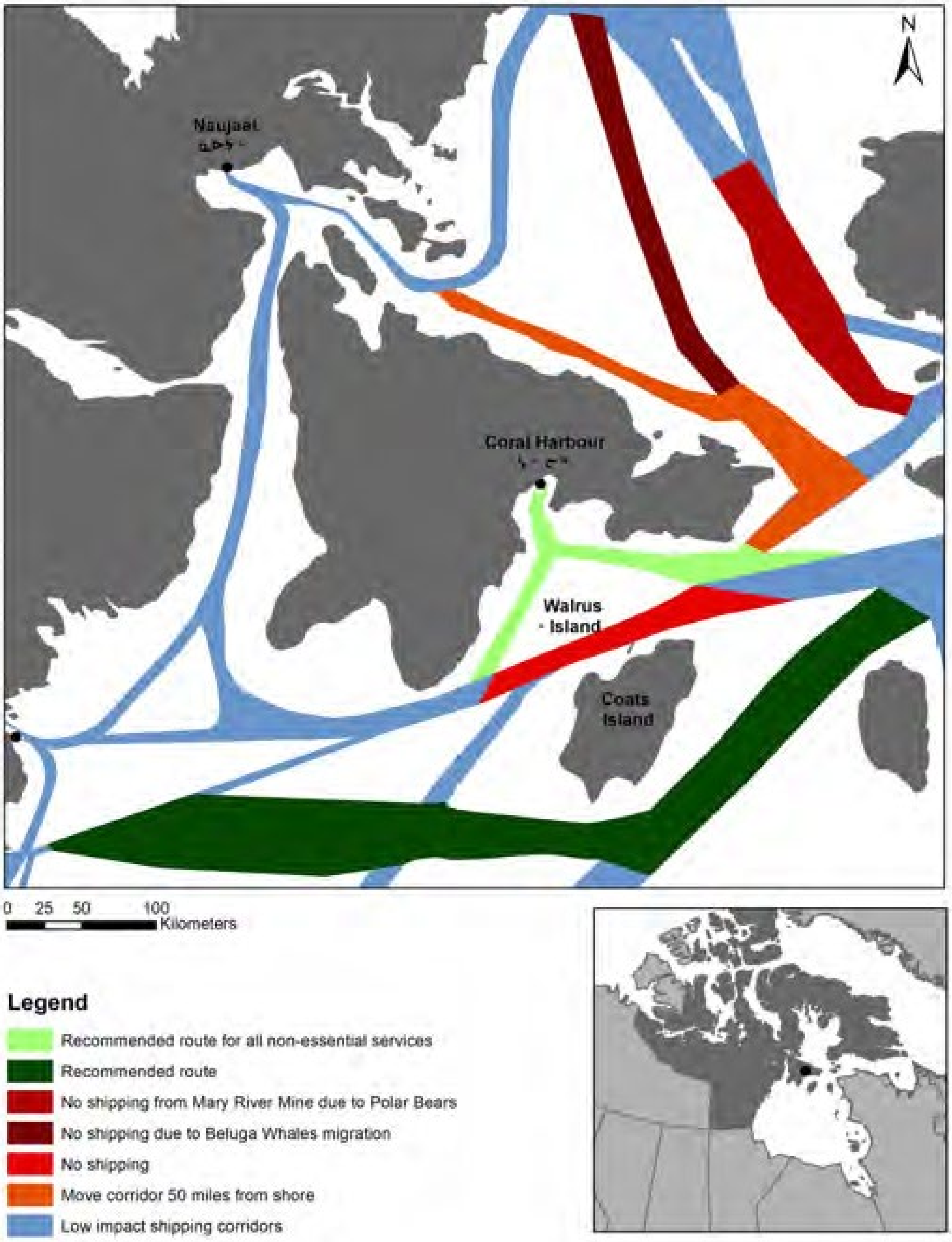


Figure 17. Recommendations for low-impact shipping corridors as identified by the Coral Harbour community (from Carter et al. 2019)

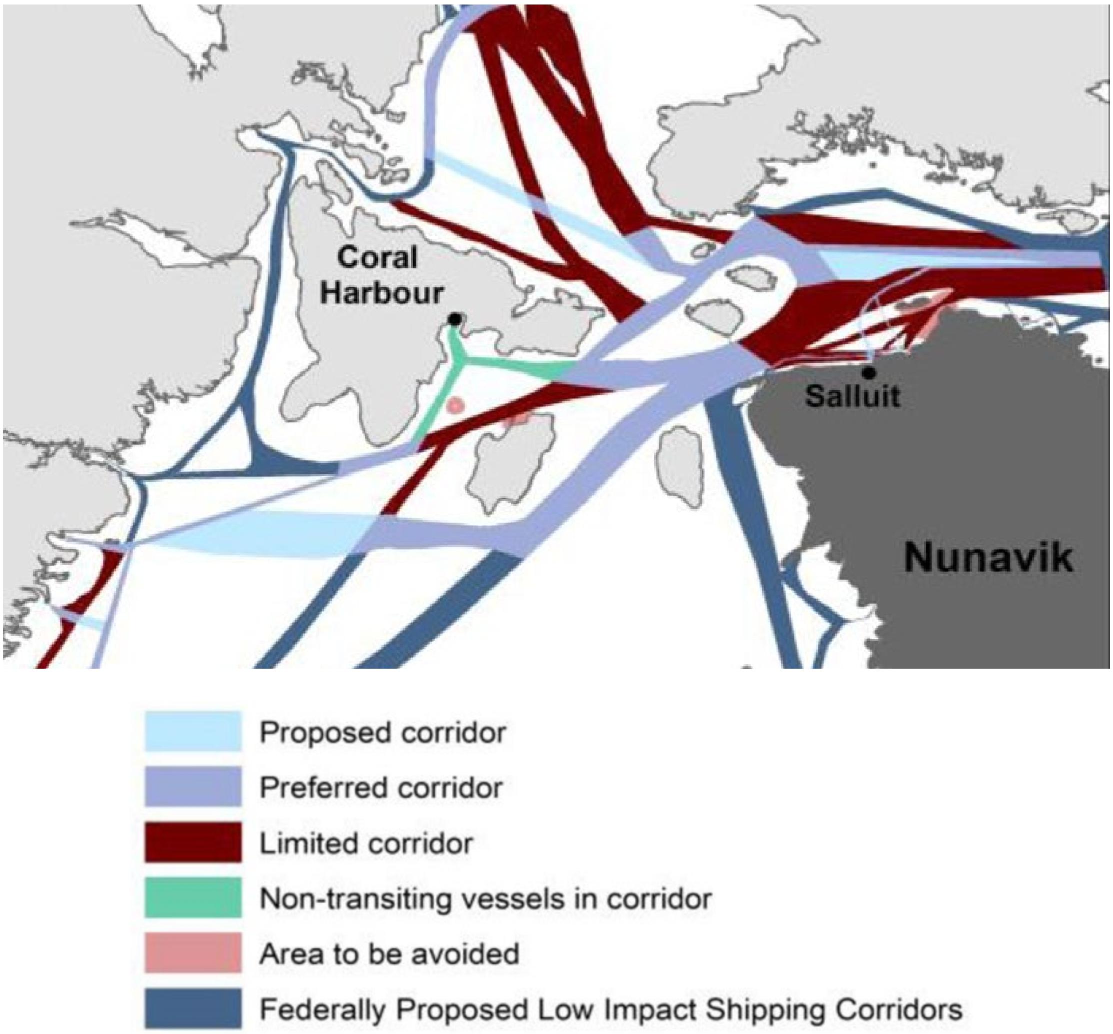


Figure 18. Community shipping-corridor recommendations from Coral Harbour. The "proposed corridor" refers to community-proposed new corridors that are not currently part of the federally proposed corridors; "preferred corridor" refers to those that are currently part of the federally proposed corridors and are preferred by communities; and "limited corridor" refers to corridors that are part of federally proposed corridors that communities have identified as routes that should be restricted or limited (from Dawson et al. 2020).

3.2.1.2 Disturbances

Little is known about the hearing ability of walruses and their noise-disturbance and hearing impact thresholds, in air or water (Southall et al. 2019). The audiometric behaviour of a single captive walrus showed that it could hear sounds in water between 0.125 and 15 kHz (Kastelein et al. 2002). Acoustic studies found walruses produce sounds over a frequency range of 0.2 (rasp) to 20 kHz (knock) in water and 0.01 (guttural sounds) to 17 kHz (burp) in air (Southall et al. 2019 and references therein). Ship noise overlaps with these walrus hearing and communication frequencies. Typical vessel propulsion noise frequencies in open water range from 10 Hz to 1 kHz (Southall et al. 2018), but the frequency range

(100Hz–22KHz) tends to be greater during ice breaking (Erbe and Farmer 2000). This overlap is a concern, as the underwater noise might disrupt transmission of important sounds made by the walruses, such as songs during the breeding season (Sjare et al. 2003) and mother-calf communications (Charriere et al. 2010; Moore et al. 2012; Stewart et al. 2012).

There is little information on Atlantic walrus response to vessels, in open water or when sea ice is present (COSEWIC 2017; DFO 2019a). Observations of Pacific walruses suggest that "the intensity of the animals' response varies with the size of the vessel, as well as its direction and speed, and that the response is least to sight and sound and greatest to the combination of sight, sound, and odor. For audible cues, the quality of the sound seems to be important. Low-frequency, diesel engines appear to cause less disturbance than high-frequency outboard engines" (Fay et al. 1984: 116).

Minimum approach distances identified in the Canadian Marine Mammal Regulations under the *Fisheries Act* do not adequately protect walruses in Canada from disturbances. These regulations (Schedule VI) prohibit approaches closer than 100 metres in water (Jan. 1 to Dec. 31), 200 metres on ice (June 1 to Oct. 31), and 300 metres on shore (June 1 to Oct. 31) — except as authorized under the regulations. Unfortunately, these regulations do not apply to vessels "in transit", including cargo and mining ships, and are mainly in place to discourage cruise ships and recreational vessels from stopping and observing the animals too closely. Work by Fisheries and Oceans Canada (DFO) to identify buffer zones that adequately protect walruses from disturbance by ships, aircraft, and tourism is ongoing to support land-use planning in the Nunavut Settlement Area (DFO 2019a). The current (2021) draft of the Nunavut Draft Land Use Plan (NPC 2021) has proposed using the United States Fish and Wildlife Service (USFWS) guidelines to reduce potential disturbance to walrus haulouts. Under these guidelines, marine vessels ≤ 50 feet (~ 15.2 metres) in length should remain at least a 0.5 nautical mile (~ 0.9 kilometres) away from walruses hauled out on land or ice; vessels 50–100 feet (~ 15.2–30.5 metres) at least one nautical mile (~ 1.9 kilometres); and vessels greater than 100 feet (30.5 metres) at least three nautical miles (~ 5.6 kilometres) away (USFWS 2019, 2020). All vessels are to refrain from anchoring, or conducting tendering or other fishing operations within three miles (~ 4.8 kilometres) of hauled out walrus, and to reduce speed and maintain a 0.5 nautical mile (~ 0.9 kilometre) exclusion zone around feeding walruses. Alaska restricts all access within three nautical miles (~ 5.6 kilometres) around Round Island to avoid disturbances at terrestrial walrus haulouts.

3.2.1.3 Physical habitat alteration (ice breaking)

Fragmentation of sea ice by ice-breaking ore carriers could have ecological consequences for walruses wintering in Hudson Strait, as it does for polar bears (Sahanatien and Derocher 2012). It might, for example, influence walrus distribution and abundance along the shipping routes by influencing migration timing, use of terrestrial haulouts, and selection of breeding and foraging habitats (Stewart et al. 2020).

When hauled out on the ice, female Pacific walruses with calves entered water when ice breaking ships were within 500–1,000 metres, and males when the ships were within 100–300 metres (Fay et al. 1984). The most energetically demanding behavioural responses to vessels by Pacific walruses in water or hauled out on sea ice were diving and changing course/speed, which occurred when the vessel was within 500 metres (McFarland and Aerts 2015). Walruses exposed to ice-management near drilling operations in the Chukchi Sea moved away from the operations, deeper into the pack ice (where noise levels approached ambient), but returned to previously occupied areas once the ice-management stopped (Brueggeman 1993).

During low-ice years, when pack ice for hauling out is limited, ice breaking could alter walrus habitat use or the availability of suitable breeding habitat. Animals that follow ship tracks through the ice risk being frozen out or possibly crushed by shifting ice. The impacts of these changes on walruses that summer in northwest Hudson Bay may be difficult to assess.

3.2.1.4 Ship strikes

As ship traffic increases, so too will interactions with walruses, particularly in Hudson Strait. The risk of ship strikes is unknown but presumed to be low in open water and higher when ice is present (Higdon and Stewart 2018). Walruses should be able to detect approaching vessels well in advance, year-round. In open water, their speed and agility should enable them to avoid oncoming vessels, but sea ice could limit avoidance. Behavioural traits such as clustering, aggressive male territorial behaviour during the winter breeding season, and vigorous defence of calves could also increase ship strike risk. Systematic observations from icebreakers are needed to properly assess this threat.

3.2.2 Aircraft overflights

Walruses are sensitive to changes in engine noise, particularly from aircraft (Salter 1979a; Fay et al. 1984; Born et al. 1995; Okonek et al. 2009; DFO 2019a; USFWS 2019). Their response to aircraft tends to increase with closer proximity and depends on many factors related to the characteristics of the aircraft and its flight, environmental conditions, and the demography and activity state of the affected animals (DFO 2019a). Dispersal of walruses from terrestrial haulouts into the water is not uncommon but causing this to occur should be avoided, particularly at larger haulouts where stampedes are more likely to harm smaller, weaker animals.

When an aircraft is operated at an altitude of less than 304.8 metres (1,000 feet) within a radius of 0.5 nautical miles (0.926 kilometres) from a walrus, Canadian Marine Mammal Regulations (Sec. 7.2 (1)) prohibit manoeuvring the aircraft to bring it closer to the walrus or otherwise disturbing it. But this does not provide the walruses with adequate protection from disturbance. Atlantic walruses at High Arctic haulouts detected the sound of a Bell 206 helicopter up to eight kilometres away, oriented towards the sea when it was within 1.3 kilometres, and sometimes escaped into the water immediately thereafter (Salter 1979a).

Most data on walrus disturbances by aircraft are from Pacific walruses at Round Island in Alaska's Walrus Islands State Game Sanctuary. Propeller planes and helicopters flying at 6,100 metres above ground level (AGL) (Weiss and Morrill 2017) and at horizontal distances of up to 2.8 kilometres (Weiss and Morrill 2014), and jet overflights at altitudes of about 9,000 metres (Okonek and Snively 2005; Okonek et al. 2009; Weiss and Sell 2013) have caused dispersal of hauled-out walruses into the water. But dispersal typically occurs when helicopters or propeller aircraft fly overhead or within several kilometres of a haulout, at elevations of 165 to 2,500 metres AGL (DFO 2019a). USFWS (2020) guidelines recommend single engine aircraft avoid flying over or within half a mile (~ 0.8 kilometres) of walruses hauled out on land or ice and maintain a minimum altitude of 2,000 feet (~ 610 metres) when that is not possible. They recommend that helicopters and multi-engine aircraft avoid flying within one mile (~ 1.6 kilometres) of walruses hauled out on land or ice, and maintain a minimum altitude of 3,000 feet (~ 914 metres) when that is not possible. Stricter guidelines are in place at Round Island, Alaska, where the USFWS (2020) recommends all aircraft maintain a minimum altitude of 5,000 feet AGL (~ 1,524 metres) within a 3-mile (~ 4.8-kilometre) radius of the island.

The USFWS (2020) discourages use of drones near walrus haulouts but does not specify the size and type of drone. Overflights by small drones during nesting bird surveys did not disturb hauled-out walruses when they were approached at low altitude from the inland side (G. Gilchrist, ECCC, pers. comm. 2020).

3.3 Biological resource use

Overhunting of walruses has been recognized as a threat to their populations and to Inuit food security since at least 1906, when A.P. Low, concerned by large and sometimes wasteful kills of walruses by whalers and traders in northwest Hudson Bay recommended that walruses be reserved for use by Inuit (Low 1906). He wrote,

> "There has been a rapid diminution in the number of walrus in the northern part of the bay during the past few years, since the *Active* has been engaged in their capture, and it is only a question of a few years, if the present methods of killing are continued, before the walrus become as rare as the Right [bowhead] whale in the waters of Hudson [B]ay. It is acknowledged that, with present methods of capture and the difficulties of the chase, only one in four or five animals killed is eventually secured....Taking into consideration the value of the animal to the native, the great waste of life in the killing, and the comparative value to civilization, it might be well to pass regulations reserving this animal wholly for the use of the [Inuit]."

Low was spurred to make this recommendation by the shift in whaling effort from bowhead whales to walruses that began in 1898 and continued until 1911 (Stewart et al. 2014). During that period, the Dundee whaler *Active* and other vessels owned by Robert Kinnes and Sons (*Polar Star* and *Ernest William*) often landed many walruses from the northwest Hudson Bay stock, sometimes taking over 500 in a single year. Low's recommendations were not implemented until 1928, well after commercial whaling in the region had ended, when Canada established regulations that restricted killing of walruses to Aboriginal hunters for their own food and clothing requirements but allowed walruses to be taken under ministerial permit for scientific purposes (Canada 1928: P.C. 1036). These regulations ended the commercial hunting of walruses in the eastern Canadian Arctic by whalers and traders, as well as subsistence and sport hunting of walruses by non-Aboriginal peoples. They were an important step towards reducing hunting pressure on the walrus populations, but they left important loopholes that enabled the traders to purchase hides and ivory.

The sustainability of the walrus population was still a concern in 1939, when the Hudson's Bay Company (HBC) post at Coral Harbour requested gear for catching bowhead whales so the hunting efforts could be shifted away from walruses. Referring to walruses the request noted that "when one consider[s] the enormous slaughter that must take place in this area each year, one cannot but wonder how long the supply can last." (HBCA RG3/26B/27 p.2). The Atlantic walrus has been assessed as "Special Concern" in Canada, partly in recognition of an historical decline in numbers (COSEWIC 2017).

An integrated fisheries management plan (IFMP) has been developed to identify the objectives (Table 1, also see Section 4.2) and requirements for the Atlantic walrus fishery in the Nunavut Settlement Area and the management measures (Table 2) that will be used to achieve these objectives (DFO 2018). This document provides basic information on the fishery and its management to establish common understanding of the basic "rules" for sustainable management of the fisheries resource to DFO staff, legislated co-management boards, Hunters and Trappers Organizations (HTOs), Regional Wildlife Organizations (RWOs), Inuit, communities, and other stakeholders.

Table 1. Long- and short-term objectives of the IFMP for the Atlantic walrus fishery in the Nunavut Settlement Area (from DFO 2018).

Long Term	Short Term
Stock Conservation	
Maintain vital, healthy walrus stocks and populations through sustainable use and effective fishery management consistent with the wildlife harvesting and management provisions under the Nunavut Agreement.	• Improve knowledge of Atlantic walrus biology, abundance and distribution. • Conduct surveys of remaining walrus stocks to obtain abundance estimates. • Use local knowledge/TEK/IQ in aerial survey designs and use local community members in conducting the surveys • Develop training materials for Inuit harvesters to maximize harvest and minimize losses. • Develop communication materials to inform elders, harvesters and community members on research methods, activities and results. • Develop/enhance monitoring program to reduce struck and lost, including an assessment of harvesting methods and equipment, and collection of data on rates of struck and loss.
Take a precautionary approach to fishery decisions for walrus stocks or populations.	• Given uncertainties related to walrus stocks, take a precautionary approach to establishing TAHs [Total Allowable Harvest] and BNLs [Basic Needs Level] for each walrus stock or population.
Ecosystem	
Protection of walrus habitat.	• Continue to identify and document traditional ecological knowledge of important walrus habitats. • Investigate and assess threats resulting from human activities (e.g. shipping routes, sonar, noise disturbance, and tourism). • Support research into the effects of invasive species on walrus and walrus habitat.
Shared Stewardship	
Promote collaboration, participatory decision-making and shared responsibilities with resource users, co-management organizations and other stakeholders.	• Conduct IFMP evaluations with walrus working groups. • Develop sport hunt guidelines. • Develop appropriate guidelines for activities that could negatively affect walrus. • Once TAH/BNLs are established for walrus stocks, co-management organizations to implement the shared responsibilities in accordance with land claims agreements, the *Fisheries Act*, and its regulations. • Develop and/or participate in more formalized discussions with Greenland on the management of shared stocks.
Social, Cultural and Economic	
Promote traditional Inuit harvesting techniques and practices within communities.	• Develop and/or enhance training programs for inexperienced hunters.

Promote and maintain vital, healthy, walrus populations capable of sustaining harvesting needs.	• Increase awareness of the importance of walrus to public, communities, and stakeholders. • Include IQ in all policies and program development. • Promote territorial health programs aimed at food safety.
Maintain access to international markets for the export of walrus products.	• Demonstrate harvest levels and practices are sustainable. • IFMP in place.
Compliance	
Support effective fisheries management through a defined compliance program.	• Conduct a risk assessment of compliance issues. • Develop a variety of compliance activities and tools to address the identified risks. • Support Communities in the development of by-laws related to walrus or activities that may affect walrus.

Table 2. Overview of current management measures for the Atlantic walrus fishery in the Nunavut Settlement Area (from DFO 2018).

Management Measure	**Applicable Legislation/Regulation**
Harvest Levels	• Unless a TAH is in place, an Inuk may, without a licence, fish for food, social or ceremonial purposes for four (4) walrus in a year except where community quotas exist (Coral Harbour (60), Sanikiluaq (10), Arctic Bay (10) and Clyde River (20)) (MMR, s. 6 and 26). • Where a TAH has been established, annual harvest may not exceed the total allowable harvest level established for a particular management unit.
Monitoring and Reporting	• Harvest information must be reported (MMR s. 17; *Fisheries Act* s. 61; and the NA s. 5.7.43). • When the quota or total allowable harvest level is reached, the community will be notified and the fishery will be closed (MMR s. 12 and 26).
Licences	• The Minister may issue a marine mammal fishing licence (MMR s. 4). • The Minister may issue a licence for certain activities such as for tagging (satellite tracking), live capture, biopsies (MMR s. 11).
Post-Harvest Walrus Tag	• Where a TAH has been established, DFO will issue Post-Harvest Walrus Tags to the RWO and/or HTOs in the amount equal to the annual harvest level for the corresponding management unit. These tags will be issued without fee or administrative charge and are not to be considered a licence to hunt.
Humane Harvesting	• Hunters shall only kill a walrus in a manner that is designed to kill it quickly (MMR s. 8). • No person shall disturb a walrus except when hunting for walrus (MMR s. 7).

Management Measure	Applicable Legislation/Regulation
Reducing Loss Rates	- Hunters must have all necessary equipment on hand to retrieve a hunted walrus (MMR s. 9). - Hunters that kill or wound a walrus must make all reasonable efforts to retrieve it without delay, must not abandon or discard it, or waste any edible part of a walrus (MMR s. 10). - Hunters are to use a rifle or shotgun with the following restrictions: a) a rifle and non-full metal jacketed ammunition that produce a muzzle energy of not less than 1,500 foot pounds; or b) a shotgun and rifled slugs that produce a muzzle energy of not less than 1,500 foot pounds (MMR s. 25).
Sale and Transportation	- A Marine Mammal Transportation Licence is required to transport walrus or walrus parts from one province to another (MMR s. 16). - A CITES Export Permit is required to transport walrus products outside of Canada.
Habitat/Ecosystem Protection	- *Fisheries Act* s. 35: prohibits any person from carrying on any work, undertaking or activity that results in serious harm to walrus that are part of a commercial, recreational or Aboriginal fishery, unless authorized by the Minister.

3.3.1 Subsistence hunting

Coral Harbour has the most complete time series of walrus catch data from the northwest Hudson Bay region. The HBC archives provide a good record of catches in the Coats Island–Southampton Island (Coral Harbour) area for 1919 through 1946, as do the RCMP game reports from 1950 through 1967 (Stewart et al. 2014). Both groups often mentioned the hunting efforts and catches of competitors and other agencies, such as the missions. Data on Inuit catches are largely unavailable prior to 1928, despite the importance of walruses for Inuit subsistence. After circa 1932, the HBC often recorded Inuit walrus catches as a matter of interest but no longer kept detailed annual ledgers of hide and ivory sales, making it impossible to track trends in the land-based catches prior to circa 1950 (Stewart et al. 2014). The transition from RCMP data collection to Government of the Northwest Territories and DFO data collection in the early 1970s was poorly managed by both governments, leaving a gap in reporting from 1968 to 1971 (Smith and Taylor 1977).

The largest subsistence catches from Coral Harbour were reported by the RCMP in the 1950s and 1960s (Figure 19). The landed catch of walruses at Coral Harbour has declined since 1950, even though the Inuit population has increased, and the geographical extent of walrus hunting appears to have contracted towards the community (Figure 20). Current data are needed to assess whether this trend continues. From 1972 through 2007, Coral Harbour landed over 60% of the total walruses reported to have been taken from the northern and western Hudson Bay region (Stewart et al. 2014). Catches were smaller in the early 1970s due to the declining use of dog teams (Welland 1976), and in 1975 because almost all of the men were employed by the hamlet for the summer and there were mechanical difficulties with the Peterhead boat (A. Helmer, GNWT in litt. to D.H. Dowler, FMS 23 April 1976).

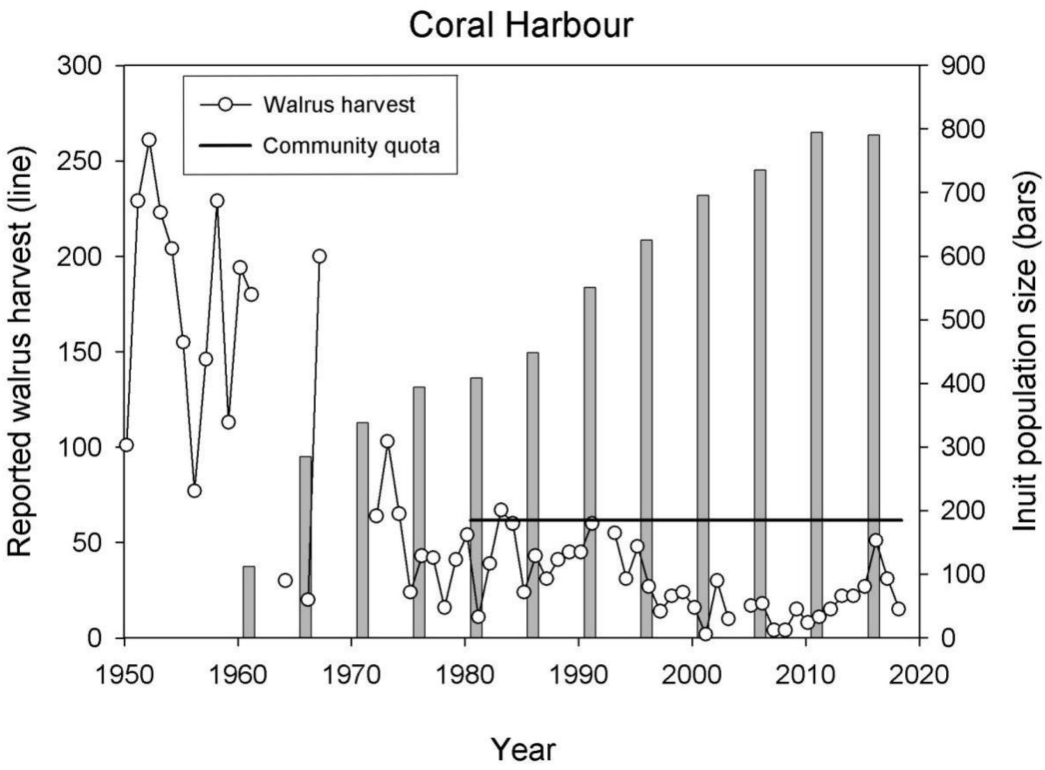


Figure 19. Reported Coral Harbour subsistence catches of walruses (open circles) in relation to community population (Nunavut Land Claims Agreement (NLCA) beneficiaries only, vertical bars) from 1950 to 2018. The horizontal black line denotes the 60-walrus catch quota established in 1980 (catch data: Stewart 2014: Supplement 4; DFO unpubl. data; census data: Marcus 1992; NPC 2008, Statistics Canada 2012, 2017).

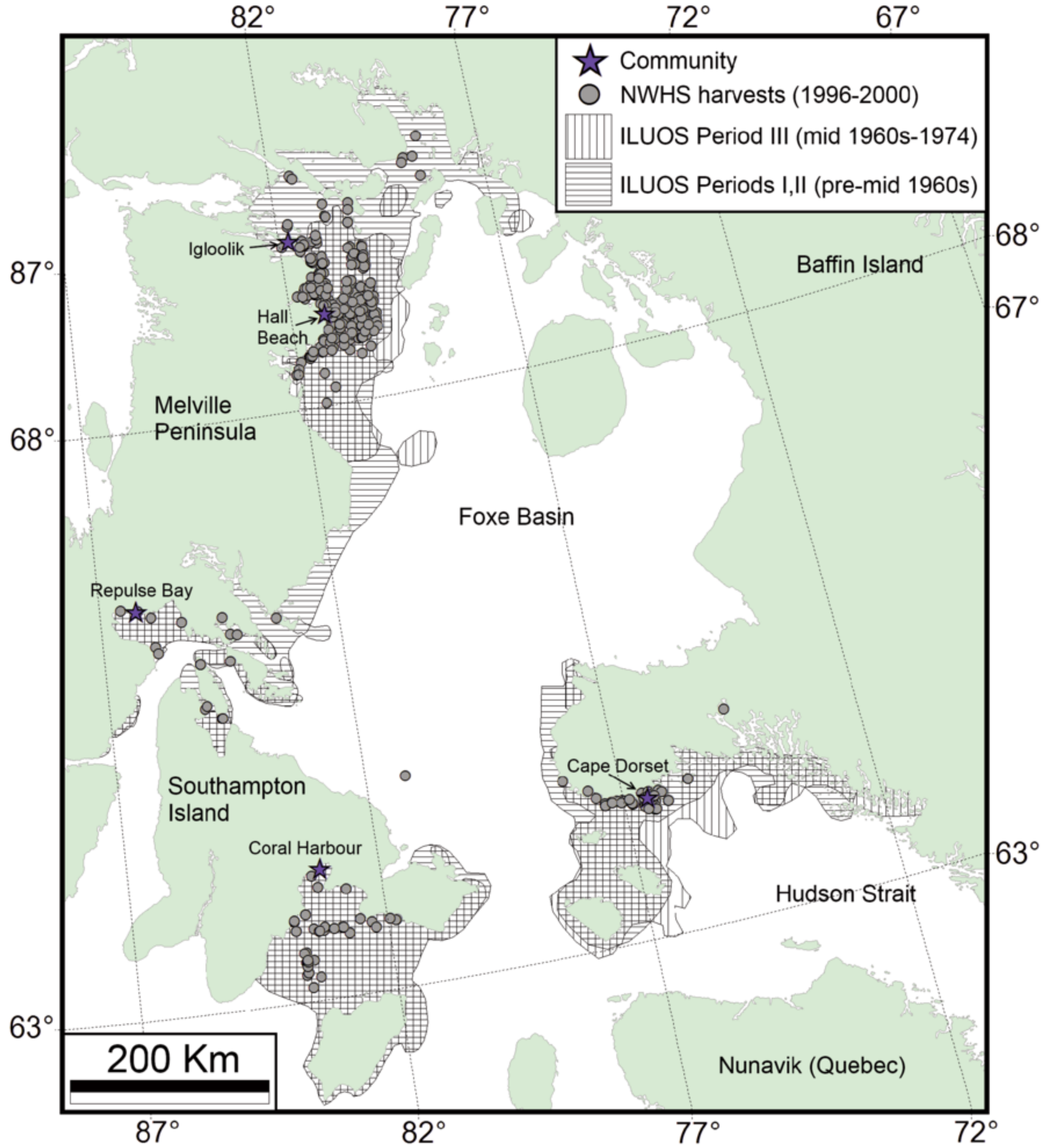


Figure 20. Areas where Inuit from the communities of Iglulik (Igloolik), Sanirajak (Hall Beach), Naujaat (Repulse Bay), Salliq (Coral Harbour), and Kinngait (Cape Dorset) hunted walruses prior to the mid-1960s, from then until 1974, and between 1996 and 2000 (figure and caption from Stewart et al. 2014: 270). Data for harvest areas used prior to 1974 are from the Inuit Land Use and Occupancy Study (ILUOS) period III, which began in 1965 for Iglulik and Sanirajak (Brody 1976b), 1963 for Naujaat (Brice-Bennett 1976), 1962 for Salliq (Welland 1976), and 1965 for Kinngait (Kemp 1976) (see also supporting maps in Freeman 1976). The 1996 to 2000 data are from the Nunavut Wildlife Harvest Study (NWHS) (Priest and Usher 2004).

The 1980 through 2018 subsistence catch data presented here are from the recent catch history of walruses in Canada (Stewart et al. 2014), which elaborates on their sources and quality, and from DFO catch statistics (DFO Iqaluit unpubl. data) (Figure 19). This period followed enactment of the Walrus Protection Regulations under the *Fisheries Act* (Canada 1980: P.C. 1980 -1216), which reduced the number of walrus “an Indian or Inuk” could hunt and kill in one year from seven to four (Section 3), except where a new annual community quota was scheduled instead. Coral Harbour was one of these communities, with an annual catch quota of 60 walruses that remains in force. Since it was implemented, the quota has only been exceeded once (67 animals landed in 1983) (Stewart et al. 2014; DFO unpubl. data).

Sources of uncertainty in reported numbers include rates of reporting harvests and rates at which animals were injured or killed but lost, both of which vary over time. There are also uncertainties in population estimates and life history parameters. Consequently, some uncertainty remains as to sustainable harvest levels, despite declines in reported catches for Coral Harbour and other communities that hunt walruses in northwest Hudson Bay and adjacent areas (Figure 21) in terms of the annual numbers and in relation to the communities' populations (Stewart et al. 2014; COSEWIC 2017). Recent survey results, when available, will help with this assessment.

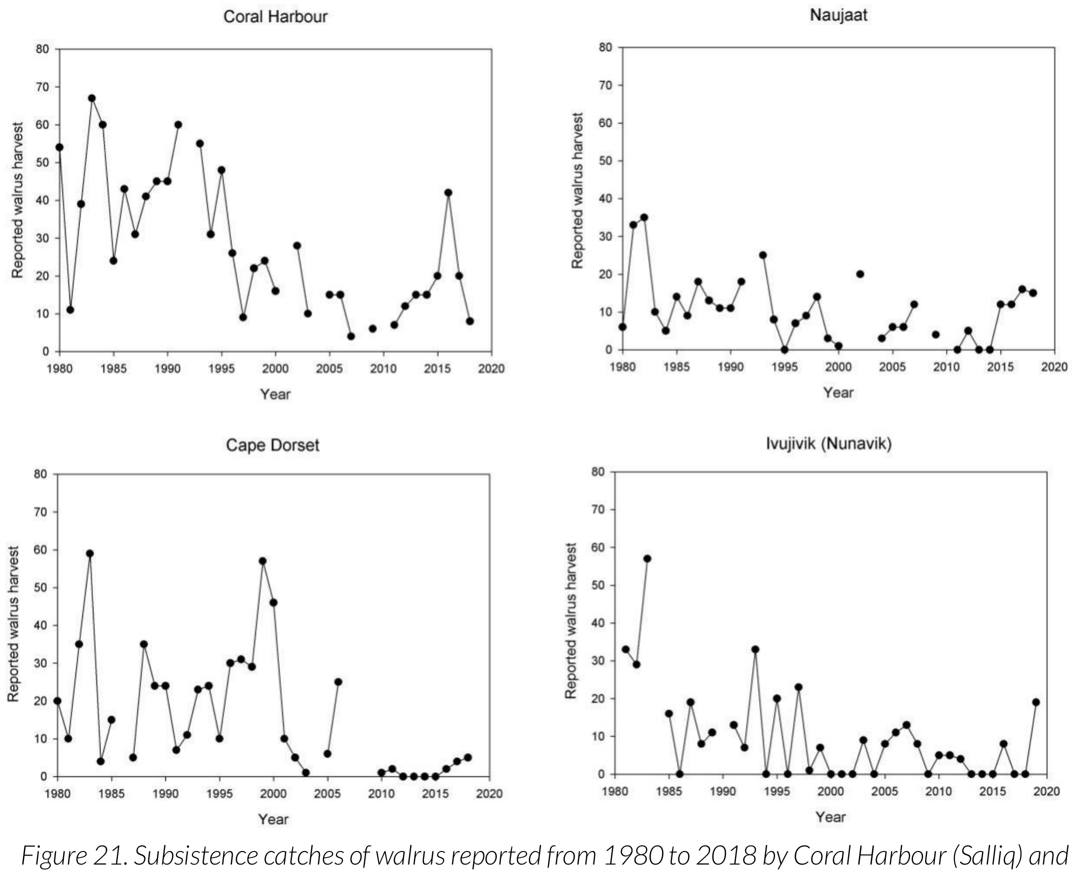


Figure 21. Subsistence catches of walrus reported from 1980 to 2018 by Coral Harbour (Salliq) and other nearby communities that harvest substantial numbers of walruses in the northwest Hudson Bay region, including Naujaat (Repulse Bay), Cape Dorset (Kinngait), and Ivujivik (in Nunavik) (data sources: Stewart et al. 2014; DFO unpubl. data)

3.3.2 Sport hunting

From 1928 through 1994, only Inuit and First Nations people could hunt Atlantic walruses in Canada. In 1995, a limited hunt was opened for non-resident hunters in order to benefit communities with nearby walrus populations. Since then, applications for sport hunts have been approved annually by the Nunavut Wildlife Management Board (NWMB), and DFO has then issued licences under the Marine Mammal Regulations (s. 4) (A. Currie DFO Iqaluit, pers. comm. 2012; A. McPhee, DFO Winnipeg, pers. comm. 2014; J. Young, DFO Iqaluit, pers. comm. 2019) (Figure 22). Coral Harbour is the only community that conducts regular sport hunts of walruses in northwest Hudson Bay. Licensing of these hunts began in 1996 and has continued since then, with occasional interruptions.

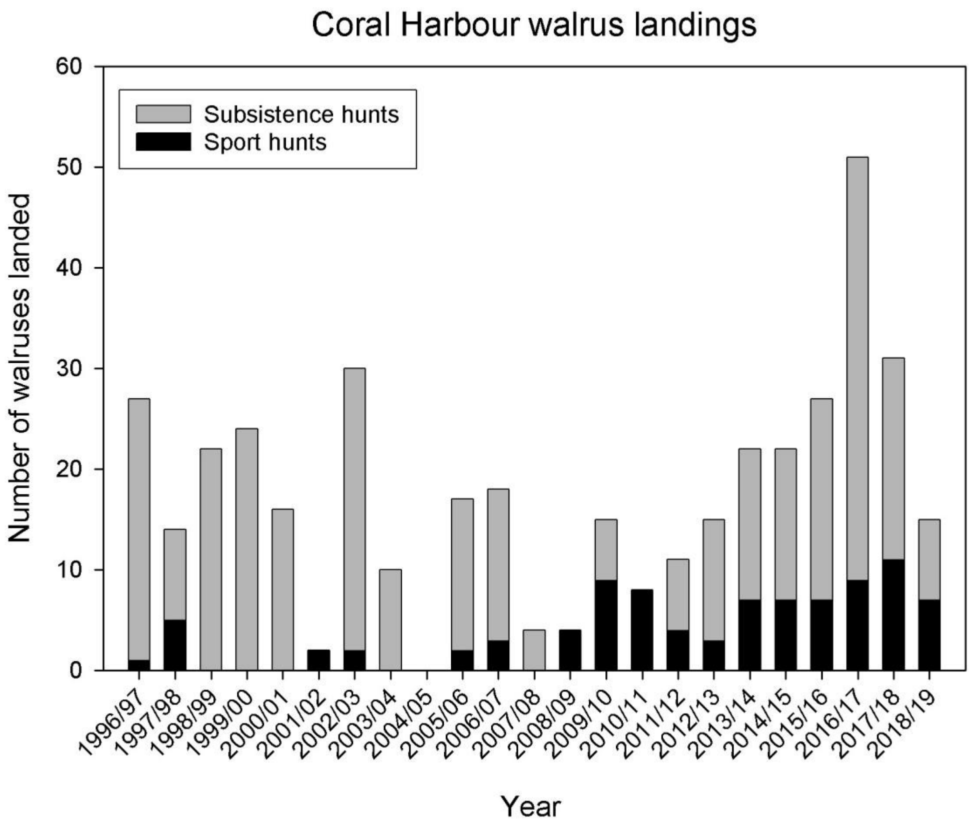


Figure 22. Annual sport and subsistence catches of walruses since sport hunting began under the Coral Harbour catch quota, 1996 to 2018 (Data sources: Priest and Usher 2004; Stewart et al. 2014; DFO unpubl. data)

In the decade from April 1, 1999, to March 31, 2009, sport hunts operated by outfitters from Coral Harbour reported only 13 walruses caught, with one year of non-reporting (Figure 22). In 2008, Igloolik suspended its sport hunts and other walrus tourism activities over concerns that this activity was disturbing walruses, driving them farther from the community and making the subsistence hunt more difficult (Stewart et al. 2014). This suspension lasted until 2010. During this time, sport landings from the Coral Harbour area increased and have remained at the higher level fairly consistently since then. In the decade from April 1, 2009, to March 31, 2019, sport hunts operated by outfitters from Coral Harbour landed 72 walruses (J. Young, DFO Iqaluit, pers. comm. 2019). Roughly one walrus is caught for every two sport hunting licences requested by the community and approved by the NWMB.

Non-resident hunters must obtain a marine mammal fishing licence and hunt with local guides approved by the local hunters and trappers organization (HTO) (DFO 2018; NWMB 2019). The sport hunters must provide DFO with hunt-related information upon completion of each hunt (e.g., animal sex, struck and lost information, location, number harvested, etc.). Sampling for walrus health or other biological parameters, such as tissue samples (e.g., liver, kidney, skin, and muscle) and morphometric measurements (e.g., tusk length, body girth), may be included as a licence condition (P. Smith, DFO Winnipeg, pers. comm. 2017). The sport hunter can take the tusks and cape but must leave the meat in the community.

3.3.3 Harvest removals

Potential impacts from hunting are not limited to the number of walruses landed (Stewart et al. 2014; COSEWIC 2017). The number of animals landed serves as an indicator of the minimum effect hunting activities are having on the walrus stock (Stewart et al. 2017). These numbers do not typically include the mortality or loss of fitness of animals that are struck and killed or injured and not retrieved nor do they include losses of orphaned calves. The subtler effects of hunting disturbances are harder to measure. These can range from trampling injuries or mortalities, to increased energy expenditures, and shifts to suboptimal feeding locations and haulouts — the same effects that can be caused by poorly managed tourism.

Interpreting these effects of hunting removals in population terms requires data on loss rates and population distribution, movements, size, demography, reproductive rates, longevity, etc. all of which are difficult to obtain (Stewart et al. 2014; COSEWIC 2017). One alternative is to gather good data on catch per unit of hunter effort as a proxy (Stewart et al. 2017). This requires careful gathering of information on landings and struck-and-lost rates and quantitative information on hunter effort, hunter experience, hunting patterns, and hunting methodology. The objective is to learn whether changing or similar catches are the result of greater or lesser effort and whether factors other than changes in abundance may be affecting the availability of walruses. If they are not, this suggests abundance may be changing and requires action if it suggests a decline. This can be a useful community-based monitoring tool in communities where increasing human activity may affect walruses.

3.4 Commercial fisheries

At present, commercial fishing vessels more than 30 metres long are not venturing into Hudson Bay, although a few have fished in Hudson Strait west of Ungava Bay since 2010 (Dawson et al. 2018). Commercial fisheries that overlap with walrus range may compete directly for food, damage feeding habitats, and cause disturbance (COSEWIC 2017). Test fisheries for Iceland scallops (*Chlamys islandica*) in Hudson Strait and eastern Hudson Bay in the 1990s using small draggers were not economically viable (Stewart et al. 1993; Lambert and Prefontaine 1995; Stewart and Howland 2009). Interactions with walruses would have been limited, as the scallops occur mostly on gravelly substrates whereas walruses forage primarily on bivalves buried in soft bottoms. Open-water-trawl or drag fisheries for shrimp (*Pandalus* sp.), turbot (*Reinhardtius hippoglossoides)*, cod (*Gadus* sp.), or other species are also unlikely to compete directly with walruses for food but could disturb them and their feeding habitat (COSEWIC 2017). Ship noise from fishing vessels could also displace walruses from their haulouts and interfere with their communication (Salter 1979a; Born et al. 1995; Stewart 2002).

The USFWS guidelines (2020) require all vessels to maintain a 0.5 nautical mile (~ 0.9 kilometre) exclusion zone around feeding walruses, and the United States National Marine Fisheries Service prohibits groundfish fisheries within 22 kilometres of walrus haulouts on Round Island and other locations in Bristol Bay (DFO 2019a).

3.5 Human intrusions and disturbance

Walruses in hunted populations tend to be skittish when approached by boats, but when asleep can sometimes be approached from downwind within 10–20 metres (Born et al. 1995). Long-term observations at Round Island have found that adult male Pacific walruses disperse and enter the water when small craft (e.g., zodiacs, skiffs) are within 800 metres, with most dispersal occurring when the craft are within 400 metres (including landings) (Salter 1979a; Born et al. 1995; DFO 2019a). Females with calves tend to be more sensitive to disturbances (Fay et al. 1984), so they may enter the water when small craft are farther away. Studies are needed to assess reactions of walruses, of both sexes and a range of age classes, to various disturbance stimuli at terrestrial and ice haulouts to fill current data gaps (DFO 2019a).

Scientists and local Inuit have expressed concern that disturbance from tourism may cause stampede mortality or drive herds farther into the pack ice or away from their traditional haulouts (Stewart 2002; Cody 2003; Dueck 2003; COSEWIC 2017). These concerns prompted the Igloolik HTO to ban all forms of tourism related to walrus in northern Foxe Basin for two years starting in May 2008 (CBC News 2008; Gagnon 2011). Cruise tourism by passenger ships and pleasure vessels in the eastern Canadian Arctic has increased dramatically since 1990, mostly north of Hudson Strait and Hudson Bay (Stewart et al. 2007, 2010; Dawson et al. 2018). But, in 2008 and again in 2009, the cruise ship *Lyubov Orlova* stopped twice at Walrus Island for passengers to make shore visits (Stewart et al. 2010). The vessel also made regular stops for walrus and polar bear viewing at Digges and Mansel islands in northeastern Hudson Bay. In 2011–2015, pleasure craft transits via Hudson Strait to northern Foxe Basin and along the south and west coasts of Southampton Island increased (Dawson et al. 2018). Potential effects of this activity on the important walrus habitats and haulouts should be monitored.

Observations on haulout disturbance behaviour from one area may not be transferable to another. For example, tourists on land and boats near the haulout sites on Svalbard did not disturb walrus haulout behaviour significantly ($p > 0.05$) at any of the sites monitored over a nine-year period, except on one occasion (Oren et al. 2018). This is probably due largely to the fact that Svalbard has not allowed the hunting of walruses since 1952 (Anon. 1952; Wiig et al. 2014; Higdon and Stewart 2018), so the living walruses are too young to remember being hunted (COSEWIC 2017). Walruses in Canadian waters are still hunted and tend to be much more sensitive to human presence. Canadian researchers, for example, were never able to walk up to herds without disturbing them — unlike researchers in Svalbard (R.E.A. Stewart, pers. obs.). Canadian researchers have observed evidence of disturbance by cruise ship tours causing walruses to scatter into the water, and guides driving walruses from their haulouts. This speaks to both human behaviour and the flightiness of the walruses, which argues the need for haulout monitoring.

3.6 Natural system modifications

Inuit in the Belcher Islands of southeastern Hudson Bay have expressed concern that large hydroelectric developments are altering the seasonality of freshwater runoff into James Bay and southern Hudson Bay, reducing winter currents, and contributing to heavier ice conditions that harm overwintering marine birds and mammals in southeastern Hudson Bay (Panel Report 2006:346; Stewart and Hamilton 2007). The northern extent of potential impacts and their effects on walruses are unknown.

3.7 Invasive and other problematic species

Risk of invasive species introductions by shipping in the Coral Harbour area is limited, since few vessels service the community and those that do rarely arrive empty and in ballast. This limits opportunities for non-indigenous species to be introduced via ballast water discharge and hull fouling and to establish reproducing populations. Potential exists for the introduction and spread of invasive species if they become established at Iqaluit, ports of export such as Churchill or Deception Bay, or future ports established for resource development (Chan et al. 2013, 2015; Goldsmit et al. 2019). In that event, effects on walruses will depend upon the species introduced and its ecological effects (e.g., competition, predation, habitat alteration, parasitism, disease).

3.8 Pollution

Little is known about contaminant levels in walruses from the Coral Harbour area. Fortunately, the absence of local industries, distance from contaminant point sources, and distance upstream from the outflow of large freshwater systems with hydroelectric impoundments limit exposure to many contaminants. As in Foxe Basin (Outridge et al. 1997, 2003), the sources of cadmium, lead, and mercury in walrus soft tissues are likely to be natural. Levels of organochlorines in walrus tissues are generally low because they primarily feed low in the food web, with the highest levels found in individuals thought to eat seals that accumulate these contaminants in their fat (Muir et al. 1995). Although the effects of contaminants on walruses are not well known (Higdon and Stewart 2018), a recent study in Svalbard found changes in thyroid and immune systems of adult male walruses that may be linked to high levels of persistent organic pollutants and perfluoroalkyl contaminant exposure in the Barents Sea (Routti et al. 2019).

Oil spills during the annual community resupply by tankers or related to shipping accidents are a potential threat to walruses that summer in the Coral Harbour area and winter in Hudson Strait. This risk may increase substantially in the future if large ore carriers for the Mary River iron mine project begin operating year-round via Hudson Strait as approved, and planned for later this decade and/or when vessel traffic to and from the port of Churchill resumes — particularly if it involves oil export (see above: Shipping activities).

The direct and indirect effects of petroleum on the walrus are unknown. The species' gregariousness (which may spread oil from animal to animal), its preference for coastal areas and loose pack ice where oil may be more likely to accumulate, and its reliance on benthic molluscs (which may accumulate petroleum hydrocarbons or succumb to the oil) may make it vulnerable to oil pollution (Born et al. 1995; COSEWIC 2017). Walrus populations may be most vulnerable to harm from oil spills during the calving period, and calves may be the most vulnerable members of the population.

3.9 Climate change

The eastern Canadian Arctic has been experiencing major changes in ice conditions (Parkinson and Cavalieri 2008; Sahanatien and Derocher 2012; Parkinson 2014) that are bound to affect walrus ecology (Stewart et al. 2020). The timing of freeze-up and breakup in Hudson Bay and Hudson Strait has been changing, with earlier spring breakup and later fall freeze-up (Markus et al. 2009; Hochheim and Barber 2014; Andrews et al. 2018; Mudryk et al. 2018; Candlish et al. 2019a; ECCC 2019) (Figure 23). The length of the open-water season has increased between three and five weeks over the past 30 years. Mudryk et al. (2018) found a significant decreasing trend of -11% to -15% per decade in the summer ice of northwest Hudson Bay from 1968 to 2016 and a declining trend of -10.8% per decade in the summer total sea ice area in Hudson Bay over the same period. Between 1968 and 2018, the Hudson Bay sub-regions (i.e., Hudson Bay, Hudson Strait, and Foxe Basin) lost about 73,000 km^2 of summer (i.e., June 18–Nov. 19) sea ice (ECCC 2019). The mean weekly thickness of landfast ice near Coral Harbour was greater in 1958–1997 than in 2002–2016 (Candlish et al. 2019a).

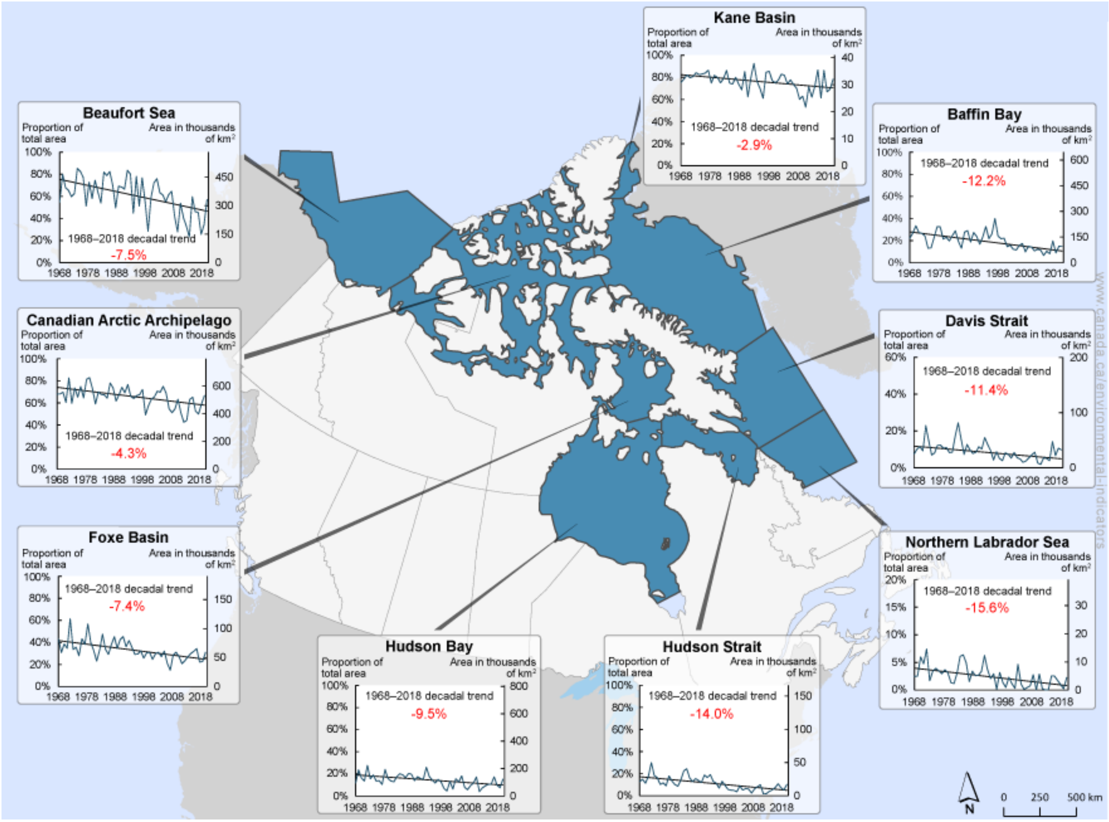


Figure 23. Sub-region sea ice area trends, northern Canadian waters, 1968 to 2018 (from ECCC 2019)

Projections of future climate change in the greater Hudson Bay marine region, while uncertain in rates and details, agree that climatic warming will continue and that the open-water season will continue to lengthen (Joly et al. 2011; Tivy et al., 2011; Derksen et al. 2012; Lavoie et al. 2013; Candlish et al. 2019b; Table 3). Hudson Bay, which is already largely ice free (i.e., <5% cover) in August and September, has a high probability of being ice free for four consecutive months (August through November) by 2050 (Laliberté et al. 2016; Greenan et al. 2018). The regions along the Arctic bridge connecting shipping between Canada and Russia via Hudson Bay could become ice free in July at some point before 2070 but are unlikely to see a substantial reduction in their sea ice cover in June before the last few decades of the century (Laliberté et al. 2016).

The direct effects of climate change (warming or cooling) on the Atlantic walrus are likely limited and not necessarily negative, but the potential for indirect effects is worrisome (COSEWIC 2006). Sea ice cover does not appear to be a critical determinant of Atlantic walrus populations, as various areas of their habitat are seasonally ice free and their pristine distribution extended far south of its present limits (Laidre et al. 2008; COSEWIC 2017), into areas where summer surface water temperatures may have ranged between 12 and 15°C (Miller 1997). However, the effects of a decline in the extent, duration, and quality of ice cover are complex, making the short-term and long-term impacts on walruses difficult to predict (COSEWIC 2017; Clarke et al. 2019).

Table 3. A general summary of atmospheric, ocean, and sea ice projections for the greater Hudson Bay marine region (from Candlish et al. 2019b: 107)

Variables	Projections over the next 20 to 50 years
Surface Air Temperature	Very likely increase in air temperatures by 1–3°C in summer and 2–8°C in winter. Greatest changes projected to occur in Foxe Basin, Hudson Strait, Ungava Bay and eastern Hudson Bay. High inter-annual variability also is to be expected.
Precipitation	Likely a slight increase in precipitation over the whole Region with larger increases projected to occur in Foxe Basin, Hudson Strait, Ungava Bay and eastern Hudson Bay.
Winds and Storms	Likely an increase in storm intensities during the fall months with increased potential for storm surges in eastern Hudson Bay, and Hudson Strait. Projections indicate an increase in wind speeds throughout the Region, with Hudson Strait showing the largest changes.
Sea Level	Within the Greater Hudson Bay Marine Region it is predicted that the rate of sea level rise will not exceed the land uplift over the next 100 years.
Sea Ice	Very likely a longer open water season throughout the Region. The sea ice is projected to breakup one to two months earlier and freeze-up one month later.
Ocean Surface Temperature and Salinity	Very likely increased average annual sea surface temperatures (0.5 – 2°C) throughout the Hudson Bay Marine Region. Projections for sea surface salinity are uncertain.

Walrus populations may be sensitive to bottom-up (e.g., changes in benthic prey) and top-down (e.g., predation by polar bears, killer whales, and people) pressures related to climate change (Hoover et al. 2013b). Climate change could affect the availability of walruses' benthic prey in several ways. For example, a decrease in the extent and duration of Arctic sea ice in response to warming might increase food availability for walruses by improving access to feeding areas in shallow inshore waters that are currently covered in winter by landfast ice (Born et al. 2003; Born and Wiig 2005; Laidre et al. 2008). Warming and loss of ice cover might cause a trophic shift from an ice algae–benthos dominance to a phytoplankton-zooplankton dominance (Piepenburg 2005) and cause a reduction in benthic production, and thereby food for walruses (Grebmeier et al. 2006; Bluhm and Gradinger 2008). Northward expansion of boreal benthic species that supported more southerly populations in the past could also occur. Ocean acidification related to increased atmospheric CO_2 may also alter trophic dynamics by reducing the availability of calcium to marine invertebrates, including bivalves, and by altering host-pathogen relationships in favour of pathogens, changing the abundance and composition of walruses' prey (Azetsu-Scott et. al. 2010; Garlich-Miller et al. 2011; Kroeker et al. 2013; Asplund et al. 2014; AMAP 2018). The likelihood of such trophic changes, their time horizon, and their possible effects on walruses in the Coral Harbour area are unknown. Monitoring walrus diet and conditions for evidence of reduced benthic feeding or shifts in prey could serve as a useful indicator of change to inform management response (Moore et al. 2014).

Similarities in stable isotope (δ13C and δ15N) composition of Pacific walruses in the Chukchi Sea over the past approximately 4,000 years, during intervals with low and high ice conditions, suggest ice conditions are not necessarily the primary driver of changes in the walrus diet (Clark et al. 2019). They also suggest walrus diet was more variable under low ice conditions, which may reflect decreased availability of preferred prey. Responses to sea ice loss may vary for the two subspecies. Haulouts are widely distributed in Atlantic walrus habitats and generally close to foraging areas, whereas Pacific walruses often have to travel farther to foraging areas, increasing energy expenditure, and may face greater intra-species competition for food resources near haulouts (COSEWIC 2017; Higdon and Stewart 2018). Females with dependent young are the animals most likely to be affected by changes in energy expenditure or competition (Garlich-Miller et al. 2011).

Top-down pressures on walruses from polar bears and killer whales may increase in response to climate change as walruses are forced to make greater use of terrestrial sites and spend more time in open water (Garlich-Miller et al. 2011; COSEWIC 2017). Young walruses will be most at risk from predation by these species. Killer whale occurrence is increasing in the eastern Canadian Arctic (Higdon and Ferguson 2009; Higdon et al. 2014; Lefort et al. 2020). While they rarely if ever hunt Atlantic walruses in the eastern Canadian Arctic (Ferguson et al. 2012), killer whales might learn to hunt them successfully in the future if walrus-hunting opportunities increase and easier prey is not available (COSEWIC 2017).

The indirect effects of climate change may pose a greater threat to walruses than the change itself (COSEWIC 2017). While ice loss may increase the seasonal duration of hunter access in open-water conditions, the animals may move farther from the communities and become more concentrated at terrestrial haulouts (Born and Wiig 2005; NAMMCO 2006; Laidler 2009; Huntington et al. 2017). It may make them less accessible when ice is present, due to changes in distribution, travel safety, migratory routes, and/or the number of animals hauled out on ice (Laidler 2009; Huntington et al. 2017). Whether hunting pressure will increase in response to a longer open-water season is unknown. Careful regulation of hunting may be required to prevent walruses disappearing from haulouts, as they did in western and northwestern Greenland during the 20th century (Born and Wiig 2005). Earlier loss of sea ice could prompt Arctic marine fisheries to expand into areas that have not been fished commercially (Nielsen 2009; Christiansen et al.

2014), thereby increasing the potential for interactions between Atlantic walruses and fisheries. Disease transmission could increase in response to increased terrestrial haulout use (Burek et al. 2008). Walruses might also be exposed to novel pathogens and parasites as vector species expand their distributions northward (COSEWIC 2017).

Climatic warming could also have unanticipated impacts, such as increased disturbance of haulouts by thunderstorms (Okonek and Snively 2005) or higher incidence of *Trichinella* infection (Garlich-Miller et al. 2011), although the life history of *T. nativa* is not well known. Walruses might be more likely to be sunburned, but study in Nunavik did not find a relationship between increased sun radiation due to ozone loss and walrus health (Martinez-Levasseur et al. 2016).

4.0 Legislation and management

Legislation pertinent to the walrus falls into two broad categories: laws that apply directly to the species and those that apply to their environment, including legislated environmental-impact assessments. Walrus populations are managed by the various range states under applicable legislation, from local to international. Wiig et al. (2014) reviewed management of Atlantic walruses by the four range states (Canada, Greenland, Norway, and Russia), and Higdon and Stewart (2018) reviewed management of both Atlantic and Pacific (USA, Russia) subspecies. In addition, Shadbolt et al. (2014) reported on international trade and walrus management.

In general, higher-level legislation and management agreements specify minimum requirements. Lower-level or local management agreements can, and often do, add statements about how those general criteria are to be applied. For example, Canada's *Fisheries Act* stipulated the number of walruses a hunter may take in a year. A local HTO may lower that number or specify where or when the walrus may be taken. Here we present the overarching legislation before discussing those that apply specifically to the walruses around Southampton Island.

4.1 Legislation protecting walruses

Direct removals (harvesting) of walrus in Canada is legislated in the *Fisheries Act* (1867). In 1928, Canada created regulations banning commercial hunting of walrus and the exportation of unworked ivory. Catch limits were introduced in 1931 and quotas for some communities in 1980. At the same time, the limit for individuals was set at four walruses per year.

In 1993, these regulations were replaced by the Marine Mammal Regulations of the *Fisheries Act* which left the limit at four walruses per Inuk or land claims beneficiary, established quotas for four communities, and set out minimum firearm and ammunition requirements for hunting (Government of Canada 2020a). Coral Harbour is one of the four communities with a catch limit (60 per year) set for the community. The others are Arctic Bay (10) Sanikiluaq (10) and Clyde River (20).

In the same year, the *Nunavut Land Claims Act* included the formation of the NWMB and the inauguration of a co-management agreement between the NWMB, RWOs, HTOs and the Government of Canada. This co-management agreement, and sometimes local bylaws, now regulate walrus hunting in Nunavut. In the adjacent waters of Nunavik, the Nunavik Marine Region Wildlife Board (NMRWB) plays a role parallel to that of the NWMB.

In addition to regulations aimed directly at managing the number of walruses killed, several trade agreements are in place that may apply to walrus. The primary aims of these agreements are to monitor the extent of the trade in designated species, such as the walrus, and in some cases (but not with walrus), to limit trade and thereby remove the high profit motive for poaching.

International trade in walrus parts and derivatives is regulated by the *Convention on International Trade in Endangered Species of Wild Fauna and Flora* (CITES). Various organizations define the word "endangered" differently, and for CITES, the inclusion in its purview begins if a species is "protected in at least one country, which has asked other CITES Parties for assistance in controlling trade." This would place the species in CITES Appendix III (CITES no date). At higher levels of concern, a species may be listed under Appendix II, even if it is not necessarily threatened with extinction if uncontrolled international trade would jeopardize its survival, or Appendix I (species threatened with extinction). Trade in species under Appendix I would be allowed only in exceptional circumstances.

Walrus are listed in CITES Appendix III, which means all international trade transactions require a permit that may only be issued if the specimen was legally obtained. If a live animal is being exported, there are requirements for the safe and healthy handling of the animals.
Trade of walrus parts, including in art and manufactured products, across provincial/territorial borders within Canada is monitored through the use of federal marine mammal transport licences.

4.2 Fisheries management

To bring legislation and regulations into effect, management agencies develop polices to translate law into actions. In 2018, an IFMP for walrus in Nunavut was formalized (DFO 2018). It follows DFO's sustainable fisheries framework, which contains policies for adopting an ecosystem-based approach to fisheries management and was developed in large part through working groups made of representatives from the HTOs of Arctic Bay, Grise Fiord, Sanirajak, Igloolik, Pond Inlet, and Resolute, the Qikiqtaaluk Wildlife Board (QWB), Nunavut Tunngavik Incorporated (NTI), NWMB, and DFO (DFO 2018).

As noted in the IFMP, in the absence of good data on population structure and reproductive rates, the default option for estimating the number of walrus that could be killed without causing the population to decline is an estimate called potential biological removal (PBR) (Wade 1998; DFO 2018). PBR incorporates an estimate of the minimum population size, an estimate of the maximum rate of reproduction, and a recovery factor based on population status. In the absence of information on carrying capacity and peak production levels, the recovery factor, which may vary from 0.1 to 1, is usually set at 0.1 for severely depleted stocks, 1.0 for undepleted stocks and 0.5 for everything else (Stewart 2008b; Stewart and Hamilton 2013).

The IFMP flagged several issues related to walrus management that pertain to walrus in northern Hudson Bay (DFO 2018). They are listed here in the order presented in the IFMP:

- Abundance estimates – the IFMP noted the requirement for population estimates for the Hudson Bay–Davis Strait stock and the south and east Hudson Bay stock. These have been completed and results are being analyzed.
- Sustainable harvest levels — the IFMP called for the establishment of sustainable harvest levels.
- Struck-and-lost rate — because the struck-and-lost rate enters into the estimation of sustainable harvest levels, consistently complete and reliable data on struck-and-lost rate are required.
- Hunter training/reducing loss rates — following from the above item, training directed, in part, at reducing losses is an important part of sustainable management of the walrus hunt.
- Monitoring and reporting — the IFMP recognized the value of timely and accurate reporting to staying within hunting limits. This would also facilitate information on loss rates, if any.
- Sport hunt — the IFMP identified the need for all relevant HTOs to develop bylaws or guidelines to codify community rules or best management practices for sport hunting.
- Ship traffic/development/tourism — the IFMP identified a number of potential impacts on walruses and their habitat including:
  - increases in the number of oil spills and ship strikes;
  - disruption of migration;
  - vessel avoidance of ecologically or biologically important areas;
  - noise disturbance;
  - the introduction of alien or invasive species; and
  - increased disturbance to important walrus areas (e.g., haulouts) by tourists.

4.3 Environmental legislation

Fish habitat, defined as "water frequented by fish [which as legally defined includes marine mammals like walrus] and any other areas on which fish depend directly or indirectly to carry out their life processes, including spawning grounds and nursery, rearing, food supply and migration areas", was protected under the *Fisheries Act* until being repealed in 2012 (Government of Canada 2020b). Various provisions in the *Act* continued to provide some habitat protection, although this does show how vulnerable wildlife habitat can be to political decisions. Restoration of protection of all fish habitat has since been restored to the *Act*. Regardless, habitat for walruses, which are hunted (and therefore a "fishery"), remains protected from the introduction of deleterious substances under the *Fisheries Act*. Release of harmful substances is also governed by *Arctic Waters Pollution Prevention Act* (R.S.C., 1985, c. A-12) and the *Canada Shipping Act* (S.C. 2001, c. 26). This may or may not include dust and ship exhaust soot if they alter the properties of the ice in a manner harmful to walrus. Neither "ice" nor "frozen" appear in the *Fisheries Act*, and it is unclear if this aspect of walrus habitat is also afforded protection under the *Fisheries Act*. Sea ice has some protection under the *Oceans Act* in the formation of Marine Protected Areas (MPAs, such as the Anguniaqvia niqiqyuam MPA in the Inuvialuit Settlement Region), but even then, navigation is permitted (Government of Canada 2020c). The *Oceans Act* does include the seabed.

The Marine Mammal Regulations prohibit disturbing marine mammals and set approach distances (which do not apply for vessels in transit). Distances for walrus are 200 metres when they are on ice and 300 metres when they are ashore, both for the period of June 1 to Oct. 21 (Government of Canada 2020a). This appears to mean there is no protection for walruses on ice during winter shipping seasons, including the calving period, other than prohibitions against placing deleterious substances on the ice.

Although the effects of noise on marine life are gaining international attention (PAME 2019), we found no evidence of regulatory control of airborne or waterborne noise, aside from Canada's moratorium on offshore petroleum exploration and drilling in 2016, extended by order-in-council in 2019 until December 2021 (Vigliotti 2019) and again to December 2022 (Government of Canada 2022). The *Canada Shipping Act* does allow the minister to make regulations on noise from pleasure craft engines (S 207(2b)) but makes no other reference to noise. The Marine Mammal Regulations make no mention of noise. DFO ran a consultation process from mid-October 2020 to mid-January 2021 to inform the framework of Canada's Ocean Noise Strategy. The consultations were to lead to a draft Ocean Noise Strategy for Canada in the summer of 2021 (DFO 2021) or 2022 (DFO 2022).

For specific projects, there are several avenues to assess potential environmental impacts. The *Canadian Environmental Assessment Act* (CEAA 2012) is the federal act that stipulates an impact review for federal projects (environmental assessment by a responsible authority) and environmental assessment by a review panel for other projects. Assessment by review panel can be conducted jointly with other jurisdictions that also require an assessment for the project.

Although co-management agreements are in place for northern environmental assessments, CEAA applies to federally regulated areas, such as offshore waters. Otherwise, impact assessments in Nunavut are the purview of Nunavut Impact Review Board under the *Nunavut Planning and Project Assessment Act*.

5.0 Marine protection that addresses walrus in the region

Walrus habitat can be protected via numerous mechanisms, ranging from officially designated protected areas and land-use planning designations to local (i.e., community-level) harvesting restrictions and rules imposed and implemented by HTOs. Official protected areas that could potentially protect walrus habitats (including terrestrial haulouts) include national parks, national marine conservation areas, national wildlife areas, migratory bird sanctuaries, marine protected areas, marine refuges, or territorial parks and reserves (although Nunavut territorial parks tend to be near communities, in areas that walruses do not frequently inhabit). The level of protection of walrus habitat in northwest Hudson Bay and adjacent regions is discussed in the following subsection, as is the Nunavut Planning Commission's NLUP development process, which specifically includes protection of walrus haulouts.

With respect to local-level protection, HTOs have the ability to set harvest rules and other regulations to reduce disturbance to walruses. As one example, the Igloolik HTO suspended sport hunts and other walrus-related tourism activities from around May 2008 through May 2011 due to concerns that tourism activities were disturbing walruses, driving them into more inaccessible areas, and making the subsistence hunt more difficult (CBC 2008; Gagnon 2011; Stewart et al. 2014). It is advantageous for communities to consult with neighbouring communities to avoid or reduce collateral consequences. For example, while the Igloolik closure was in place, sport-hunt landings of walruses from the Coral Harbour area increased (COSEWIC 2017).

5.1 Protected areas and land-use planning

Walruses rely on marine habitat for travel, feeding, and reproduction; on the ice phase of the marine environment for resting and reproduction; and on the terrestrial environment for resting. Protecting areas to guard these three habitats often crosses jurisdictional boundaries.

5.1.1 Protected areas

Existing national parks, national wildlife areas, migratory bird sanctuaries, and other federal lands afford little protection of important walrus habitats (CEAA 2012; DFO 2019b, also see COSEWIC 2017). Most of the protected areas that do afford some habitat protection are found in the High Arctic. This includes Tallurutiup Imanga National Marine Conservation Area, which protects walrus habitat in Lancaster Sound and adjacent waters and is the largest marine protected area in Canada (109,000 $kilometres^2$) (DFO 2019b).

Within the range of the central/low Arctic population (as defined by COSEWIC 2017, and including the Hudson Bay–Davis Strait stock (DFO 2002; Stewart 2008a)) of walruses that occurs in northwest Hudson Bay, the Ninginganiq, Qaqulluit, and Akpait national wildlife areas along the east Baffin coast include small areas of marine habitat frequented by walruses (DFO 2019b). The marine fiords included in Auyuittuq National Park may also be used as habitat. In offshore Davis Strait, three DFO marine refuges (Disko Fan, Davis Strait, and Hatton Basin conservation areas) have been created to protect overwintering habitat for narwhal (*Monodon monoceros*) (Disko Fan) or conserve sensitive benthic areas (Davis Strait and Hatton Basin) (DFO 2019b). All bottom-contact fishing activities are prohibited in these areas. These conservation areas may be used by walruses that travel between Canada and western Greenland (Dietz et al. 2014) but they do not offer explicit protection for the species. Given the limited understanding of walrus movements, it is possible that some of these protected areas in Davis Strait and along east Baffin Island are used by animals that also frequent northwest Hudson Bay.

At present, there are limited marine protected areas covering the important walrus habitats found in Hudson Strait, Ungava Bay, and northwest Hudson Bay. Ungava Bay (Quebec) has a provincial park (Kuururjuaq) and a proposed biodiversity reserve (Quaqtaq-Kangirsuk) that include coastal waters (DFO 2019b). Along the Nunavik coast of Hudson Strait, there are two proposed biodiversity reserves (Kangiqsujuaq and Fjord-Tursukattaq) and one national park reserve (Iluiliq), all of which protect some coastal walrus habitats (DFO 2019b). The proposed Arqvilliit Indigenous Protected and Conserved Area (Gignac 2020) will similarly protect some walrus habitat in the Ottawa Islands. None of the major islands of importance (Akpatok Island in Ungava Bay and Charles, Nottingham, and Salisbury islands in Hudson Strait) have any protected areas (either terrestrial haulout locations or adjacent coastal waters). On Southampton Island, walruses may occasionally haul out at the East Bay (Qaqsauqtuuq) Migratory Bird Sanctuary (COSEWIC 2017), and the Harry Gibbons (Ikkattuaq) Migratory Bird Sanctuary in Bay of Gods Mercy (DFO 2019b) may receive some use. In western Hudson Bay, Ukkusiksalik National Park protects Wager Bay, but this area is not regularly used by walruses, and neither is the coastal zone of McConnell River (Kuugaarjuk) Migratory Bird Sanctuary, south of Arviat (COSEWIC 2017). To the north, the Dewey Soper (Isulijarnik) Migratory Bird Sanctuary in eastern Foxe Basin (western Baffin Island) (DFO 2019b) may afford some protection, but walrus use of this area is not well understood (COSEWIC 2017).

There are three DFO MPAs in the Canadian Arctic, none of which are in the Hudson Bay region (two in the Beaufort Sea, one in the High Arctic) (DFO 2019b) or offers protection for Atlantic walrus populations. The greatest potential for protection of marine areas important to walruses in northwest Hudson Bay lies with the ongoing DFO process to identify and establish additional MPAs. The process starts with the identification of areas of interest (AOIs), which are areas that contain ecologically sensitive habitats or species that need extra protection. Southampton Island was identified by DFO as an AOI in May 2019 (DFO 2019c). The AOI extends over 90,000 kilometres^2 and encompasses nearshore waters around Southampton Island and Chesterfield Inlet (Figure 24, DFO 2019c; Loewen et al. 2020). The Southampton Island AOI captures portions of three identified ecologically and biologically significant areas (Cobb 2011): Southampton Island, Repulse Bay/Frozen Strait, and the western Hudson Bay coastline. One of the potential conservation priorities for this AOI offers important habitat and haulout sites for the central/low Arctic walrus population (DFO 2019c; Loewen et al. 2020).

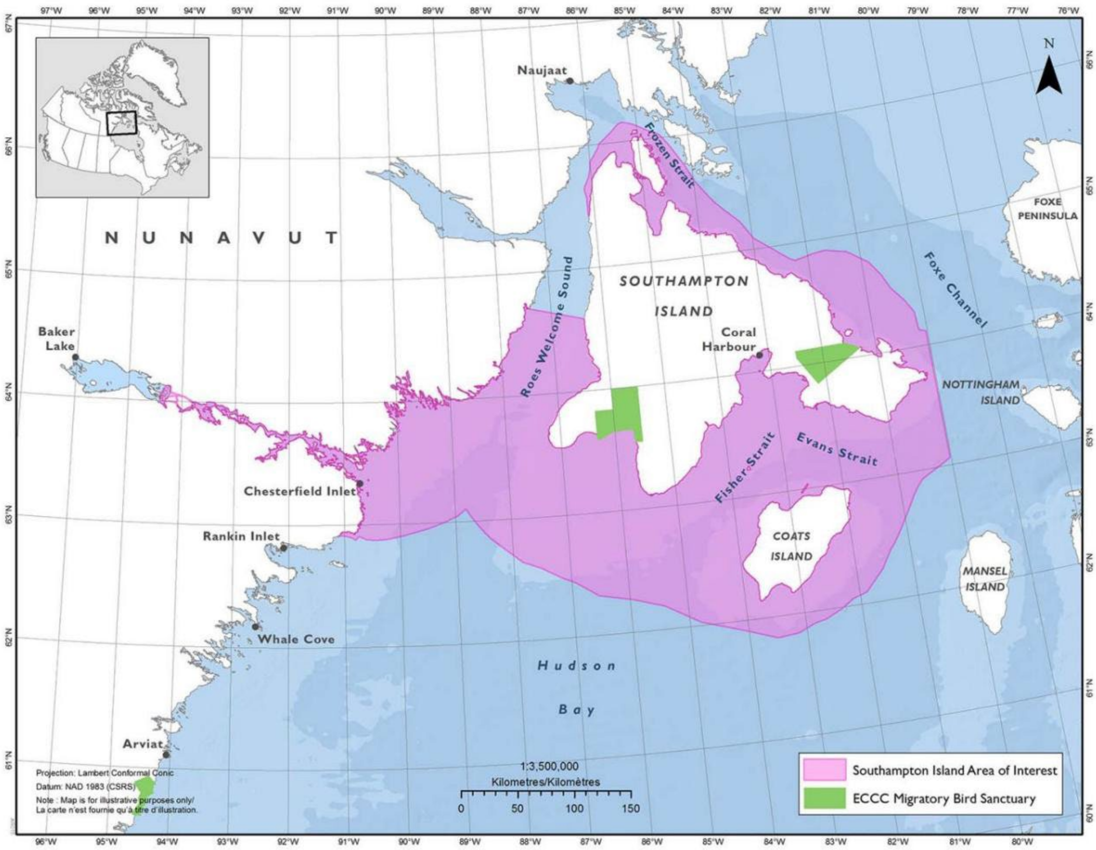


Figure 24. The Southampton Island Area of Interest (AOI) defined by DFO for potential marine protected area (MPA) establishment (from DFO 2019c)

5.1.2 Land-Use planning

The Nunavut Planning Commission (NPC) is preparing a Nunavut Land Use Plan (NLUP), which is a legal requirement under Article 11.5.1 of the Nunavut Agreement and Part 2 of the *Nunavut Planning and Project Assessment Act* (S.C. 2013, c. 14, s. 2). The land-use planning process in ongoing, with a draft plan produced in 2016 (NPC 2016) and an updated draft in 2021 (NPC 2021). In the 2016 draft plan, walrus haulouts were assigned a protected-area land-use designation, which prohibits incompatible uses and includes setback requirements of up to five kilometres (NPC 2016). The list of walrus haulouts identified and mapped in NPC (2016) was incomplete, and a significant number of known haulout sites were missing. Higdon (2016) compiled a comprehensive walrus haulout database using all available data sources, and these data were provided to the NPC. The haulout locations were added to the NPC land-use planning database (V. Sahanatien, NPC, pers. comm., 2019) and updates are reflected in the 2021 draft plan (NPC 2021). Participants in Coral Harbour community meetings on the draft NLUP stressed the importance of protecting walrus habitats and noted that Walrus Island is a very important area (NPC 2014). Community members also specified that areas where walruses haul out during summer should be protected from any nearby development (NPC 2014). DFO has been involved in the land-use planning process, and has built upon the efforts of Higdon (2016) to map haulout locations and develop buffer-zone recommendations to minimize disturbance by vessels and aircraft (DFO 2019a).

The 2021 draft plan treats all mapped haulouts as Limited Use areas within which oil and gas exploration and production, mineral exploration and production, quarries, hydro-electrical developments and related infrastructure, wind turbines over 15 metres in height, and all-weather roads are prohibited (NPC 2021). Additional protections proposed in the draft plan include minimum distance requirements based on vessel size, limitations on vessel operations and anchoring for project proponents, and minimum flight altitudes for aircraft in the vicinity of mapped haulouts (NPC 2021). Walrus Island has also been identified as a Community Area of Interest and the entire island is proposed as a Limited Use area with similar restrictions as noted above for haulout sites (prohibitions on oil and gas exploration and production, quarries, etc.), with additional restrictions on at sea disposal and piloting vessels within 5 kilometres seaward of a haul-out on Walrus Island (NPC 2021).

In Nunavik, the Nunavik Marine Region Planning Commission (NMRPC) was established as an institution of public government upon the signing and ratification of the *Nunavik Inuit Land Claims Agreement Act* (S.C. 2008, c. 2). The NMRPC is responsible for developing planning policies and priorities for the Nunavik marine region. This process has not developed to the extent that the Nunavut process has, but any land-use plans developed can be expected to address walrus habitat.

6.0 Current research on walruses

In April 2016, DFO (central and Arctic region and Quebec region) convened a workshop to develop a five-year research plan for walrus in Canada (Stewart et al. 2017). The workshop summarized recent walrus research and discussed priority issues for future research. Participants reviewed DFO's management objectives and priorities and information needs. Key information needs for sustainable use of walrus stocks include abundance estimates, sustainable harvest levels, struck-and-lost rate, improved harvest reporting, walrus response to shipping and other disturbances, and stock delineation (Stewart et al. 2017). Key information gaps were identified, including those related to population structure (stock distribution and boundaries, age and sex distribution) and abundance (including the ability for co-managers to detect increases or decreases in numbers) (Stewart et al. 2017). There was no priority-setting component to the workshop, but the report editors (who are also the three authors of this report) offered suggestions, including fostering working relationships between DFO and relevant communities, organizations, and research colleagues; reviewing existing data to assess their suitability for modelling and addressing emerging questions; developing a risk-assessment process for dealing with perpetually data-poor species; and collecting new data on walrus distribution, movements, and abundance estimates, particularly for the Hudson Bay–Davis Strait and south and east Hudson Bay stocks (Stewart et al. 2017).

DFO science staff have accepted these recommendations and have been conducting research to help address these gaps. For example, the 2014 aerial survey (Hammill et al. 2016a) was followed up with a 2017 survey that used three aircraft to cover most of the Hudson Bay–Davis Strait stock range (C. Matthews, DFO, pers. comm. 2020). The 2017 field program also included some satellite tagging (although most tags failed quickly) and some trail camera deployments at haulout sites on Walrus Island (C. Matthews, DFO, pers. comm. 2020). Analyses of the 2017 fieldwork were presented at a DFO peer-review meeting in February 2020 (C. Matthews, DFO, pers. comm. 2020). A walrus tusk research project is funded and underway, for which DFO is collecting tusks to measure trace elements in the annual layers, (C. Matthews, DFO, pers. comm. 2020). DFO has a marine mammal sampling program that includes walrus, with kits submitted to community HTOs for distribution to hunters. A walrus catch monitoring program is being established with hunters in Coral Harbour, following the completion of a similar three-year program in Sanirajak. The tongues from harvested walruses are also submitted for *Trichinella* testing to ensure animals are safe for human consumption (Larrat et al. 2012).

There are numerous gaps in published knowledge on oceanography and food web dynamics in northern Hudson Bay. The Churchill Marine Observatory (CMO) environmental observatory (EO) system project is attempting to address some of these gaps and should provide important information on walrus ecology in the region. The project, by the Centre for Earth Observation Science (CEOS) at the University of Manitoba, includes the use of a 65-foot research vessel (MV William Kennedy) and oceanographic moorings deployed along the main shipping channel across Hudson Bay and Hudson Strait (CEOS 2018). The CMO-EO system will collect data to increase baseline knowledge of general oceanography and includes physical, chemical, and biological oceanographic investigations and monitoring within the Hudson Bay complex. This is intended to be a long-term project that will, pending community support, return to Hudson Bay for multiple years and provide important information on the marine ecosystem in this region.

7.0 Information gaps and directions for further research

A number of information gaps have been identified by DFO, as the responsible agency for management and research on Atlantic walrus in Canada. Both the IFMP (DFO 2018) and the April 2016 walrus planning workshop (Stewart et al. 2017) discussed information and research needs. Some of the identified gaps are in the process of being filled. For example, the IFMP noted the requirement for population estimates for the Hudson Bay–Davis Strait stock, and surveys were conducted in 2014 (Hammill et al. 2016a) and 2017 (C. Matthews, DFO, pers. comm. 2020).

The IFMP also noted a need to establish sustainable harvest levels, which requires information on walrus abundance, harvest levels, and struck and lost rates. With respect to the latter, consistently complete and reliable data on struck-and-lost rates are needed. These data can only be provided by Inuit harvesters (or through observation of hunts by a third party). Related to struck and loss, the IFMP (2018) recommended hunter training to improve walrus harvesting success and reduce loss rates. It also recognizes the value of timely and accurate reporting, both of harvests and loss rates. Recent efforts to establish a harvest reporting and community catch monitoring program (C. Matthews, DFO, pers. comm. 2020) should assist with these efforts.

With respect to walrus sport hunts, the IFMP identified a need for all relevant HTOs to develop bylaws or guidelines to codify community rules or best management practices for these hunts. This is of particular relevance to Coral Harbour, as one of the primary communities for walrus sport hunt outfitting. Community-led bylaws can help to ensure that sport hunts cause minimal disturbance to both walruses and Inuit harvesters. Sport hunts are one aspect of walrus-related tourism that, along with non-consumptive tourism (i.e., wildlife viewing and photography), has the potential to cause disturbance. The IFMP identifies a number of issues and concerns with regard to tourism, shipping traffic, and development, including fuel spills, disruption of migration, avoidance of sensitive areas, and noise and other disturbance (including at haulouts).

The 2016 DFO workshop identified similar information gaps, including the need for updated abundance estimates, information on struck and lost rates, improved harvest reporting (for sustainable harvest management), research and monitoring on walrus response to shipping and other disturbances, and information on population structure and abundance and stock delineation (stock distribution and boundaries, age and sex distribution, ability for co-managers to detect changes in numbers) (Stewart et al. 2017). The workshop did not establish a priority list, but the report editors suggested fostering working relationships between DFO and co-management partners, including communities; reviewing existing data for added value (e.g., additional modelling); and collecting new data on walrus distribution, movements, and abundance (Stewart et al. 2017).

The collection of new and updated data on walrus distribution should also include updates to haulout location and use status. The current DFO walrus survey protocol is to count animals at haulouts (e.g., Stewart 2002, 2008a; Stewart et al.

2013; Hammill et al. 2016a). All previously known haulouts in the study area are surveyed and noted to be in use or not-in-use, and the location of any new haulouts observed (which could be newly established or previously unknown sites) is recorded. Haulouts should not be defined as 'abandoned' even if no use has been recorded in multiple years, as a lack of observed use in the short-term does not guarantee that it will not be used again at some point in the future. The location and status of haulouts is constantly updated as new surveys are conducted, and database updates should be conducted regularly as new information becomes available.

Many of the items noted above fall under the purview of DFO as the responsible management agency (e.g., conducting aerial surveys, satellite-tagging programs to study movements/diving, stock assessment research). Co-management groups (RWOs, HTOs) and other research partners (universities, non-governmental organizations) should also play a role in advancing walrus research, management, and monitoring progress in the northwest Hudson Bay region.

8.0 Literature cited

Agnico Eagle Nunavut. 2020. Sealift Season 2020 Shipping Routes. Online: http://aemnunavut.ca/wp-content/uploads/2020/07/Sealift-Season-2020.pdf [accessed January 2020]

AMAP. 2017. Snow, water, ice and permafrost in the Arctic (SWIPA) 2017. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway.

AMAP. 2018. AMAP assessment 2018: Arctic Ocean acidification. Arctic Monitoring and Assessment Programme (AMAP), Tromso, Norway. vi + 187 pp.

Andrews, J., D. Babb, and D.G. Barber. 2018. Climate change and sea ice: Shipping in Hudson Bay, Hudson Strait, and Foxe Basin (1980–2016). Elementa: Science of the Anthropocene 6(1): 19. DOI: http://doi.org/10.1525/elementa.281

Anon. 1952. Fredning av hvalross. Kongelig Resolusjon av 20. Juni 1952. (Protection of walrus. Royal Decree 20 June 1952). Oslo, Norway. Available from Fiskeridepartementet, Ovre Slottsg. 2, P.B. 8118 Dep., 0032 Oslo, Norway.

Asplund, M.E., S.P. Baden, S. Russ, R.P. Ellis, N. Gong, and B.E. Hernroth. 2014. Ocean acidification and host–pathogen interactions: blue mussels, *Mytilus edulis*, encountering *Vibrio tubiashii*. Environ. Microbiol. 16: 1029–1039. doi: 10.1111/1462-2920.12307 .

Azetsu-Scott, K., A. Clarke, K. Falkner, J. Hamilton, E.P. Jones, C. Lee, B. Petrie, S. Prinsenberg, M. Starr, and P. Yeats. 2010. Calcium carbonate saturation states in the waters of the Canadian Arctic Archipelago and the Labrador Sea. J. Geophys. Res. 115: C11021. doi:10.1029/2009JC005917.

BIMC (Baffinland Iron Mines Corporation). 2012. Mary River Project final environmental impact statement. NIRB File No.: 08MN053, February 14, 2012. Toronto, ON.

BIMC (Baffinland Iron Mines Corporation). 2018. Addendum to the final environmental impact statement, Mary River Project - phase 2 proposal. 142 pp. (Nunavut Impact Review Board File No. 08MN053)

Bluhm, B.A., and R. Gradinger. 2008. Regional variability in food availability for Arctic marine mammals. Ecol. Appl. 18(2) Suppl.: S77-S96.

Born, E.W., and M. Acquarone. 2007. Estimation of walrus (*Odobenus rosmarus*) predation on bivalves in the Young Sound area (NE Greenland). Medd Grønland Biosci. 58:176-191.

Born, E.W., and Ø. Wiig. 2005. Potential effects on Atlantic Walrus of warming in the Arctic. Working paper to the NAMMCO workshop on Walrus in the North Atlantic, Copenhagen, 11-14 January 2005. 13 pp.

Born, E. W., M.P. Heide-Jørgensen, and R. Davis. 1994. The Atlantic walrus (*Odobenus rosmarus rosmarus*) in West Greenland. Medd. Grønland, Biosci. 40: 1-33.

Born, E.W., I. Gjertz, and R.R. Reeves. 1995. Population assessment of Atlantic Walrus. Norsk Polarinst. Medd. 138: 100 pp.

Born, E.W., S. Rysgaard, G. Ehlmé, M. Sejr, M. Acquarone, and N. Levermann. 2003. Underwater observations of foraging free-living Atlantic walruses (*Odobenus rosmarus rosmarus*) and estimates of their food consumption. Polar Biology 26(5): 348-357.

Born, E.W., M. Aquarone, L.Ø. Knutsen, and L. Toudal. 2005. Homing behavior in an Atlantic walrus (*Odobenus rosmarus rosmarus*). Aquat. Mamm. 31(1): 11-21.

Brice-Bennett, C. 1976. Inuit land use in the east central Canadian arctic. pp. 63-81, in M.M.R. Freeman (ed.) Inuit land use and occupancy study, Vol. 1. Canada Department of Indian and Northern Affairs, Ottawa.

Brody, H. 1976a. Land Occupancy: Inuit Perceptions. Pages 185-242 in: Freeman, M.M.R. (Ed.). 1976. Inuit Land Use and Occupancy Project Report, Volume 1. Canada Department of Indian and Northern Affairs, Ottawa, ON.

Brody, H. 1976b. Inuit land use in northern Baffin Island and northern Foxe Basin. Pages 153-172 in: M.M.R. Freeman (ed.): Inuit land use and occupancy study, Volume 1. Canada Department of Indian and Northern Affairs, Ottawa, ON.

Brueggeman, J. 1993. Walrus response to offshore drilling operations (A). J. Acoust. Soc. Am. 94(3): 1828.

Calvert, W., and I. Stirling. 1990. Interactions between polar bears and overwintering walruses in the central Canadian High Arctic. International Conference of Bear Research and Management. 8: 351-356.

Candlish, L.M., D.G. Babb, J. Andrews, P.G. Myers, N. Ridenour, J. Landy, and J. Ehn. 2019a. Characteristics of the seasonal sea ice cover, pp. 79-95. *In* Z.A. Kuzyk and L.M. Candlish (eds.) From science to policy in the Greater Hudson Bay Marine Region: an integrated regional impact study (IRIS) of climate change and modernization. ArcticNet, Québec City.

Candlish, L.M., D.G. Babb, and J. Andrews. 2019b. Climate change projections, pp. 97-111. In Z.A. Kuzyk and L.M. Candlish (eds.) From science to policy in the Greater Hudson Bay Marine Region: an integrated regional impact study (IRIS) of climate change and modernization. ArcticNet, Québec City, 424 pp.

Carter, N.A., J. Dawson, and M. Weber. 2019. Arctic Corridors and Northern Voices: governing marine transportation in the Canadian Arctic (Coral Harbour, Nunavut community report). University of Ottawa, Ottawa, ON. DOI: 10.20381/RUOR38505.

CBC News North. 2008. Ban on Walrus tourism divides Igloolik. May 7, 2008, 3:45 PM. CT. Online: https://www.cbc.ca/news/canada/north/ban-on-walrus-tourism-divides-igloolik-1.743798 [Accessed January 2020].

CEAA. 2012. *Canadian Environmental Assessment Act*, 2012 (S.C. 2012, c. 19, s. 52). Government of Canada, Ottawa, ON.

CEOS. 2018. Churchill Marine Observatory - Environmental Observing (CMO-EO). Abstract submitted to the Nunavut Impact Review Board (NIRB) for Project Screening. Nunavut Impact Review Board, Cambridge Bay, NU.

Chan, F., S. Bailey, C. Wiley, and H. MacIsaac. 2013. Relative risk assessment for ballast-mediated invasions at Canadian Arctic ports. Biol. Invasions 15(2):295–308.

Chan, F.T., H. MacIsaac, and S.A. Bailey. 2015. Relative importance of vessel hull fouling and ballast water as transport vectors of nonindigenous species to the Canadian Arctic. Can. J. Fish. Aquat. Sci. 72(8):1230–42.

Charrier, I., T. Aubin, and N. Mathevon. 2010. Mother–calf vocal communication in Atlantic walrus: a first field experimental study. Anim. Cogn. 13: 471–482.

Christiansen, J.S., C.W. Mecklenburg, and O.V. Karamushko. 2014. Arctic marine fishes and their fisheries in light of global change. Global Change Biol. 20: 352–359, doi: 10.1111/gcb.12395

CIRNAC. 2018. Northern Oil and Gas Annual Report 2017. Crown-Indigenous Relations and Northern Affairs, Petroleum and Mineral Resources Management Directorate, Gatineau. QC. 14 pp.

CIRNAC. 2019. Northern Oil and Gas Annual Report 2018. Crown-Indigenous Relations and Northern Affairs, Petroleum and Mineral Resources Management Directorate, Gatineau. QC. 15 pp.

CIS (Canadian Ice Service). 2011. Sea Ice Climatic Atlas for the Northern Canadian Waters 1981-2010. Canadian Ice Service, Ottawa, ON.

CITES (*Convention on International Trade in Endangered Species of Wild fauna and Flora*). n.d. How CITES works. Online: https://www.cites.org/eng/disc/how.php

Clark, C.T., L. Horstmann, A. de Vernal, A.M. Jensen, and N. Misarti. 2019. Pacific walrus diet across 4000 years of changing sea ice conditions. Quater. Res. 1-17. DOI:10.1017/qua2018.140

Cobb, D.G. 2011. Identification of Ecologically and Biologically Significant Areas (EBSAs) in the Canadian Arctic. DFO Canadian Science Advisory Secretariat Research Document 2011/070. vi + 38 p.

Cody, M. 2003. Round Island field report, May 3 - August 10, 2003. Marine Mammals Management, U. S. Fish and Wildlife Service, Anchorage, Alaska. 67 pp.

COSEWIC. 2006. COSEWIC assessment and update status report on the Atlantic walrus *Odobenusrosmarus rosmarus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. ix + 65 pp.

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. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xxi + 89 pp.

Davis, R.A., Koski, W.R., and K.J. Finley. 1978. Numbers and distribution of Walrus in the central Canadian High Arctic. LGL Limited, Environmental Research Associates, 44 Eglinton Avenue West, Toronto, ON. vii + 50 pp.

Dawson J., L. Pizzolato, S.E.L. Howell, L. Copland, and M.E. Johnston. 2018. Temporal and spatial patterns of ship traffic in the Canadian Arctic from 1990 to 2015. Arctic 71(1): 15-26. https://doi.org/10.14430/arctic4698.

Dawson, J., N. Carter, N. van Luijk, C. Parker, M. Weber, A. Cook, K. Grey, and J. Provencher. 2020. Infusing Inuit and local knowledge into the low impact shipping corridors: an adaptation to increased shipping activity and climate change in Arctic Canada. Environ. Sci. Policy 105: 19–36.

de March, B.G.E., L.D. Maiers, and R.E.A. Stewart. 2002. Genetic relationships among Atlantic Walrus (*Odobenus rosmarus rosmarus*) in the Foxe Basin and Resolute Bay–Bathurst Inlet area. DFO Canadian Science Advisory Secretariat Research Document 2002/92: 20 pp.

Derksen, C., S.L. Smith, M. Sharp, L. Brown, S. Howell, L. Copland, D.R. Mueller, Y. Gauthier, C.G. Fletcher, A. Tivy, M. Bernier, J. Bourgeois, C.R. Burn, C. Duguay, P. Kushner, A. Langlois, A.G. Lewkowicz, A. Royer, and A. Walker. 2012. Variability and change in the Canadian cryosphere. Climatic Change 115: 59-88.

DFO (Fisheries and Oceans Canada). 2002. Atlantic Walrus. DFO Canadian Science Advisory Secretariat Stock Status Rep. E5–17, 18, 19, 20: 19 pp.

DFO. 2012. Science review of Baffinland's Mary River Project final environmental impact statement. DFO Can. Sci. Advis. Sec. Sci. Resp. 2012/016: 51 pp.

DFO. 2013. Proceedings of the Pre-COSEWIC Peer Review Meeting for Atlantic Walrus (*Odobenus rosmarus rosmarus*); February 28 to March 1, 2012. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2012/041: iv + 29 p.

DFO. 2018. Integrated Fisheries Management Plan for Atlantic Walrus (*Odobenus rosmarus rosmarus*) in the Nunavut Settlement Area. Fisheries and Oceans Canada, Ottawa, ON and Iqlauit, NU.

DFO. 2019a. Mitigation Buffer Zones for Atlantic Walrus (*Odobenus rosmarus rosmarus*) in the Nunavut Settlement Area. DFO Canadian Science Advisory Secretariat Science Response 2018/055: 27 pp.

DFO 2019b. Canada's marine protected and conserved areas. Online: https://www.dfo-mpo.gc.ca/oceans/maps-cartes/conservation-eng.html (interactive map, last modified 2019-08-16) [Accessed 23 January 2020].

DFO. 2019c. Southampton Island Area of Interest (AOI). Online: https://www.dfo-mpo.gc.ca/oceans/aoi-si/southampton-eng.html (last modified: 2019-08-26) [Accessed 23 January 2020].

DFO. 2021. Public consultation on the discussion document for Canada's Ocean Noise Strategy. Date modified: 2021-04-29. Online: https://www.dfo-mpo.gc.ca/oceans/consultations/noise-bruit/index-eng.html [Accessed June 2022]

DFO 2022. Mitigating the impacts of ocean noise. Date modified: 2022-05-16. Online: https://www.dfo-mpo.gc.ca/oceans/noise-bruit/index-eng.html [Accessed June 2022]

Dietz, R., E.W. Born, R.E.A. Stewart, M.P. Heide-Jørgensen, H. Stern, F. Rigét, L. Toudal, C. Lanthier, M.V. Jensen, and J. Teilmann, 2014. Movements of walrus (*Odobenus rosmarus*) between central West Greenland and southeast Baffin Island, 2005-2008. NAMMCO Scientific Publications 9: 53-74.

Dueck, L. 2003. Proceedings of the RAP Meeting on Atlantic Walrus, 29–30 January, 2000, Navigator Inn, Iqaluit, NU. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2002/024: 20 pp.

ECCC (Environment and Climate Change Canada). 2019. Canadian Environmental Sustainability Indicators: Sea ice in Canada. Online: www.canada.ca/en/environment-climate-change/services/environmental-indicators/sea-ice.html. [Accessed March 2020].

Elliott, R.E., V.D. Moulton, S.W. Raborn, and R.A. Davis. 2013. Hudson Strait marine mammal surveys, 10 March – 2 April 2012. LGL Report No. TA8129-2. Prepared by LGL Limited, King City, ON for Baffinland Iron Mines Corporation, Toronto, ON. 87 p.

Erbe, C., and D.M. Farmer. 2000. Zones of impact around icebreakers affecting beluga whales in the Beaufort Sea. J. Acoust. Soc. Am. 108 (3): 1322-1340.

Fay, F.H., B.P. Kelly, P.H. Gehnrich, J.L. Sease, and A.A. Hoover. 1984. Modern populations, migrations, demography, trophics, and historical status of the Pacific walrus. Final Report R.U. #611. NOAA Outer Continental Shelf Environmental Assessment Program, Anchorage AK., 142 pp.

Ferguson, S.H, J.W. Higdon, and K.H. Westdal. 2012. Prey items and predation behavior of killer whales (*Orcinus orca*) in Nunavut, Canada based on Inuit hunter interviews. Aquatic Biosystems 8: 3.

Fisher, H.D. 1962. Annual report and investigators summaries April 1 1961-March 31, 1962. Fisheries Research Board of Canada, Arctic Unit. Montreal, QC.

Fisher, K.I. 1989. Food habits and digestive efficiency in walrus, *Odobenus rosmarus*. Thesis (M.Sc.) University of Manitoba, Winnipeg, MB. x + 88 p.

Fisher, K.I., and R.E.A. Stewart. 1997. Summer foods of Atlantic walrus, *Odobenus rosmarus rosmarus*, in northern Foxe Basin, Northwest Territories. Canadian Journal of Zoology 75(7): 1166-1175.

Fisher, K.I., R.E.A. Stewart, R.A. Kastelein, and L.D. Campbell. 1992. Apparent digestive efficiency in Walrus (*Odobenus rosmarus*) fed herring (*Clupea harengus*) and clams (*Spisula* sp.). Canadian Journal of Zoology 70: 30-36.

Fleming, M. and S. Newton. 2003. Hudson Bay TEKMS Report on select Hudson Bay features. Prepared for consideration by Bruce Stewart for incorporation into Hudson Bay Ecosystem Overview, 24 pp.

Franz-Warkentin, P. 2019. Grain leaves Churchill for first time in four years. Western Producer September 9, 2019. Online: https://www.producer.com/2019/09/grain-leaves-churchill-for-first-time-in-four-years/. [Accessed February 2020].

Freeman, M.M.R. (Ed.). 1976. Inuit Land Use and Occupancy Project Report, 3 volumes. Supply and Services Canada, Ottawa, ON.

Freitas, C. 2008. Habitat selection by Arctic pinnipeds: patterns, tactics, and predictions in a dynamic environment. Thesis (Ph.D.) University of Tromso, Norway. 192 p.

Freitas, C., K.M. Kovacs, R.A. Ims, M.A. Fedak, and C. Lydersen. 2009. Deep into the ice: over-wintering and habitat selection in male Atlantic walruses. Marine Ecology Progress Series 375: 247-261.

Gagnon, J. 2011. Walrus tourism back on. Nunavut News/North, Monday, May 16, 2011, p. 4. Online: http://www.nnsl.com/archive/pdf-archives/nu051611.pdf [Accessed April 2013].

Gagnon, A.S., and W.A. Gough. 2005. Trends in the dates of ice freeze-up and breakup over Hudson Bay, Canada. Arctic 58(4): 370-382.

Galbraith, P.S., and R. Larouche. 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 88(3): 463-475.

Galicia, M.P., G.W. Thiemann, M.G. Dyck, S.H. Ferguson, and J.W. Higdon. 2016. Dietary habits of polar bears in Foxe Basin, Canada: possible evidence of a trophic regime shift mediated by a new top predator. Ecology and Evolution 6(16): 6005-6018.

Garlich-Miller, J., MacCracken, J.G., Snyder, J., Meehan, R., Myers, M., Wilder, J.M., Lance, E., and Matz, A. 2011. Status review of the Pacific walrus (*Odobenus rosmarus divergens*). U.S. Fish and Wildlife Service, Anchorage, AK. vi + 155 p.

Ghazal, M. 2014. Nunavut Coastal Resource Inventory - Foxe Basin Walrus. Report prepared for NWMB's Establishment of a Walrus Management Unit and Total Allowable Harvest in Foxe Basin, by Fisheries and Sealing Division Department of Environment, Government of Nunavut.

Gignac, J. 2020. Canada gives $1.4 million to support Nunavik Inuit's management of Arqvilliit Indigenous Protected Area. The Narwhal, 19 Nov. 2020. Online: https://thenarwhal.ca/arctic-nunavik-arqvilliit-indigenous-protected-area/ [Accessed December 2020].

Goldsmit, J., C. McKindsey, P. Archambault, and K.L. Howland. 2019. Ecological risk assessment of predicted marine invasions in the Canadian Arctic. PLoS ONE 14(2): e0211815.

Gosselin, M., M. Levasseur, P. Wheeler, R. Horner, and B. Booth. 1997. New measurements of phytoplankton and ice algal production in the Arctic Ocean. Deep Sea Research Part II: Topical Studies in Oceanography 44(8): 1623-1625, 1627-1644.

Government of Canada. 2019a. Order in Council, PC Number: 2019-1121. Order Prohibiting Certain Activities in Arctic Offshore Waters. Date: 2019-07-28. Online: https://orders-in-council.canada.ca/attachment.php?attach=38451&lang=en [Accessed February 2020].

Government of Canada. 2019b. Restoring lost protections to fish and fish habitat (Archived content, August 28, 2019). Online:

https://www.canada.ca/en/services/environment/conservation/assessments/environmental-reviews/fish-habitat-protection.html [Accessed February 2020].

Government of Canada. 2020a. Marine Mammal Regulations SOR/93-56. Current to February 26, 2020. Last amended on November 2, 2018. Published by the Minister of Justice, Government of Canada. Online: https://laws-lois.justice.gc.ca/eng/regulations/SOR-93-56/FullText.html. [Accessed March 2020].

Government of Canada. 2020b. *Fisheries Act* R.S.C., 1985, c. F-14 L.R.C. (1985), ch. F-14. Current to February 26, 2020. Last amended on August 28, 2019. Published by the Minister of Justice, Government of Canada. Online: https://laws-lois.justice.gc.ca/eng/acts/f-14/FullText.html [Accessed March 2020].

Government of Canada. 2020c. Anguniaqvia niqiqyuam Marine Protected Areas Regulations (SOR/2016-280) (OCEANS ACT). Current to February 26, 2020. Published by the Minister of Justice, Government of Canada. Online: https://laws-lois.justice.gc.ca/eng/regulations/SOR-2016-280/FullText.html [Accessed March 2020].

Government of Canada. 2022. Order Prohibiting Certain Activities in Arctic Offshore Waters (Order Amending), pursuant to the *Canada Petroleum Resources Act*. Date modified: 2022-04-01. Online: https://www.rcaanc-cirnac.gc.ca/eng/1647022447627/1647022668724 [Accessed June 2022]

GN (Government of Nunavut). 2014. Nunavut Coastal Resource Inventory (NCRI) - Coral Harbour. GN Department of Environment, Iqaluit, NU.

Grebmeier, J.M., J.E. Overland, S.E. Moore, E.V. Farley, E.C. Carmack, L.W. Cooper, K.E. Frey, J.H. Helle, F.A. McLaughlin, and S.L. McNutt. 2006. A major ecosystem shift in the northern Bering Sea. Science 311(10 March 2006): 1461-1464.

Greenan, B.J.W., T.S. James, J.W. Loder, P. Pepin, K. Azetsu-Scott, D. Ianson, R.C. Hamme, D. Gilbert, J.-E. Tremblay, X.L. Wang, and W. Perrie. 2018. Changes in oceans surrounding Canada, Chapter 7, p. 343–423. *In* Bush and Lemmen (eds.), Canada's changing climate report. Government of Canada, Ottawa, Ontario.

Gunn, A., Arlooktoo, G., and Kaomayok, D. 1988. The contribution of ecological knowledge of Inuit to wildlife management in the Northwest Territories. In Traditional knowledge and renewable resource management in northern regions. Edited by M.M.R Freeman and L.N. Carbyn, The University of Alberta Press Occasional Publication 23: 22–30.

Hamilton, A.L. 2013. The Hudson Bay Complex in flux: Contemplating the future of the world's largest seasonally ice-covered inland sea. International Institute for Sustainable Development, Winnipeg, MB.

Hammill, M.O., A. Mosnier, J.-F. Gosselin, J.W. Higdon, D.B. Stewart, T. Doniol-Valcroze, S.H Ferguson and J.B. Dunn. 2016a. 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.

Hammill, M.O., Doniol-Valcroze, T., Mosnier, A. and Gosselin, J.-F. 2016b. Modelling walrus population dynamics: A direction for future assessments. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/050. v + 47 p.

Hammill, M.O., Blanchfield, P., Higdon, J.W., Stewart, D.B., and Ferguson, S.H. 2016c. Estimating abundance and total allowable removals for walrus in Foxe Basin. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/014. iii + 22 p.

Hanna, M.C., C.J. Lister, K. Kublik, H.M. King, L.E. Kung, W.M. McCarthy, K.T. McDannell, and Y. Jassim. 2018. Qualitative petroleum resource assessment of western Hudson Bay, Foxe Channel, and Repulse Bay, Manitoba, Nunavut, Ontario, and Quebec; Geological Survey of Canada, Open File 8434, 31 p. https://doi.org/10.4095/311260

Hansen, K. 2018. When Churchill needed Ottawa, the town was ignored. Now, Ottawa needs Churchill. McLeans November 13, 2018. Online: https://www.macleans.ca/opinion/when-churchill-needed-ottawa-the-town-was-ignored-now-ottawa-needs-churchill/ [Accessed February 2020].

Hantzsch, B.A. 1977. My life among the Eskimos: Baffinland journeys in the years 1909 to 1911. University of Saskatchewan, Mawdsley Memoir 3: xxii + 395 p. + map. [Translated from German and edited by L.H. Neatby].

Hauser, D.D.W., K.L. Laidre, and H.L. Stern. 2018. Vulnerability of Arctic marine mammals to vessel traffic in the increasingly ice-free Northwest Passage and Northern Sea Route. Proc. Nat. Acad. Sci. 115(29): 7617-7622. DOI: 10.1073/pnas.1803543115

HBCA RG3/26B/27 Annual Report, Southampton Island, Outfit 270, 12 June 1940 [Hudson Bay Company Archives, Winnipeg. MB]

Heide-Jørgensen, M.P., J. Flora, A. Oberborbeck Andersen, R.E.A. Stewart, N.H. Nielsen, and R.G. Hansen. 2017. Walrus movements in Smith Sound: A Canada–Greenland shared stock. Arctic 70(3): 308-318.

Heywood, W.W., and B.V. Sanford. 1976. Geology of Southampton, Coats, and Mansel Islands, District of Keewatin, Northwest Territories. Geological Survey of Canada, Memoir 382, 35 p. (3 sheets). https://doi.org/10.4095/102311

Higdon, J.W. 2016. Walrus haulouts in the eastern Canadian Arctic: a database to assist in land use planning initiatives. Report and GIS database by Higdon Wildlife

Consulting, Winnipeg, MB, on behalf of WWF-Canada, Iqaluit, NU, for submission to the Nunavut Planning Commission, Cambridge Bay, NU.

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

Higdon, J.W., and D.B. Stewart. 2018. State of circumpolar walrus (*Odobenus rosmarus*) populations. Prepared by Higdon Wildlife Consulting and Arctic Biological Consultants, Winnipeg, MB for WWF Arctic Programme, Ottawa, ON. 100 pp.

Higdon, J.W., K.H. Westdal, and S.H. Ferguson. 2014. Distribution and abundance of killer whales (*Orcinus orca*) in Nunavut, Canada – an Inuit knowledge survey. J. Mar. Biol. Assoc. UK 94(6): 1293-1304.

Hochheim, K.P., and D.G. Barber. 2014. An update on the ice climatology of the Hudson Bay system. Arct. Antarct. Alp. Res. 46(1): 66-83.

Hocheim, K.P., D.G. Barber, and J.V. Lukovich. 2010. Changing sea ice conditions in Hudson Bay, 1980-2005. Pages 39-52 in S.H. Ferguson, L.L. Loseto, and M.L. Mallory (eds.), A Little Less Arctic: Top Predators in the World's Largest Northern Inland Sea, Hudson Bay. Springer Science and Business Media.

Hoover, C. 2010. Hudson Bay Ecosystem: Past, Present, and Future. Pages 217-236 in S.H. Ferguson, L.L. Loseto, and M.L. Mallory (eds.), A Little Less Arctic: Top Predators in the World's Largest Northern Inland Sea, Hudson Bay. Springer Science and Business Media.

Hoover, C., T. Pitcher, and V. Christensen, 2012. An ecosystem model of Hudson Bay, Canada with changes from 1970–2009. Pages 2-66 in: C. Wabnitz, and C. Hoover (Eds.), From the Tropics to the Poles: Ecosystem Models of Hudson Bay, Kaloko-Honokohau, Hawai'i, and the Antarctic Peninsula, vol. 20(2). UBC Fisheries Centre, Fisheries Centre Research Report, Vancouver, BC.

Hoover, C., T. Pitcher, and V. Christensen. 2013a. Effects of hunting, fishing and climate change on the Hudson Bay marine ecosystem: I. Re-creating past changes 1970–2009. Ecological Modelling 264: 130-142.

Hoover, C., T.J. Pitcher, and V. Christensen. 2013b. Effects of hunting, fishing and climate change on the Hudson Bay marine ecosystem: II. Ecosystem model future projections. Ecological Modelling 264:143-156

Huntington, H.P., L.T. Quakenbush, and M. Nelson. 2017. Evaluating the effects of climate change on indigenous marine mammal hunting in northern and western Alaska using traditional knowledge. Front. Mar. Sci. 4:319. doi: 10.3389/fmars.2017.00319

Immaroitok, E. 1996. Interview IE-377. Archives of the Inullariit Society, Igloolik Research Centre, Igloolik, Nunavut.

Joly, S., S. Senneville, D. Caya, and F.J. Saucier. 2011. Sensitivity of Hudson Bay Sea ice and ocean climate to atmospheric temperature forcing. Clim. Dyn. 36: 1835–1849 DOI 10.1007/s00382-009-0731-4

Jones, J. 2013. Oil's new Arctic passage to Europe. Globe and Mail, August 15, 2013. Online: http://www.theglobeandmail.com/report-on-business/oils-new-arctic-passage-to-europe/article13803628/ [Accessed February 2020].

Kappianaq, G. 1992. Interview IE-234. Archives of the Inullariit Society, Igloolik Research Centre, Igloolik, Nunavut.

Kappianaq, G. 1997. Interview IE-409. Archives of the Inullariit Society, Igloolik Research Centre, Igloolik, Nunavut.

Kastelein, R.A., S. Stevens, and P. Mosterd. 1990. The tactile sensitivity of the mystacial vibrissae of a Pacific Walrus (*Odobenus rosmarus divergens*), part 2: masking. Aquat. Mamm. 16(2): 78-87.

Kastelein, R.A., R.C.V.J. Zweypfenning, H. Spekreijse, J.L. Dubbeldam, and E.W. Born. 1993. The anatomy of the walrus head (*Odobenus rosmarus*). Part 3: the eyes and their function in walrus ecology. Aquat. Mamm. 19: 61–92.

Kastelein, R.A., P. Mosterd, B. van Santen, and M. Hagedoorn, 2002. Underwater audiogram of a Pacific walrus (*Odobenus rosmarus divergens*) measured with narrow-band frequency-modulated signals. J. Acoust. Soc. Am. 112: 2173–2182.

Kemp, W.B. 1976. Inuit land use in south and east Baffin Island. pp. 125-151. in M.M.R. Freeman (ed.) Inuit land use and occupancy project. Volume 1: Land use and occupancy. Supply and Services Canada, Ottawa, ON.

Killian, H.P.L., and I. Stirling. 1978. Observations on overwintering walruses in the eastern Canadian High Arctic. Journal of Mammalogy 59(1): 197-200.

Kopaq, M. 1987. Interview IE-017. Archives of the Inullariit Society, Igloolik Research Centre, Igloolik, Nunavut.

Kowal, S., W.A. Gough, and K. Butler. 2017. Temporal evolution of Hudson Bay sea ice (1971–2011). Theoretical and Applied Climatology 127(3–4): 753-760.

Kroeker, K.J., R.L. Kordas, R.N. Crim, I.E. Hendriks, L. Ramajo, G.G. Singh, C.M. Duarte, and J.P. Gattuso. 2013. Impacts of ocean acidification on marine organisms: quantifying sensitivities and interactions with warming. Global Change Biol. 19(6): 1884-1896.

Kupaaq, M. 1996. Interview IE-360. Archives of the Inullariit Society, Igloolik Research Centre, Igloolik, Nunavut.

Kyhn, L.A., D. Boertmann, J. Tougaard, K. Johansen, and A. Mosbech. 2011. Guidelines to environmental impact assessment of seismic activities in Greenland waters. 3rd revised edition, Dec. 2011. Danish Center for Environment and Energy: 61 pp.

Laidler, G.J., J.D. Ford, W.A. Gough, T. Ikummaq, A.S. Gagnon, S. Kowal, K. Qrunnut, and C. Irngaut. 2009. Travelling and hunting in a changing Arctic: assessing Inuit vulnerability to sea ice change in Igloolik, Nunavut. Climatic Change 94: 363–397. DOI 10.1007/s10584-008-9512-z.

Laidre, K.L., I. Stirling, L.F. Lowry, O. Wiig, M.P. Heide-Jorgensen, and S.H. Ferguson. 2008. Quantifying the sensitivity of arctic marine mammals to climate-induced habitat change. Ecol. Appl. 18(2 Suppl): S97–S125.

Laliberté, F., S.E.L. Howell, and P.J. Kushner (2016), Regional variability of a projected sea ice- free Arctic during the summer months, Geophysical Research Letters 43: 256-263. doi:10.1002/2015GL066855.

Lambert, J., and G. Préfontaine. 1995. The Iceland scallop (*Chlamys islandica*) in Nunavik. Can. Tech. Rep. Fish. Aquat. Sci. 2071: vii + 40 p.

Lambert, S. 2020. Shipping crude oil through Manitoba has been floated, rejected before. CBC February 5, 2020. Online: https://www.cbc.ca/news/canada/manitoba/sask-churchill-oil-pipeline-1.5453570 [Accessed February 2020].

Larrat, S., M. Simard, S. Lair, D. Bélanger, and J.-F. Proulx. 2012. From science to action and from action to science: the Nunavik Trichinellosis Prevention Program. International Journal of Circumpolar Health 71: 10.3402/ijch.v71i0.18595.

Lavoie, D., R. Macdonald, and K. Denman. 2009. Primary productivity and export fluxes on the Canadian shelf of the Beaufort Sea: a modelling study. Journal of Marine Systems 75: 17-31.

Lavoie, D., N. Lambert, and A. van der Baaren. 2013. Projections of future physical and biogeochemical conditions in Hudson and Baffin bays from CMIP5 Global Climate Models, Can. Tech. Rep. Hydrogr. Ocean Sci. 289: xiii + 129 pp.

Lavoie, D., N. Pinet, J. Dietrich, S. Zhang, K. Hu, E. Asselin, Z. Chen, R. Bertrand, J. Galloway, V. Decker, P. Budkewitsch, D. Armstrong, M. Nicolas, J. Reyes, B.P. Kohn, M.J. Duchesne, V. Brake, P. Keating, J. Craven, and B. Roberts. 2013. Geological framework, basin evolution, hydrocarbon system data and conceptual hydrocarbon plays for the Hudson Bay and Foxe basins, Canadian Arctic. Geological Survey of Canada, Open File 7363 https://doi.org/10.4095/293119 (210 pp.).

Lavoie, D., N. Pinet, J. Dietrich,and Z. Chen. 2015.The Paleozoic Hudson Bay Basin in northern Canada: new insights into hydrocarbon potential of a frontier intracratonic basin. AAPG Bull. 99(5): 859– 888.

Lefort, K. J., C.J.D. Matthews, J.W. Higdon, S.D. Petersen, K.H. Westdal, C.J. Garroway, and S.H. Ferguson. 2020. A review of Canadian Arctic killer whale (*Orcinus orca*) ecology. Canadian Journal of Zoology 98(4): 245-253.

Legendre, L., B. Robineau, M. Gosselin, C. Michel, R. Ingram, L. Fortier, J. Therriault, S. Demers, and D. Monti. 1996. Impact of freshwater on a subarctic coastal ecosystem under seasonal sea ice (southeastern Hudson Bay) Canada II. Production and export of microalgae. Journal of Marine Systems 7: 233-250.

Levermann, N., A. Galatius, G. Ehlme, S. Rysgaard, and E.W. Born. 2003. Feeding behaviour of free-ranging walruses with notes on apparent dextrality of flipper use. BMC Ecology 3: 9.

Loewen, T.N., C.A. Hornby, M. Johnson, C. Chambers, K. Dawson, D. MacDonell, W. Bernhardt, R. Gnanapragasam, M. Pierrejean, and E. Choy. 2020. Ecological and Biophysical Overview of the Southampton proposed Area of Interest for the Southampton Island Ecologically and Biologically Significant Area. DFO Can. Sci. Advis. Sec. Res. Doc. 2020/032. vi + 96 p.

Loughrey, A.G. 1959. Preliminary investigation of the Atlantic walrus *Odobenus rosmarus rosmarus* (Linnaeus). Can. Wildl. Serv. Bull. (Ott.) (Series 1) 14: 123 pp.

Low, A.P. 1906. Report of the Dominion Government expedition to Hudson Bay and the Arctic Islands on board the D.G.S. *Neptune*, 1903–1904. Government Printing Bureau, Ottawa, ON. xvii + 355 pp. + map

Lowry, L.F., and F.H. Fay. 1984. Seal eating by walruses in the Bering and Chukchi Seas. Polar Biology 3(1): 11-18.

MacDonald, M., L. Arragutainaq, and Z. Novalinga (compilers). 1997. Voices From the Bay: Traditional Ecological Knowledge of Inuit and Cree in the Hudson Bay Bioregion. Canadian Arctic Resources Committee, Ottawa, ON, and Environmental Committee of Municipality of Sanikiluaq, Sanikiluaq, NU. xiii + 98 pp.

Maerospace. 2020. Spatial Analysis of Vessel Traffic in the Canadian Arctic Southampton Island AOI. Contract #: 9F013-160288/001/MTB. Report by Maerospace Corp., Waterloo ON for Canadian Space Agency, St. Hubert, QC.

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

Mansfield, A.W. 1958. The biology of the Atlantic walrus *Odobenus rosmarus rosmarus* (Linnaeus) in the eastern Canadian Arctic. Fisheries Research Board of Canada Manuscript Report 653: xiii + 146 p.

Mansfield, A.W. 1959. The Walrus in the Canadian Arctic. Fisheries Research Board of Canada Arctic Unit Circular 2: 1-13.

Mansfield, A.W. 1973. The Atlantic Walrus *Odobenus rosmarus* in Canada and Greenland. IUCN Publications New Series Supplemental Paper 39: 69–79.

Mansfield, A.W. and D.J. St. Aubin. 1991. Distribution and abundance of the Atlantic Walrus, *Odobenus rosmarus rosmarus*, in the Southampton Island-Coats Island region of northern Hudson Bay. Canadian Field-Naturalist 105: 95-100.

Marcus, A.R. 1992. Out in the cold: the legacy of Canada's Inuit relocation experiment in the high Arctic. International Work Group for Indigenous Affairs, København. 117 pp.

Markus, T., J.C. Stroeve, and J. Miller. 2009, Recent changes in Arctic sea ice melt onset, freezeup, and melt season length, J. Geophys. Res. 114: C12024. doi:10.1029/2009JC005436.

Martinez-Levasseur, L.M., C.M. Furgal, M.O. Hammill, and G. Burness. 2016. Towards a better understanding of the effects of UV on Atlantic Walrus, *Odobenus rosmarus rosmarus*: A study combining histological data with local ecological knowledge. PLoS ONE 11(4): e0152122. doi:10.1371/journal.pone.0152122

Maxwell, J.B. 1986. A climate overview of the Canadian inland seas. Pages 79–99 in Martini, I.P., ed. Canadian inland seas. Elsevier, Amsterdam.

McFarland, S.E., and L.A.M. Aerts. 2015. Assessing disturbance responses of Pacific Walrus (*Odobenus rosmarus divergens*) to vessel presence in the Chukchi Sea (Abstract). Chukchi Sea Environmental Studies Program (CSESP), Olgoonik-Fairweather, Fairweather Science, Anchorage, AK. Online: https://www.chukchiscience.com/Portals/0/Public/Science/MarineMammals/2015_CSESP_MarineMammals_SMM_Abstract_WalrusResponseVessels.pdf [Accessed February 2020]

McMahon, K., J.W. Ambrose Jr., B. Johnson, M. Sun, G. Lopez, L. Clough, and M. Carroll. 2006. Benthic community responses to ice algae and phytoplankton in Ny Alesund, Svalbard. Marine Ecology Progress Series 310: 1-14.

McNeill, M. 2014. OmniTrax suspends plan to ship crude oil through Port of Churchill. Winnipeg Free Press, August 14, 2014. Online: http://www.winnipegfreepress.com/business/OmniTrax-suspends-plan-to-ship-crude-oil-through-Port-of-Churchill--271319961.html [Accessed February 2020].

Megannety, M. 2011. A review of the planned shipping activity for the Baffinland Mary River Project: assessing the hazards to marine mammals and migratory birds, and identifying gaps in proposed mitigation measures. Master of Marine Management thesis, Dalhousie University, Halifax, Nova Scotia. xviii + 137 pp.

Miller, R.F. 1997. New records and AMS radiocarbon dates on Quaternary walrus (*Odobenus rosmarus*) from New Brunswick. Géogr. Phys. Quat. 51: 1–5.

Moore, S.E., and H.P, Huntington. 2008. Arctic marine mammals and climate change: impacts and resilience. Ecol. Appl. 18: S157-S165. doi: 10.1890/06-0571.

Moore, S.E., R.R. Reeves, B.L. Southall, T.J. Ragen, R.S. Suydam, and C.W. Clark. 2012. A new framework for assessing the effects of anthropogenic sound on marine mammals in a rapidly changing Arctic. BioScience 62(3): 289-295.

Moore, S.E., E. Logerwell, L. Eisner, E.V. Farley Jr., L.A. Harwood, K. Kuletz, J. Lovvorn, J.R. Murphy, and L.T. Quakenbush. 2014. Chapter 11. Marine fishes, birds and mammals as sentinels of ecosystem variability and reorganization in the Pacific Arctic Region, p. 337-392. *In* J.M. Grebmeier and W. Maslowski (eds.), The Pacific Arctic Region: ecosystem status and trends in a rapidly changing environment. Springer, Drodrecht. DOI 10.1007/978-94-017-8863-2_11

Mudryk, L.R., C. Derksen, S. Howell, F. Laliberté, C. Thackeray, R. Sospedra-Alfonso, V. Vionnet, P.J. Kushner, and R. Brown. 2018. Canadian snow and sea ice: historical trends and projections. The Cryosphere 12: 1157–1176.

Muir, D.C.G., M.D. Segstro, K.A. Hobson, C.A. Ford, R.E.A. Stewart, and S. Olpinski. 1995. Can seal eating explain elevated levels of PCBs and organochlorine pesticides in walrus blubber from eastern Hudson Bay (Canada). Environmental Pollution 90: 355-348.

NAMMCO. 2006. NAMMCO (North Atlantic Marine Mammal Commission) Scientific Committee Working Group on the stock status of Walrus in the North Atlantic and adjacent seas, Final Report. Copenhagen, 11-14 January 2005. 27 pp.

Nielsen, M.R. 2009. Is climate change causing the increasing narwhal (*Monodon monoceros*) catches in Smith Sound, Greenland? Polar Research 28: 238–245.

NIRB (Nunavut Impact Review Board). 2012. NIRB Project Certificate [No.: 005]. NIRB File No. 08MN053, December 28, 2012.

NIRB. 2019. Nunavut Impact Review Board Final Report for the Strategic Environmental Assessment in Baffin Bay and Davis Strait. NIRB File No. 17SN034. 3 Volumes.

NPC (Nunavut Planning Commission). 2008. Socio-demographic and economic sector analysis - final report. Appendix E2: Qikiqtani Community Profiles and

Appendix E3: Kivalliq Community Profiles. Prepared by Terriplan Consultants for Nunavut Planning Commission, Cambridge Bay, NU.

NPC. 2014. Summary of Community Meetings on the Draft Nunavut Land Use Plan, Coral Harbour, February 6-7, 2014. Revised May 2014. Nunavut Planning Commission, Cambridge Bay, NU. 37 pp.

NPC. 2016. Nunavut Land Use Plan, 2016 Draft. Nunavut Planning Commission, Cambridge Bay, NU. ii + 89 pp.

NPC. 2021. Nunavut Land Use Plan, Draft July 2021. Nunavut Planning Commission, Cambridge Bay, NU. v + 103 pp.

NTI and KIA (Nunavik Tunngavik Incorporated and Kivalliq Inuit Association). 2015. Technical review of the Final Environmental Impact Statement (FEIS) for the Kiggavik Project. Prepared for Nunavut Impact Review Board. 38 pp. + 12 appendices. [NIRB Public Registry file: 150116-09MN003-NTI and KIA Submission-IA2E.pdf and appendices]

NWMB (Nunavut Wildlife Management Board). 2019. Letter from NWMB Chair Daniel Shewchuk to Hon. Bernadette Jordan, Minister of Fisheries and Oceans, RE: Nunavut Wildlife Management Board's decision on 2020 walrus sport hunt applications, dated 16 December 2019. 7 pp. [Available online: 191216 NWMB ltr to Min DFO Walrus sport hunt applications 2020 ENG.pdf , accessed online March 28, 2020]

Okonek, D.C., and M. Snively. 2005. Walrus Islands State Game Sanctuary annual report 2005. Alaska Department of Fish and Game, Special Areas Management Report. Anchorage, AK. iii + 46 p.

Okonek, D.C., B. Okonek, and M. Snively. 2008. Walrus Islands State Game Sanctuary Annual Report 2008. Alaska Department of Fish and Game, Special Areas Management Report. Anchorage, AK. 60 p.

Øren, K., K.M. Kovacs, N.G. Yoccoz, and C. Leydersen. 2018. Assessing site use and sources of disturbance at walrus haul-outs using monitoring cameras. Polar. Biol. 41: 1737-1750.

Orr, J.R. and T. Rebizant. 1987. A summary of information on the seasonal distribution and abundance of Walrus (*Odobenus rosmarus*) in the area of northern Hudson Bay and western Hudson Strait, NWT, as collected from local hunters. Canadian Data Report of Fisheries and Aquatic Science 624: iv + 16.

Orr, J.R., B. Renooy, and L. Dahlke. 1986. Information from hunts and surveys of Walrus (*Odobenus rosmarus*) in northern Foxe Basin, Northwest Territories, 1982-1984. Canadian Manuscript Report of Fisheries and Aquatic Science 1899: iv + 29 pp.

Outridge, P.M. and R.E.A. Stewart. 1999. Stock discrimination of Atlantic Walrus (*Odobenus rosmarus rosmarus*) in the eastern Canadian Arctic using lead isotope and element signatures in teeth. Can. J. Fish. Aquat. Sci. 56: 105-112.

Outridge, P.M., R.D. Evans, R. Wagemann, and R.E.A. Stewart. 1997. Historical trends of heavy metals and stable lead isotopes in beluga (*Delphinapterus leucas*) and Walrus (*Odobenus rosmarus*) in the Canadian Arctic. Sci. Total Environ. 203: 209–219.

Outridge, P.M., W.J. Davis, R.E.A. Stewart, and E.W. Born. 2003. Investigation of the stock structure of Atlantic Walrus (*Odobenus rosmarus rosmarus*) in Canada and Greenland using dental Pb isotopes derived from local geochemical environments. Arctic 56: 82-90.

PAME. 2019. Underwater Noise in the Arctic: A State of Knowledge Report, Roveniemi, May 2019. Protection of the Arctic Marine Environment (PAME) Secretariat, Akureyri.

Panel Report (Federal Review Panel for the Eastmain-1-A Diversion Project). 2006. Environmental assessment of the Eastmain-1-A and Rupert Diversion Project. xxiv + iv + 486 pp.

Paniaq, H. 2005. Interview IE-523. Archives of the Inullariit Society, Igloolik ResearchCentre, Igloolik, Nunavut.

Parkinson, C.L. 2014. Spatially mapped reductions in the length of the Arctic sea ice season. Geophys. Res. Lett., 41, DOI: 10.1002/2014GL060434

Parkinson, C.L., and D.J. Cavalieri. 2008. Arctic sea ice variability and trends, 1979–2006. J. Geophys. Res. 113: C07003. DOI: 10.1029/2007JC004558

Piepenburg, D. 2005. Recent research on Arctic benthos: common notions need to be revised, Polar Biol. 28(10): 733–755. doi: 10.1007/s00300-005-0013-5

Piugattuk, N. 1990. Interview IE-136. Archives of the Inullariit Society, Igloolik Research Centre, Igloolik, Nunavut.

Post, E., U.S. Bhatt, C.M. Bitz, J.F. Brodie T.L. Fulton, M. Hebblewhite, J. Kerby, S.J. Kutz, I. Stirling, and D.A. Walker. 2013. Ecological consequences of sea-ice decline. Science 341: 519-524.

Post, E., R.B. Alley, T.R. Christensen, M. Macias-Fauria, B.C. Forbes, M.N. Gooseff, A. Iler, J.T. Kerby, K.L. Laidre, M.E. Mann, J. Olofsson, J.C. Stroeve, F. Ulmer, R.A. Virginia, and M. Wang. 2019. The polar regions in a 2°C warmer world. Science Advances 5(12): eaaw9883.

Poulin, M., N. Daugbjerg, R. Gradinger, L. Ilyash, T. Ratkova, and C. von Quillfeldt. 2011. The pan-Arctic biodiversity of marine pelagic and sea-ice unicellular eukaryotes: A first-attempt assessment. Marine Biodiversity 41: 13-28.

Priest, H., and P.J. Usher. 2004. The Nunavut wildlife harvest study, August 2004, final report. Nunavut, Canada. 822 pp.

Qikiqtani Inuit Association. 2011. Conformity Technical Review – October 5, 2011, QIA submission of Technical Review Comments titled "Submission of Technical Review Comments". Appendix D: Fresh water aquatics and marine, 96 pp.

Qikiqtani Inuit Association. 2012. Qikiqtani Inuit Association's final written submission for Baffinland Iron Mines Corporation, Mary River Project, Final Environmental Impact Statement. Submitted May 30th, 2012 to the Nunavut Impact Review Board (NIRB). 40 pp + appendices.

Reeves, R.R. 1995. Walrus of Nunavik. Prepared for Canada Department of Fisheries and Oceans under the Québec Federal Fisheries Development Program (QFFDP), Québec. x + 48 pp.

Richard, P.R. 1993. Summer distribution and abundance of Walrus in northern Hudson Bay, western Hudson Strait, and Foxe Basin: 1988–1990. Background document prepared for the Arctic Fisheries Science Advisory Meeting, 17–18 February 1993 by Canada Department of Fisheries and Oceans, Central and Arctic Region, Winnipeg, MB. 11 pp. + figures.

Routti, H., B. Diot, C. Panti, N. Duale, M.C. Fossi, M. Harju, K.M. Kovacs, C. Lydersen, S.E. Scotter, G.D. Villanger, and S. Bourgeon. 2019. Contaminants in Atlantic walruses Part 2: Relationships with endocrine and immune systems. Environ. Pol. 246: 658-667. doi: https://doi.org/10.1016/j.envpol.2018.11.097.

Sahanatien, V., and A.E. Derocher. 2012. Monitoring sea ice habitat fragmentation for polar bear conservation. Anim. Conserv. 15(4): 397–406.

Salter, R.E. 1979a. Site utilization, activity budgets, and disturbance responses of Atlantic Walrus during terrestrial haul-out. Canadian Journal of Zoology 57: 1169-1180.

Salter, R.E. 1979b. Observations on social behaviour of Atlantic Walrus (*Odobenus rosmarus* (L.)) during terrestrial haul-out. Canadian Journal of Zoology 58: 461-463.

Shadbolt, T., T. Arnbom, and E.W.T. Cooper. 2014. Hauling Out: International Trade and Management of Walrus. TRAFFIC and WWF-Canada. Vancouver, B.C. viii + 166 pp.

Shafer, A.B.A., C.S. Davis, D.W. Coltman, and R.E.A. Stewart. 2014. Microsatellite assessment of Walrus (*Odobenus rosmarus rosmarus*) stocks in Canada. NAMMCO Scientific Publication 9: 15-31.

Sjare, B., I. Stirling, and C. Spencer. 2003. Structural variation in the songs of Atlantic walruses breeding in the Canadian High Arctic. Aquatic Mammals 29.2: 297-318.

Smith, T.G., and D. Taylor. 1977. Notes on marine mammals, fox and polar bear harvests in the Northwest Territories 1940 to 1972. Can. Fish. Mar. Serv. Tech. Rep. 694: v + 37 pp.

Southall, B.L., L. Hatch, A. Scholik-Schlomer, T. Bergmann, M. Jasny, K. Metcalf, L. Weilgart, A.J. Wright, and M.E. Perera. 2018. Reducing noise from large commercial ships: progress and partnerships. Proc. Mar. Saf. Sec. Council 1: 58–65.

Southall, B., J. Finneran, C. Reichmuth, P. Nachtigall, D. Ketten, A. Bowles, W. Ellison, D. Nowacek, and P. Tyack. 2019. Marine mammal noise exposure criteria: updated scientific recommendations for residual hearing effects. Aquat. Mamm. 45: 125-232. DOI 10.1578/AM.45.2.2019.125

Statistics Canada. 2012. Census profiles, 2011 census. Statistics Canada Catalogue no. 98-316-XWE. Ottawa. Released October 24, 2012.

Statistics Canada. 2017. Census profiles, 2016 census. Statistics Canada Catalogue no. 98-316-X2016001. Ottawa. Released February 28, 2017.

Stewart, D.B., and D.G. Barber. 2010. The ocean-sea ice-atmosphere system of the Hudson Bay complex. Pages 1-38 in S.H. Ferguson, L.L. Loseto, and M.L. Mallory (eds.), A Little Less Arctic: Top Predators in the World's Largest Northern Inland Sea, Hudson Bay. Springer Science and Business Media.

Stewart, D.B., and A.L. Hamilton. 2007. Outcomes of the Community Environmental Monitoring Systems (CEMS) Workshop at Sanikiluaq, Nunavut, 22-26 January 2007. Prepared by Arctic Biological Consultants, Winnipeg for the Municipality of Sanikiluaq, Nunavut. iv + 26 p.

Stewart, D.B., and K.L. Howland. 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 +92 p.

Stewart, D.B., R.A. Ratynski, L.M.J. Bernier, and D.J. Ramsey. 1993. A fishery development strategy for the Canadian Beaufort Sea–Amundsen Gulf area. Can. Tech. Rep. Fish. Aquat. Sci. 1910: vi + 127 p.

Stewart, D.B., J.W. Higdon, R.R. Reeves, and R.E.A. Stewart. 2014. Catch history for Atlantic Walrus (*Odobenus rosmarus rosmarus*) in the eastern Canadian Arctic. NAMMCO Scientific Publication 9: 219-313.

Stewart, D.B., Higdon, J.W., and Stewart, R.E.A. 2020. Threats and effects pathways of shipping related to non-renewable resource developments on Atlantic walruses (*Odobenus rosmarus rosmarus*) in Hudson Strait and Foxe Basin, Nunavut. Can. Tech. Rep. Fish. Aquat. Sci. 3283: x + 59 p.

Stewart, E.J., S.E.L. Howell, D. Draper, J. Yackel, and A. Tivy. 2007. Sea ice in Canada's Arctic: implications for cruise tourism. Arctic 60(4): 370-380.

Stewart, E.J., A. Tivy, S.E.L. Howell, J. Dawson, and D. Draper. 2010. Cruise tourism and sea ice in Canada's Hudson Bay region. Arctic 63(1): 57-66.

Stewart, R.E.A. 2002. Review of Atlantic Walrus (*Odobenus rosmarus rosmarus*) in Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2002/091: 20 pp.

Stewart, R.E.A. 2008a. Refining Walrus stocks in Canada. Arctic 61(3): 292-308.

Stewart, R.E.A. 2008b. Can we calculate Total Allowable Harvests for walrus using Potential Biological Removal? DFO Canadian Science Advisory Secretariat Research Document 2008/025. 1-13 p.

Stewart, R.E.A., and Hamilton, J.W. 2013. Estimating total allowable removals for walrus (*Odobenus rosmarus rosmarus*) in Nunavut using the potential biological removal approach. DFO DFO Canadian Science Advisory Secretariat Research Document 2013/031. iii + 12 p.

Stewart, R.E.A., P.R. Richard, and B.E. Stewart (ed). 1993. Report of the 2nd Walrus International Technical and Scientific (WITS) Workshop, 11–15 January 1993, Winnipeg, Manitoba, Canada. Can. Tech. Rep. Fish. Aquat. Sci. 1940: viii + 91 pp.

Stewart, R.E.A., P.M. Outridge, and R.A. Stern. 2003. Walrus life-history movements reconstructed from lead isotopes in annual layers of teeth. Marine Mammal Science 19: 806–818.

Stewart, R.E.A., V. Lesage, J.W. Lawson, H. Cleator, and K.A. Martin. 2012. Science Technical Review of the draft Environmental Impact Statement (EIS) for Baffinland's Mary River Project. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/086. vi + 62 p.

Stewart, R.E.A., J.W. Hamilton, and J.B. Dunn. 2013. Results of Foxe Basin Walrus (*Odobenus rosmarus rosmarus*) surveys: 2010-2011. DFO Canadian Science Advisory Secretariat Research Document 2013/017: iv + 12 pp. (Erratum: February 2014)

Stewart, R.E.A., D.B. Stewart, and J.W. Higdon. 2017. Report of the 2016 workshop to inform the DFO five-year research plan for Atlantic walruses in Canada. Can. Tech. Rep. Fish. Aquat. Sci. 3200: vi + 90 p.

Stirling, I., Parkinson, C., 2006. Possible effects of climate warming on selected populations of polar bears (*Ursus maritimus*) in the Canadian Arctic. Arctic 59(3): 261-275.

Tedesco, L., M. Vichi, and E. Scoccimarro. 2019. Sea-ice algal phenology in a warmer Arctic. Science Advances 5(5): eaav4830.

The PEW Charitable Trusts. 2016. The Integrated Arctic Corridors Framework: Planning for responsible shipping in Canada's Arctic waters. Oceans North Canada, The Pew Charitable Trusts. iii + 33 pp.

Thiemann, G.W., S.J. Iverson, and I. Stirling. 2008. Polar bear diets and Arctic marine food webs: insights from fatty acid analysis. Ecological Monographs 78(4): 591–613.

Tivy, A., S.E.L. Howell, B. Alt, S. McCourt, R. Chagnon, G. Crocker et al. 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.: Oceans 116: C03007.

Tremblay, C., J. Runge, and L. Legendre. 1989. Grazing and sedimentation of ice algae during and immediately after a bloom at the ice–water interface. Marine Ecology Progress Series 56: 291-300.

Trent University and Makivik Corporation. 2015. Using Nunavimmiut Knowledge and Science to study Walrus in Nunavik, Final Report (2013-2015) Inukjuak. Report prepared by L. Martinez-Levasseur, C. Furgal, G. Burness, B. Doidge, M. Simard, and the communities of Inukjuak, Ivujivik, Quaqtaq, Kangiqsualujjuaq, Nunavik, QC. 11 pp.

USFWS (United States Fish and Wildlife Service). 2019. How to avoid disturbance of Pacific walruses in Bristol Bay – guidelines for mariners. Online: https://www.fws.gov/r7/fisheries/mmm/walrus/pdf/guidelinesmariners.pdf [Accessed March 2020].

USFWS (United States Fish and Wildlife Service). 2020. Approach and viewing guidelines for Pacific walrus. Online: https://www.fws.gov/alaska/pages/marine-mammals/pacific-walrus/approach-viewing-guidelines [Accessed March 2020].

Vigliotti, M. 2019. Trudeau government expands moratorium on oil and gas work in arctic waters. Published on Aug 8, 2019 4:50 PM. iPolitics. Online: https://ipolitics.ca/2019/08/08/trudeau-government-expands-moratorium-on-oil-and-gas-work-in-arctic-waters/ [Accessed December 2020].

Wade, P. 1998. Calculating limits to the allowable human-caused mortality of cetaceans and pinnipeds. Mar. Mamm. Sci. 14(1): 1-37.

Wagemann, R. and R.E.A. Stewart. 1994. Concentrations of heavy metals and selenium in tissues and some foods of Walrus (*Odobenus rosmarus rosmarus*) from the eastern Canadian Arctic and sub-Arctic, and associations between metals, age, and gender. Can. J. Fish. Aquat. Sci. 51: 426-436.

Wagemann, R., W.L. Lockhart, H. Welch, and S. Innes. 1995. Arctic marine mammals as integrators and indicators of mercury in the arctic. Water Air Soil Poll. 80: 683-693.

Weiss, E.W., and R.P. Morrill. 2014. Walrus Islands State Game Sanctuary annual management report 2013. Alaska Department of Fish and Game, Special Areas Management Report ADF&G/DWC/SAMR-2014-2, Anchorage, AK. iv + 86 p.

Weiss, E.W., and R.P. Morrill. 2017. Walrus Islands State Game Sanctuary annual management report 2016. Alaska Department of Fish and Game, Special Areas Management Report ADF&G/DWC/SAMR-2017-4, Juneau, AK. v + 156 p.

Weiss, E.W., and S.K. Sell. 2013. Walrus Islands State Game Sanctuary annual management report 2012. Alaska Department of Fish and Game, Special Areas Management Report ADF&G/DWC/SAMR-2013-1, Juneau, AK. vi +99 p.

Welland, T. 1976. Inuit land use in Keewatin District and Southampton Island. In: M.M.R. Freeman (ed.) Inuit Land Use and Occupancy Project, Volume 1, pp 83-114. Milton Freeman Research Limited for the Department of Indian and Northern Affairs, Ottawa, ON.

Wiig, Ø., E.W. Born, and R.E.A. Stewart. 2014. Management of Atlantic walrus (*Odobenus rosmarus rosmarus*) in the arctic Atlantic. NAMMCO Scientific Publications 9: 315-342.