3.6 Marine Mammals

R.H. Meehan[1], S. Belikov[2], G. Desportes[3], S.H. Ferguson[4], K.M. Kovacs[5], K.L. Laidre[6], G.B. Stenson[4], P.O. Thomas[3], F. Ugarte[6] and D. Vongraven[5]

[1] ArcticTurn Consulting, U.S., [2] All Russian Research Institute for Nature Protection, Russia,[3] Marine Mammal Commission, U.S., [4] Fisheries and Oceans Canada, Canada, [5] Norwegian Polar Institute, Norway, [6] Greenland Institute of Natural Resources, Greenland

Snapshot

- Marine mammals are top predators in Arctic marine ecosystems.
- Many Arctic marine mammal species are important resources and hold special cultural significance for traditional and local communities
- In a warmer Arctic, endemic marine mammal species face extreme levels of habitat change, which is expected to result in dramatic reductions in sea ice dependent species.
- Extirpations of some marine mammal stocks are likely.
- The effects of climate change are expected to be exacerbated by increasing oil and gas exploration and production, marine mining, commercial fisheries, tourism, pollution, noise and shipping, which in combination can profoundly impact marine mammal populations and disrupt complex ecological relationships.
- Changes underway are affecting marine mammal behaviour, abundance, growth rates, body condition and reproduction, impacting the resilience of marine mammal populations with concomitant effects on the people who rely on them for subsistence, economic and cultural purposes.
- Interpretation of current population dynamics and trends has to take into account historical overharvest, which can mask the potential effects of climate change.
- Marine mammals are harvested in many regions, mostly under sustainable management regimes.
- Changing environmental conditions present new challenges to managing marine mammal populations.
- Effective marine mammal population monitoring will need improved techniques at appropriate geographic scales and detail to measure trends that can be evaluated relative to changes in climate (e.g., sea-ice cover) and human activities (e.g., hunting, shipping, mineral exploration)

3.6.1 Introduction

Sea ice declines across the circumpolar Arctic are the most visible and dramatic impact of climate change. Changes to this defining aspect of the environment will have transformative impacts on ice-associated Arctic marine mammals through direct habitat loss; and indirectly through 1) changes in prey species abundance and distribution; 2) increased levels of ocean noise due to increased ship traffic and industrial activities; 3) increased risks of disease; and, 4) alteration of predator-prey relationships (Kovacs et al. 2011, Laidre et al. 2015). Initially, five marine mammal species (walrus (*Odobenus rosmarus*), ringed seal (*Pusa hispida*) , beluga (*Delphinapterus leucas*), bowhead whale (*Balaena mysticetus*) and polar bear (*Ursus maritimus*)) were identified as Focal Ecosystem Components (FECs) in the Circumpolar Biodiversity Monitoring Program's (CBMP) *Arctic Marine Biodiversity Monitoring Plan* (*CBMP Marine Plan*; Gill et al. 2011) as they are of substantial value to Arctic residents. In further evaluating Arctic marine mammals that require sea ice for part, or all, of their life histories, the CBMP Marine Mammal Expert Network included an additional six species for a total of 11 species considered useful for evaluating changes in Arctic biodiversity (Moore and Huntington 2008, Gill et al. 2011, Kovacs et al. 2011, Laidre et al. 2015). These species are highly visible components of the Arctic ecosystems and also an integral part of Arctic subsistence culture. The seven selected species are: beluga, narwhal (*Monodon monoceros*), bowhead whale, the ice seals—ringed and bearded (*Erignathus barbatus*)—, walrus, and polar bear. Four of the selected species are sub-Arctic seals that breed on sea ice and spend part of the year deep into the Arctic: spotted seal (*Phoca largha*) and ribbon seal (*Phoca fasciata*) in the Bering Sea area (Burns 1981), and harp (*Phoca groenlandica*) and hooded seals (*Cystophora cristata*) in the North Atlantic area. These species are associated with sea ice and will be affected by sea ice loss to various degrees depending on regional conditions, individual species ecological requirements, and individual species or stocks historic status. These 11 species, and the aspects related to them, are discussed in this chapter. Marine mammals that are present in the Arctic, but not endemic, are not considered here.

Marine mammals associated with sea ice in the Arctic use all types of ice: glacier ice, multi-year ice, landfast ice and free-floating pack ice. Of all ice types, loose seasonal pack ice is the most important as it serves as habitat for all 11 species (Laidre et al. 2008, Eamer et al. 2013). Seasonally formed annual ice provides breeding habitat for pinnipeds, serving as an essential platform for birthing and pup rearing activities as well as a substrate for energy-efficient moulting platform (Feltz and Fay 1966). Most Arctic and sub-Arctic pinnipeds use sea ice (when available) throughout the year. Polar bear depend upon sea ice for travel and access to ice-associated seals, and generally fast when on land during ice-free periods. Polar bear mainly den on land but also den on sea ice in the Southern Beaufort Sea. Sea ice denning has decreased, however, as ice cover has seasonally diminished (Fishbach et al. 2007, Durner 2015). Sea ice provides a sheltered environment for whales and their calves, which is likely important protection against storms. Sea ice also provides protection from predators (killer whale (*Orcinus orca*)) and competitors of Arctic whales.

Ice seals and whales forage in ice-covered waters, as do polar bear, and are part of an ice-linked food web (Eamer et al. 2013). Seals and whales consume both fish and invertebrate prey, often focusing on Arctic endemic species such as polar


Beluga.
Photo: Vicki Beaver, NOAA


Narwhal.
Photo: Magnus Andersen, Norwegian Polar Institute


Bowhead whale.
Photo: Vicki Beaver, NOAA


Ringed seal.
Photo: Fernando Ugarte


Bearded Seal.
Photo: Allan Hopkins/Flickr.com


Ribbon seal.
Photo: Michael Cameron, NOAA


Harp seal.
Photo: Vladimir Melnik/Shutterstock.com


Hooded seal.
Photo: Aqqa Rosing-Asvid/ILoveGreenland.com


Spotted seal.
Photo: Jay Verhoef, NOAA


Walrus.
Photo: Vladimir Melnik/Shutterstock.com


Polar bear.
Photo: Kit M. Kovacs and Christian Lydersen, Norwegian Polar Institute

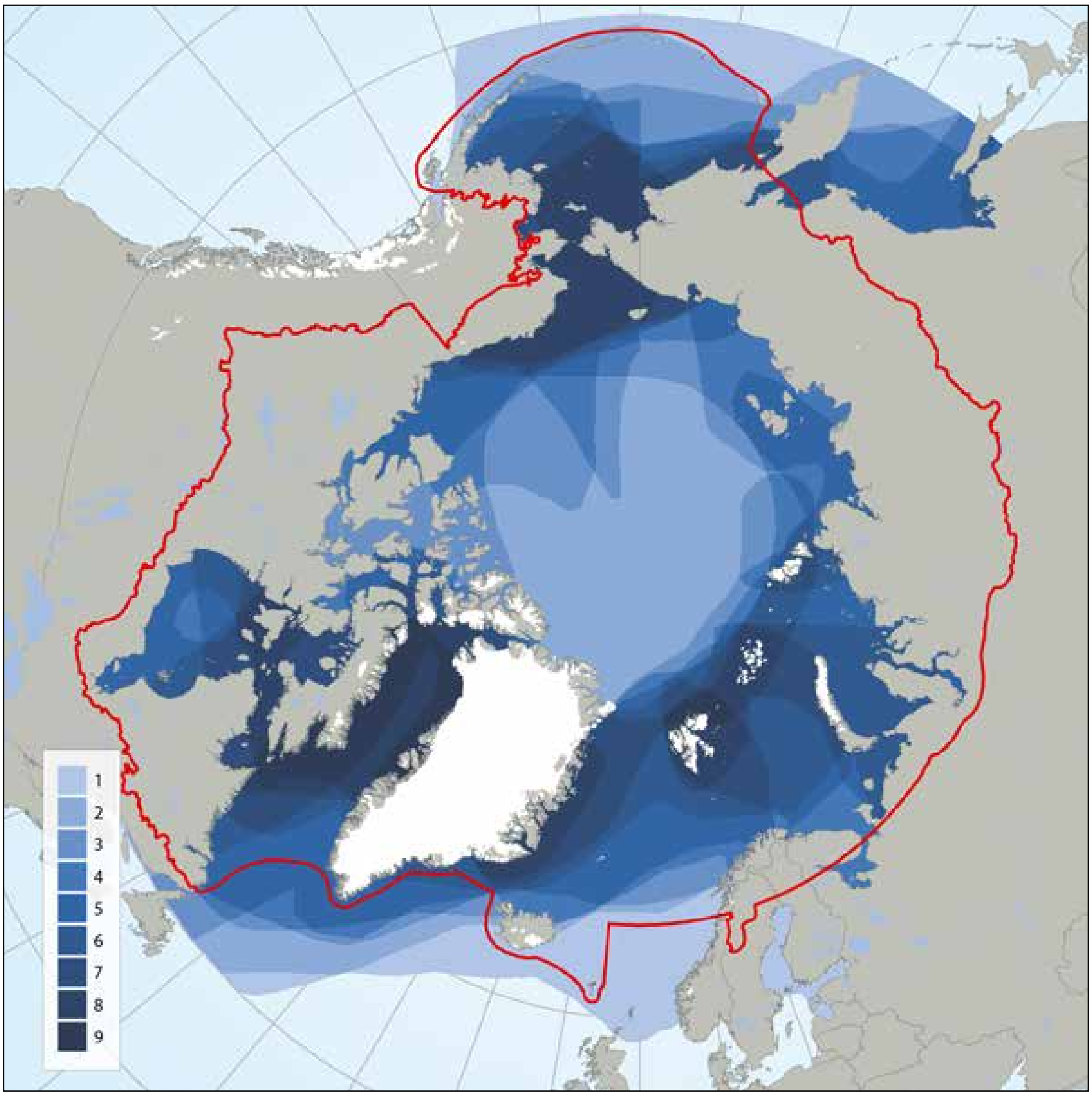


Figure 3.6.1. Circumpolar depiction of species richness based on the distributions of the 11 ice-associated Focal Ecosystem Components (according to the distributions reported in IUCN Red List species accounts). A maximum of nine species occur in any one geographic location. The Arctic gateways in both the Atlantic and Pacific regions have the highest species diversity.

cod (*Boreogadus saida*) and Arctic cod (*Arctogadus glacialis*) and fat-rich *Calanus* copepods and krill (euphausiids), while polar bear feed primarily on seals. Changes in sea ice dynamics affect distribution and timing of primary production, with subsequent effects throughout the food web (Eamer et al. 2013). Changes documented on a regional basis include increased benthic productivity in the Barents Sea (Cochrane et al. 2009) and a complex suite of changes in the northern Bering and Chukchi Seas highlighted by northward shifts in primary productivity and changes in benthic species composition (Grebmeier 2012). Marine mammal responses to changing ice conditions similarly differ by region. Ringed seal body condition and reproductive rate has declined in Hudson Bay and in the Eastern Beaufort Sea (Chambellant et al. 2012, Harwood et al. 2012). In contrast, analyses of ringed and bearded seals off Alaska (Chukchi and western Beaufort Seas), taken in subsistence harvests (2003-2012 compared with 1975-84), documented dietary changes along with increased blubber thickness and earlier female maturation indicating a positive effect to the population (Crawford et al. 2015). Ringed seal are foraging generalists and may be able to adapt to a changing suite of prey, but may be affected by other factors. Understanding characteristics of sea ice use by individual species and populations and tracking responses to changes in ice conditions will be important in determining the significance of environmental changes to ice-affiliated marine mammals and to the human communities.

Population dynamics of many Arctic marine mammal species are also driven by past and present harvests (Laidre et al. 2015). Such dynamics can mask the potential effects of climate change; therefore, it is important to understand the history of exploitation. High historic levels of take depleted a number of marine mammal populations. For some species, such as bowhead whale (George et al. 2015), harp seal (Stenson et al. 2016), and Atlantic walrus (Kovacs et al. 2015), reductions in harvest levels have allowed populations to increase. In other cases, such as the Greenland Sea hooded seal, there is no sign of recovery from a severe harvest-induced decline even decades after catch levels have been reduced (Øigård et al. 2014). Harvest history must therefore be considered in analyses of population trends and effects of various drivers including climate change.

Box 3.6.1 Greenland hooded seals

Greenland Sea hooded seal has been commercially exploited for centuries (ICES 2016). Catches increased substantially after the 1920s and following World War Two to such a high level that regulatory measures were brought in to reduce effort. Eventually, catches declined and quotas were imposed beginning in 1971. It was assumed that with reduced catches, the population would increase. No successful surveys were conducted until 2005, at which time the population was much lower than expected. Consequently, the population has been fully protected from commercial harvesting since 2007. A recent assessment estimates that Greenland Sea hooded seal decreased from approximately one million seals in the late 1940s to approximately 84,000 in 2013 (Øigård et al. 2014). The main decline occurred before 1980 and is thought to have been driven primarily by harvest (Øigård et al. 2014). No statistically significant change in abundance has occurred between aerial surveys conducted in 2005 and 2012, but modelling suggests that the population may still be decreasing slightly even in the absence of hunting (Øigård et al. 2014). Only small scientific catches have been allowed from the population since 2007 (a total of 515 pups and 268 adults over the period 2007-2014) and Greenland hunters take few hooded seals from this population. Hooded seal are not exhibiting the expected density dependent compensation (e.g. increased reproductive rates, lower mortality) that normally occurs when populations are low compared to available resources. Clearly, some other factors such as food shortages, predation levels or disease, have become important in controlling the population's trajectory. Recent studies document increased predation on harp and hooded seals by East Greenland polar bear, which may be mediated by the reduced distance from the Greenlandic coast to the pack ice edge (McKinney et al. 2013). This has likely affected survival rates of both harp and hooded seals in the area. Morphometric data collected over the period from the 1950s through to the present show reduced length-at-age and body condition of female hooded seals from the Greenland Sea compared to the highest levels observed for Northwest Atlantic hooded seals. Particularly poor conditions seem to have prevailed in the 1980s and 1990s, prior to the recent severe decline in ice cover in the Greenland Sea, and may be more related to competition with commercial fisheries (Anne Kirstine Frie, Institute of Marine Research, Norway, unpubl. data.).

Marine mammal biodiversity— if described as a simple tally of species present—masks the impact of climate driven changes on endemic Arctic species. Using a simple tally, biodiversity in the Arctic may increase as temperate species move into the area with shifting ice and warming conditions. Their arrival may further stress Arctic endemic species already faced with changing physical and ecological conditions. The cumulative and synergistic effects of multiple stressors associated with the changing environment and additional competition as temperate species move northward may become significant challenges for ice-dependent marine mammal species (Moore et al. 2014). The selection of ice-dependent and ice-adapted species as a focal group in CBMP reflects the importance of evaluating changes in biodiversity of Arctic marine ecosystems.

The efforts to track and understand trends in population status in each of the marine mammal FECs will provide insights into their responses to ecosystem changes and, ultimately changes in Arctic biodiversity. Population status may be defined as both population abundance measured by counts, or as population level relative to carrying capacity inferred from demographic parameters and/or condition indices (Gill et al. 2011). Responses will vary by species, population and region (Moore and Huntington 2008). Endemic Arctic species range across jurisdictional boundaries and their responses to environmental change, whether in distribution, behaviour, abundance, or other factors, will result in new conservation and management challenges. To address these challenges, current population and distribution information is essential, and represents basic information needed by those charged with marine mammal management. It is essential to provide the resources for such monitoring and that management-relevant information be collected and disseminated widely.

3.6.2. Current monitoring

Monitoring is necessary to assess population trends and status and the effect of environmental changes and anthropogenic activities, to support informed management. Assessing trends, which are important indicators of population status, requires knowledge of stock structure, abundance data over many years or demographic analysis of vital rates (e.g., reproduction and survival) and statistics of direct and indirect human-caused mortality (e.g., catch, bycatch, ship strikes). These parameters are available for relatively few populations of marine mammals (Laidre et al. 2015).

Tracking animals in space and time provides data on connectivity among groups and populations as well as raw distributional information. Photographic ID catalogues are useful for species with individual markings and are maintained for several whale species. The purpose of identity catalogues is to track individuals and provide information on movements and abundance; examples include bowhead whales in the Bering-Chukchi-Beaufort Seas, killer whales in Canada, humpback whales (*Megaptera novaeangliae*) in the North Atlantic and in the North Pacific. Satellite telemetry is broadly applicable and used on a variety of species. Telemetry studies can provide vital information about stock structure and seasonal movements as well as baseline data useful for comparisons of changes in distribution over time and for comparisons of changes in activity budgets and other parameters with changing environmental situations. An example is the telemetry studies of ringed seals in Svalbard, which show how changes in ice conditions have influenced foraging behaviour of a strongly ice-associated seal (Hamilton et al. 2015, 2016). Further examples include studies that used telemetry linked changes in ice conditions to observed reductions in reproductive rates of Northwest

Atlantic harp seals (Stenson et al. 2016) and body condition declines of Barents Sea harp seals (Bogstad et al. 2015).

Similar to mammalian status assessments elsewhere (e.g. IUCN Red List for Mammals), a key parameter used for determining the status of marine mammals in the Arctic is the estimate of abundance. The most common abundance estimation method for marine mammals is visual and/or photographic aerial surveys of the entire population or the visible component (e.g., pups). Generally, survey estimates must be corrected for animals missed by the observer (perception bias) or animals that may not be present to be counted (availability bias, e.g., whales that are below the surface). If only a component of the population is surveyed, total abundance is estimated using a population model that incorporates additional data such as reproductive rates and/or survival rates, pregnancy rates or other population parameters. Mark-recapture studies use individual identification (appearance, tags, or genetic sequencing) to mark part of the population and then the proportion of marked animals subsequently re-sighted is used to estimate the total population. Passive acoustic monitoring devices are increasingly in use, often within area-based arrays to get an index of abundance. These devices also permit the assessment of changes in phenology (timing of events), such as breeding or migration, if the devices are maintained over periods of decades and in some cases can identify potential sub-stock structure in whale populations (e.g., Delarue et al. 2009).
To determine population trends, surveys must be repeated over time, though the level of variation around estimates often precludes trend estimation. Multiple estimates can be used to evaluate trends in the whole population using a population model, or used simply as an index of change in abundance. Given the large ranges of many species, expense of ships and aircraft, and challenging climatic conditions in the Arctic, surveys of most stocks are only carried out sporadically and time-series data for most stocks are limited (Laidre et al. 2015).

Population surveys for the 11 FECs are generally conducted by or for resource management agencies at the national level or as a cooperative effort between jurisdictions (e.g., North Atlantic Sightings Survey (NASS)). In Canada, Fisheries and Oceans Canada is responsible for assessing stock status for whales and seals in the Arctic while Environment and Climate Change Canada and provincial and territorial and provincial governments conduct surveys and research on polar bears. In the U.S., the U.S. Fish and Wildlife Service (USFWS; walrus and polar bear) and the National Marine Fisheries Service (ice seals and whales) are responsible for monitoring the status of marine mammals. In Greenland, the Institute of Natural Resources (GINR) oversees marine mammal stock monitoring. GINR provides the Greenland Self Rule with advice on sustainable exploitation of living resources and safeguarding of the environment and biodiversity. In Norway, the Norwegian Polar Institute (NPI) is responsible for monitoring most Arctic endemic marine mammals, except for harp and hooded seal, which are the responsibility of the Institute of Marine Research. NPI acts as scientific and strategic adviser to the Norwegian government in polar issues. Marine mammal monitoring in Russia is conducted by regional research and management agencies and studies on protected areas (parks and nature reserves) are the responsibility of the protected area managers.
Stock assessments are carried out at national, bilateral (Inuvialuit/Inupiat Agreement; Canada/U.S. Agreement; and Canada-Nunavut-Greenland Memorandum of Understanding for polar bear; Joint Commission on Narwhal and Beluga between Canada and Greenland; U.S.-Russia assessment of shared populations of walrus, ice seals and polar bears in the Bering/Chukchi Sea region; Norway and Russia cooperation to assess status of shared marine mammal populations, such as polar bear), regional (i.e., North Atlantic Marine Mammal Commission (NAMMCO), or international levels (International Whaling Commission (IWC), International Union for the Conservation of Nature (IUCN) Polar Bear Specialist Group (PBSG)). These international efforts are key in setting management parameters ultimately implemented by individual jurisdictions.

International cooperative efforts are critical for tracking scientific research and identifying issues of concern for shared stocks. NAMMCO consists of representatives from the Faroe Islands, Greenland, Iceland and Norway and was formed to cooperate on the conservation, management and study of marine mammals in the North Atlantic. Under the *1973 Agreement on the Conservation of Polar Bears* the Polar Bear Range States are implementing a Circumpolar Action Plan for Polar Bear (Polar Bear Range States 2015). One focus of this work is to help coordinate and improve monitoring and research efforts for polar bear. Under the umbrella of the IUCN PBSG tracks and evaluates polar bear population status and trends throughout the circumpolar region. The IWC evaluates whale populations and is responsible for setting harvest limits for bowhead whales. These international efforts are key in setting management parameters and identifying information needs that are ultimately implemented by individual jurisdictions.

Harvested animals are another important data source (Harwood et al. 2015). Arctic and sub-Arctic marine mammals, which are an important resource for northern people (Hovelsrud et al. 2008), are harvested for both subsistence and commercial purposes. Most harvests are monitored and some operate with allocated quotas. The availability of subsistence harvest samples provides an opportunity, in collaboration with communities, to obtain a suite of metrics (e.g., age at maturity, pregnancy rate, growth rate, body condition, pollution and contaminant loads) that could serve as broader ecological indicators.

Monitoring of community subsistence hunts of marine mammals is conducted throughout the Canadian Arctic sporadically, with about one-third of the communities participating in general, and the extent of sampling varies with the region (Inuvialuit settlement region, Nunavut, Nunavik, Nunatsiavut). Monitoring of polar bear subsistence harvest is conducted through the whole Canadian Arctic with the exception of Quebec where a monitoring program is being developed through a co-management process. For all marine mammal subsistence harvest monitoring, tissue samples and harvest information are collected for genetics, disease, body condition, contaminants, reproduction, feeding ecology, and stress with collaborations at a number of universities. The longest monitoring programs exist for ringed seal, beluga, and polar bear. Fisheries and Oceans Canada, in partnership with regional Inuit co-management groups, collects national harvest statistics for walrus, whales, and seals. The provincial and territorial governments collect harvest information for polar bears in collaboration with Inuit. In the U.S., harvest information is collected by the USFWS and through collaborative efforts with marine mammal co-management groups, communities, and the Alaska Department of Fish and Game, U.S. In Greenland, catch data are collected and administrated by the Ministry of Fisheries and Hunting. Catches of species not regulated by quotas, including seals, are reported on a form that hunters have to send to the government in order to renew their hunting permit. Catches of species harvested according to quotas (narwhal, beluga, walrus, polar bear and large whales) are reported in more detailed special forms, which include, for each catch, date and position, information about the hunting method and time to death and biological data such as age class, gender, size, reproductive state and stomach contents.

Marine mammal studies can benefit from Traditional Knowledge (TK), which provides a long-term and detailed wealth of information and understanding of wildlife and resources upon which communities depend. Sources are not necessarily marine mammal specific, such as a general overview of TK possessed by the Chukotkan peoples (Bogoslovskaya and Krupnik 2014) that provides insights on local patterns and environmental changes over time. Another localized study around Diomede Island in the Bering Straits region details currents and regional anomalies around the island that affect, among other things, marine mammal distribution (Social Science Program 2014). Other studies are species specific, such as the Final Report of the Inuit Bowhead Knowledge Study (Hay 2000). Studies repeated over time, such as polar bear habitat use studies in the Chukchi and Bering Straits region (Kalxdorff 1997, Kochnev et al. 2003, Voorhees et al. 2014) document local knowledge in a changing environment. Community based sampling programs provide biological parameters for ringed and bearded seal research in the Canadian Arctic (Harwood et al. 2012). Subsistence harvests provide another important source of information, both from hunters' knowledge of the animals and their environment and from samples taken from harvested animals (e.g., Laidre et al. 2015). Community participation in conservation efforts, co-management of harvest monitoring, inclusion of TK in identification of research priorities, and direct local involvement in scientific sampling are ways to continue access to this important source of information and expertise.

In some cases, TK holders provide important insights on data utility and limitations. For example, in Alaska, the Ice Seal Committee, a co-management group supported by the National Marine Fisheries Service, supported a compilation of historic ice seal harvest information and identified both the strengths and limitations of the information. Data on harvest by village from 1960-2012 demonstrate the importance of seal harvest as a subsistence resource throughout the region. Extrapolation of the data is limited, however, as most information was collected as part of household surveys conducted intermittently in different villages. As a result, the data are insufficient to measure changes in harvest patterns across villages, regions or years (Ice Seal Committee 2014)

Monitoring polar bear in Greenland. Photo: Fernando Ugarte

3.6.3. Status and trends of FECs

The CBMP Marine Mammals Expert Network updated the estimates and abundance table developed in Laidre et al. (2015) and new information on status and harvest was added. The table includes the initial five FECs (beluga, bowhead whale, walrus, ringed seal and polar bear), as well as an additional six species we identified as important for tracking ecosystem changes (narwhal and bearded, spotted, ribbon, harp and hooded seals). The eight Arctic Marine Areas (AMAs) referred to in our table are as defined by the CBMP (Gill et al. 2011). These areas differ slightly from those used in Laidre et al. (2015), who described 12 geographic regions that extend further south in the Pacific (including the southern Bering Sea and the Sea of Okhotsk) and identified the Chukchi Sea, Baffin Bay, Labrador Sea, Greenland Sea and Barents Seas as distinct regions and did not include the central Arctic Basin. Notable population updates include new estimates for narwhal, beluga, walrus and polar bear in some regions.

Nearly all stocks are harvested, primarily for subsistence. One stock, belugas in Southwest Greenland, was extirpated in the first half of the twentieth century (Heide-Jørgensen and Laidre 2006). Of the 83 remaining stocks, only 11 are not subject to harvest, and six of these are in the Atlantic Arctic. Many harvests are managed within a quota system; of the 73 harvested populations, 39 (or 54%) are harvested with quotas throughout their entire range. The majority of harvested populations in Canadian and Greenlandic waters are taken under a quota system. In Canada, most hunts are by quotas (beluga, narwhal, bowhead whale, walrus and polar bear) and more detailed harvest information is collected periodically. In Greenland harp, hooded, ringed, and bearded seals are not under quotas, while walrus, beluga, narwhal, bowhead, and polar bear are. All the protected stocks are in Norway, Russia or the Arctic Basin, while all stocks in Alaska, Arctic Canada and Greenland are harvested.

With the exception of bowhead whale and polar bear, formal quotas do not limit marine mammal harvest in the U.S.; however, the harvest must be non-wasteful and it must be conducted for subsistence and cultural purposes. Harvesting occurs across the Arctic although to a lesser extent along the coastline of northern Russia (Kara and Laptev Seas) and off Norway. The majority of the protected (not harvested) stocks are in the Barents Sea region, off the coast of Norway.

Trend information remains elusive for the ringed, bearded, ribbon and spotted seals and some polar bear populations, and is limited for beluga subpopulations outside the Atlantic Arctic region. More is known about other cetaceans, with a majority of narwhal subpopulations considered stable and most bowhead subpopulations considered to be increasing. The status and trends of harp and hooded seal populations are regularly documented (Hammill et al. 2015, Stenson et al. 2016). The status column in Table 3.6.1 incorporates information on exploitation history to facilitate the interpretation of temporal trends. Specifically, an increasing population may be the result of a positive reaction by the species to changing ecological conditions, e.g., increasing primary production resulting in increased prey abundance. Alternatively, and most commonly among Arctic marine mammals, a species that has been overharvested in the past may simply be increasing due to a cessation or regulation of harvest. While not definitive in sorting out details, the status information provides important context for evaluating trend information.

From a regional perspective, little abundance and trend information is available for the many populations that

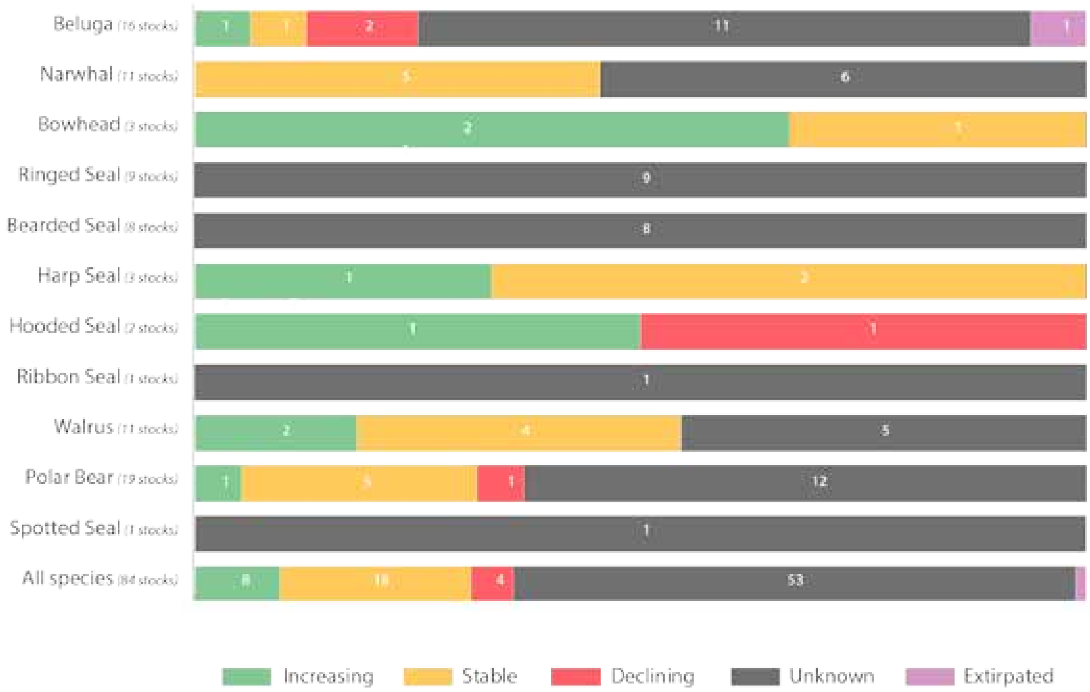


Figure 3.6.2. Trends in abundance of Arctic marine mammal Focal Ecosystem Components based on the most recent assessment for each recognized subpopulation of a species (red, declining trend; yellow, stable trend; green, increasing trend; grey, unknown trend). Number of subpopulations is given after species name. Each column is divided into equal segments, the sizes of which are not proportional to the size of the subpopulation. Ringed seal and bearded seal segments represent subspecies. Walrus segments represent subpopulations within subspecies. See Table 3.6.1 for details on abundance.

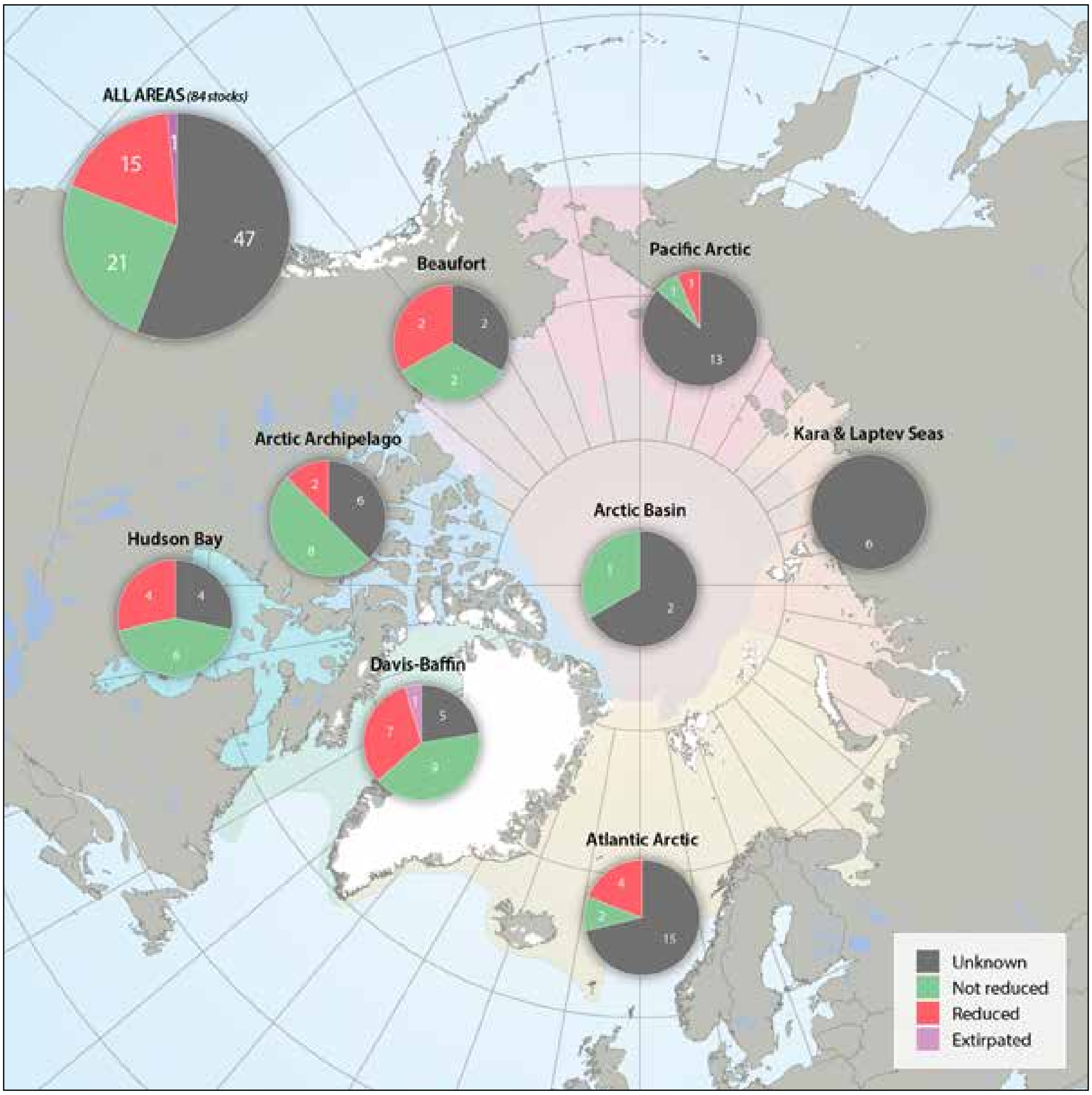


Figure 3.6.3 Status of marine mammal Focal Ecosystem Component stocks by Arctic Marine Area.

occupy the Pacific Arctic and Atlantic Arctic regions. Both areas include extensive open-ocean as compared with other regions that are comparatively more defined seas over continental shelves or within archipelagos. The Arctic Basin and adjacent Beaufort and Kara-Laptev regions have the lowest number of marine mammal populations and trend information is also limited in these regions.

Long-term population monitoring is important for the ability to detect changes in vital rates that can influence population dynamics and in some cases point to the main drivers of population change. For example, changes in harp seal abundance, growth rates, body condition and reproductive rates in Labrador and Newfoundland since the 1950s have been linked to changes in harvest levels and ice conditions (Stenson et al. 2016). Situated at the southern edge of the seasonal pack ice, the pupping areas of Northwest Atlantic harp (and hooded) seals have undergone significant warming, with concomitant sea ice losses, over the past four decades (Stenson and Hammill 2014). During the same period, the population has recovered from a low level due to management actions and reduced harvests (Hammill et al. 2015). Monitoring of reproductive rates since the 1950s has shown that pregnancy rates of mature females have declined while the interannual variability in the proportion of seals that are pregnant has increased (Stenson et al. 2016). These changes are associated with increased population size, and annual changes in mid-winter ice extent and prey abundance. The changes in ice extent likely reflect or even cause many concurrent ecosystem changes, including changes in food availability, notably for capelin the main forage fish in the area (Buren et al. 2014). In Barents Sea harp seals, body condition has declined during the past 10 years, when Barents Sea ice cover has been lower than in the late 1990s. This could be related to longer travel distances to the ice edge or changes in prey availability (Øigård et ak 2013). The latter may be partly due to increased competition from a historically large Atlantic cod stock, which has profited from the warming trend (Bogstad et al. 2015). Comparisons of swimming distances and dive behaviour in ringed seals off Svalbard before and after a major retreat of summer ice showed an increased foraging effort suggesting increased energetic costs of finding food associated with changes in ice conditions (Hamilton et al. 2015, 2016). The complexity inherent in interpreting Arctic marine mammal population status underscores the need for long-term monitoring as carrying capacity changes due to changing climatic conditions.

Distributional changes within polar bear populations have led to differing perceptions of population trends. Increasing interactions with polar bears in northern communities can

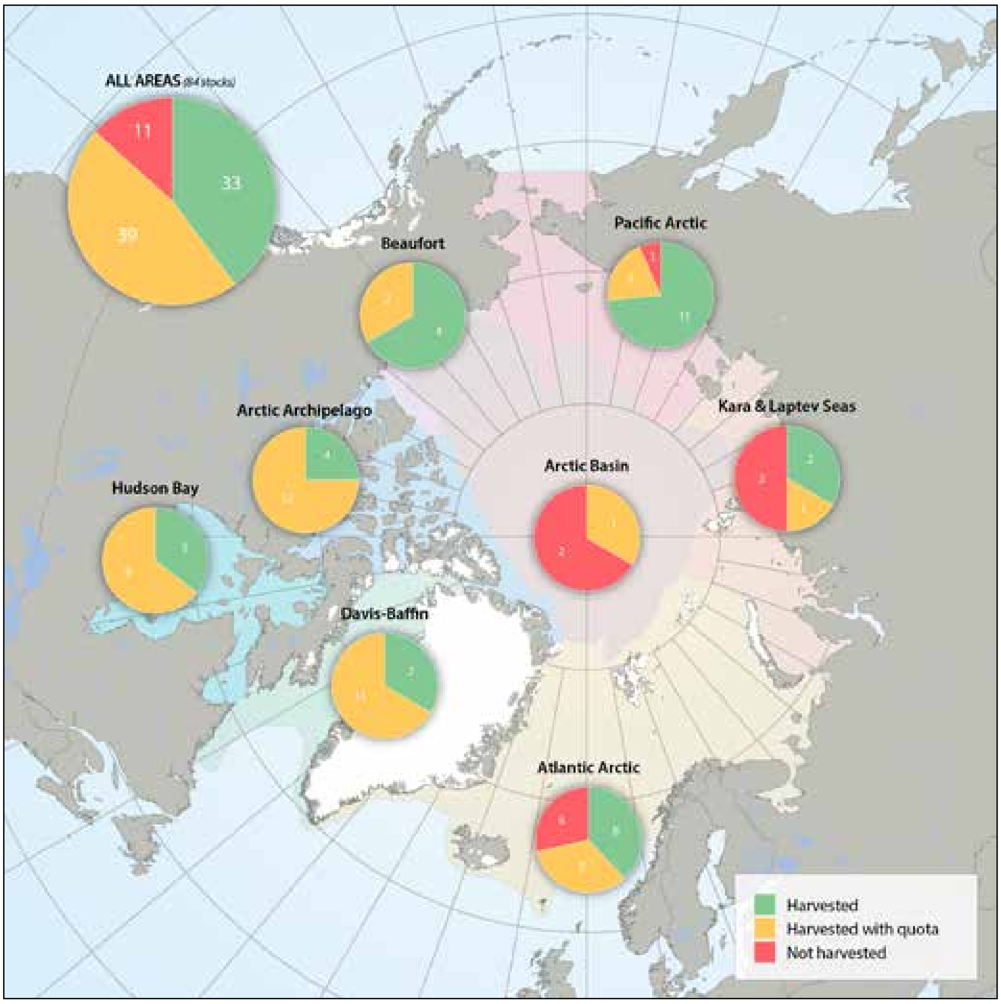


Figure 3.6.4. Harvest marine mammal Focal Ecosystem Component stocks in Arctic Marine Areas. Harvested without quotas, with quotas or not harvested.

be due to changes in population, but they may also be because of changes in distribution due to loss of sea ice. Understanding both the reality and perception of population status is critical to developing effective management strategies. While humans and polar bear have existed side by side in the Arctic for centuries, the frequency of conflicts between bears and humans has increased in parallel with sea ice reduction and increasing numbers of people residing in and visiting the Arctic (Derocher et al. 2004, Stirling and Parkinson 2006, Hovelsrud et al. 2008, Towns et al. 2009). The Polar Bear Range States have given this issue high priority, and began developing a database tool in 2009 to document interaction events throughout the range of polar bears and develop appropriate mitigation strategies (Polar Bear Range States 2015). However, this tool is not fully implemented. In Alaska, local residents and management agencies are working collaboratively to minimize human/polar bear conflicts. In oilfield developments along the Beaufort coast, industry activities are required to have formal polar bear management plans that include site design features that minimize polar bear attraction, polar bear guards, and spring den site surveys. In the Indigenous village of Kaktovik, where bears congregate in the autumn to feed on whale bones from the subsistence harvest, the village and the USFWS in collaboration with numerous partners implements and updates as needed comprehensive strategies to manage polar bear viewing opportunities, food storage, and village safety. As with other marine mammal's subject to subsistence hunt, a co-management group comprised of coastal village representatives in the range of polar bears was used to support ongoing partnerships to develop local management plans for villages along the Chukchi Sea coast.

In partnership with the World Wildlife Fund-Canada, the town of Arviat in Nunavut participated in a Human-Polar Bear Conflict Reduction Project. A polar bear guard was trained in deterrence techniques (spotlights and bear bangers) and in identifying and reducing bear attractants in the community (like garbage and poorly protected meat storage). In addition, electric fences were installed and steel bins were provided for meat storage. Over the three-year project the number of bears killed per year in Defense of Life and Property in Arviat dropped from eight to zero. In addition, the Polar Bear Alert Program (PBAP) in Churchill, Manitoba is well known for its effective approach to protect polar bears and humans. The town of Churchill lies on the western coast of Hudson Bay and is in the path of an annual travel route for polar bears that are traveling north to reach ice as it re-forms for the season. The PBAP has two tiers for protecting the bears and humans. When bears first approach the Churchill area they are chased away by Conservation Officers using a variety of deterrence techniques. If they return they are captured and put in a holding facility until the ice re-forms in the fall and they are released. This prevents bears from entering the city and becoming problem animals that need to be killed and protects residents from possible encounters.

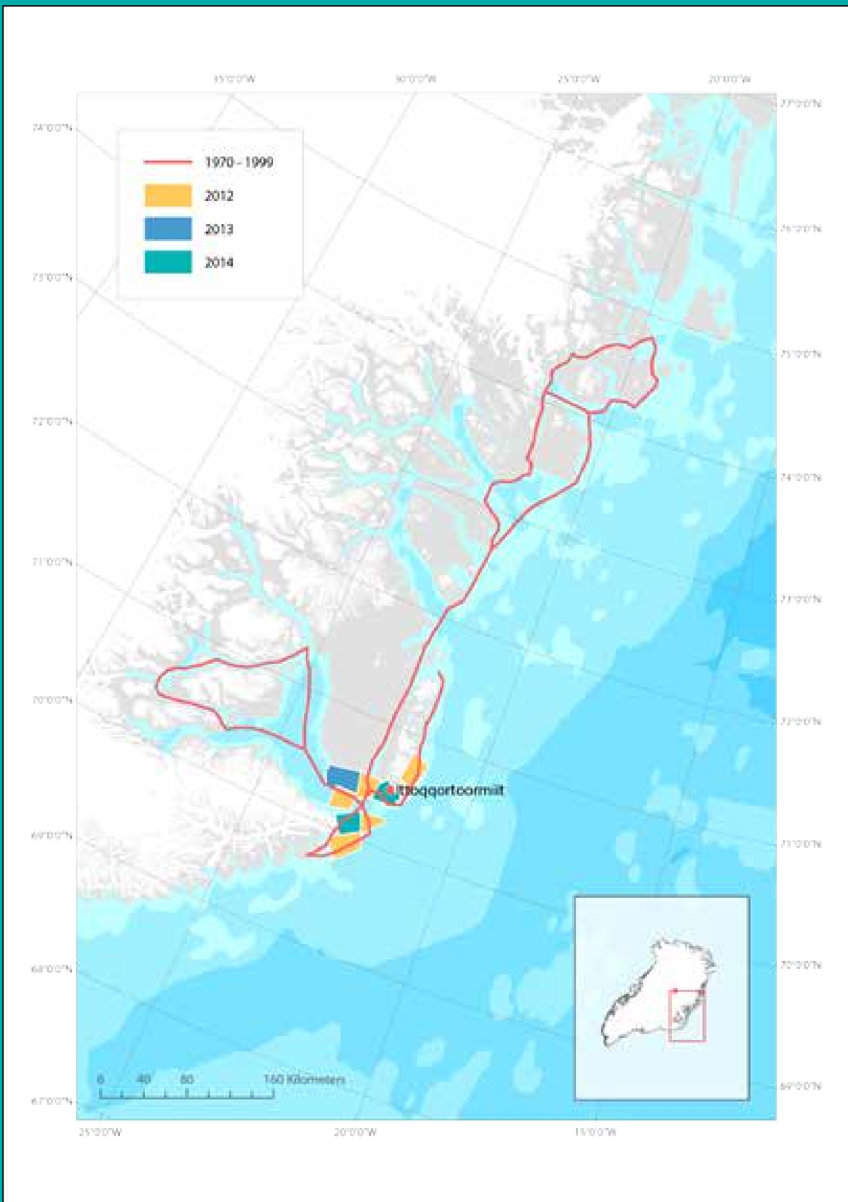
Box 3.6.2: Polar bear Traditional Knowledge

Traditional Knowledge (TK) contributes insights into polar bear condition and abundance, particularly in the face of rapidly changing sea ice environments. Extensive hunter interviews in the 1990s and early 2000s in the Chukchi and northern Bering Sea regions documented polar bear seasonal use and distribution around villages, and the importance of polar bears in Indigenous culture (Kalxdorff 1997, Kochnev et al. 2003). Since then, subsequent studies provide insight about how polar bears are faring in the face of rapid environmental changes, notably the loss of summer sea ice. The value of the information is in part due to the technical challenges of collecting baseline and updated information on polar bear, and in large part on the insights provided by hunters that live in and depend upon the same environment as polar bear. Similar studies to connect past and present knowledge to add insights to the effects of climate change on polar bear have been conducted in Canada (Kotierk 2010, Slavik 2012) and Greenland (Sandell et al. 2001, Born et al. 2010).

Hunters in all villages observed changes in distribution and timing of seasonal movements and in local abundance in recent years. Other important conclusions from these studies include observations on polar bear condition and diets. In general, bears were considered to be in good condition, even when stranded on land during the summer or late autumn. Bears were observed eating a variety of terrestrial foods indicating flexibility to deal with changing conditions. Despite this, hunters cautioned that the ultimate effect of sea ice loss is not clear and speculation on the future is avoided in St. Lawrence Island Yupik and Inupiaq cultures (Voorhees and Sparks 2012, Voorhees et al. 2014).

Inuit hunters from Greenland have experienced profound changes in their subsistence harvest of polar bear (Born et al. 2010). In the 1990s and before, sea ice conditions allowed for hunting trips in dog sledges over very long distances. It took several days to hunt a few polar bear, as bear densities were low. Since the 2000s, the season when the sea ice is safe for sledge travel is increasingly shorter, and the areas where transport over the ice is possible have been greatly reduced. As consequence, the number of polar bear harvested from skiffs, instead of dog sledges has increased. In addition, polar bears are now found closer to settlements. As a result, trips for hunting polar bear are much shorter than before. This change, coupled with the introduction of quotas in 2006, result in an increased presence of polar bear in areas inhabited by people and more bears killed to protect human lives.

TK and science are knowledge systems that for the most part complement each other, however, there are instances in which their conclusions differ. For example, information on polar bear population status and trends can be particularly difficult to reconcile due to variability in scope and methods (e.g., IUCN Polar Bear Specialist Group 2017, Polar Bear Technical Committee 2013). Progress has been made in the utilization of both knowledge systems in assessments, and efforts continue to determine the best path forward in using TK effectively in decision making.



Box figure 3.6.1. Routes used for hunting polar bear in Ittoqqoortoormiit, East Greenland before 1999 (red line), and in 2012 (yellow), 2013 (blue) and 2014 (green).

Table 3.6.1. Estimates of abundance (with associated estimate of uncertainty, if available), status - reduced versus not reduced, trend - increasing, stable, decreasing, and harvest regime – harvested (H), harvested with quotas (HQ) or protected (P) for subpopulations of Arctic marine mammals. The table is an update of table 1 in Laidre et al. (2015). Sources included dedicated surveys, population viability analyses, expert opinion.

Species	**Subpopulation/ Stock**	**CBMP Arctic Marine Area**	**Abundance** (with 95% confidence interval (CI) or coefficient of variation (CV) if available)	**Year**	**Status:** Unknown (U), Reduced (R) or Not Reduced (N)	**Trend:** Unknown(U), Increasing(I), Stable (S), Declining (D)	**Harvest:** harvested without quota (H), harvested with quota (HQ), currently protected (P)	**Survey/trend reference from Laidre et al. unless noted**
Beluga	East Siberian and West Chukchi Seas	Pacific Arctic	Unknown		Unknown	Unknown	HQ	
	Eastern Chukchi Sea	Pacific Arctic	3,700	1992	Unknown	Unknown	H	Frost et al 1993
	Eastern Beaufort Sea	Beaufort Sea	41,800	1999	Not Reduced	Unknown	H	Allen et al 2011
	Eastern Bering Sea	Pacific Arctic	18,000	1989-1991	Unknown	Unknown	H	Allen et al 2011
	Bristol Bay	Pacific Arctic	2,877	2005	Not Reduced	Increasing	H	Lowry et al 2008
	Western Hudson Bay	Hudson Bay	57,300 (95% CI 37,700-87,100)	2004	Not Reduced	Unknown	H	Richard 2005
	James Bay	Hudson Bay	14,967 (95% CI 8,316-26,939)	2011	Not Reduced	Unknown	H	Gosselin et al 2013
	Eastern Hudson Bay	Hudson Bay	3,351 (95% CI 1,552-7,855)	2011	Reduced	Stable	HQ	Gosselin et al 2013
	Ungava Bay	Hudson Bay	32 (95% CI 0 – 94)	2012	Reduced	Unknown	HQ	Doniol-Valcroze and Hammill 2012
	Cumberland Sound	Davis-Baffin	1,150 (CV = 0.214, 95% CI = 761–1744)	2014	Reduced	Declining	HQ	Marcoux et al. 2016
	East high Arctic and Baffin Bay	Arctic Archipelago	21,200 (CV 0.25)	1996	Reduced	Unknown	H (Canada), HQ (Greenland)	Innes et al 2002
	" - West Greenland Winter component"	*Davis-Baffin*	*9,072 (95% CI 4,895 - 16,450)*	*2012*	*Reduced*	*Stable*	*HQ*	*NAMMCO/JCNB 2015*
	"- NOW Polynya Winter component"	*Davis-Baffin*	*2,324 (95 % CI 1,786 - 2,820)*	*2014*	*Reduced*	*Unknown*	*HQ*	*NAMMCO / JCNB 2015*
	White Sea	Atlantic Arctic	6,498 (95% CI 4,664-8,818)	2008	Unknown	Declining	HQ	Glazov et al 2010
	Southwest Greenland winter	Davis-Baffin	0	ca 1930	Extirpated	Extirpated	Extirpated	Heide-Jørgenen and Laidre 2006
	Svalbard	Atlantic Arctic	Unknown		Unknown	Unknown	P	Gjertz and Wiig 1994
	Kara and Laptev Seas	Kara -Laptev Seas	Unknown		Unknown	Unknown	HQ	
	Gulf of Anadyr	Pacific Arctic	15,127 (95% CI 7447 -30741)	2006	Unknown	Unknown	HQ	Litovka 2013

Species	**Subpopulation/ Stock**	**CBMP Arctic Marine Area**	**Abundance** (with 95% confidence interval (CI) or coefficient of variation (CV) if available)	**Year**	**Status:** Unknown (U), Reduced (R) or Not Reduced (N)	**Trend:** Unknown(U), Increasing(I), Stable (S), Declining (D)	**Harvest:** harvested without quota (H), harvested with quota (HQ), currently protected (P)	**Survey/trend reference from Laidre et al. unless noted**
Narwhal	Eclipse Sound	Arctic Archipelago, Davis-Baffin	10,489 (CV 0.24)	2013	Unknown	Unknown	HQ	NAMMCO/JCNB 2015
	Admiralty Inlet	Arctic Archipelago, Davis-Baffin	35,043 (CV 0.42)	2013	Not Reduced	Stable	HQ	NAMMCO/JCNB 2015
	Somerset Island	Arctic Archipelago, Davis-Baffin	49,758 (CV 0.20)	2013	Not Reduced	Stable	HQ	NAMMCO/JCNB 2015
	Jones Sound	Arctic Archipelago, Davis-Baffin	12,694 (CV 0.33)	2013	Not Reduced	Unknown	HQ	NAMMCO/JCNB 2015
	Smith Sound	Arctic Archipelago, Davis-Baffin	16,360 (CV 0.65)	2013	Not Reduced	Unknown	HQ	NAMMCO/JCNB 2015
	East Baffin Island fjords	Davis-Baffin	17,555 (CV 0.35)	2013	Not Reduced	Stable	HQ	NAMMCO/JCNB 2015
	Northern Hudson Bay	Hudson Bay	12,485 (CV 0.26)	2011	Not Reduced	Unknown	HQ	Asselin et al 2012
	Inglefield Bredning, West Greenland	Davis-Baffin	8,368 (95% CI 5209-13,442)	2007	Reduced	Stable	HQ	NAMMCO/JCNB 2015
	Melville Bay, West Greenland	Davis-Baffin	3,091 (95% CI 1,228-7,783)	2014	Reduced	Stable	HQ	NAMMCO / JCNB 2015
	"- West Greenland winter aggregation"	*Davis-Baffin*	*18,583 (95% CI 7,308-47,254)*	*2006*	*Reduced*	*Stable*	*HQ*	*NAMMCO / JCNB 2015*
	East Greenland	Atlantic Arctic	6,444 (95% CI 2505-16,575)	2008	Unknown	Unknown	HQ	Heide-Jørgensen et al 2010
	Svalbard / Franz Josef Land	Atlantic Arctic	Unknown		Unknown	Unknown	P	
Bowhead whale	Bering-Chukchi-Beaufort Seas (BCB)	Pacific Arctic, Beaufort	16,892 (95% CI 15,704– 18,928)	2011	Reduced	Increasing	HQ	Givens et al 2013
	East Canada-West Greenland (BBDS and FBHB)	Arctic Archipelago, Davis Baffin, Hudson Bay	6,745 (CV 0.22)	2013	Reduced	Increasing	HQ	Wiig et al 2011
	"-West Greenland winter component"	*Davis Baffin*	*1,538 (95% CI 827 - 2,249)*	*2012*	*Reduced*	*Stable*	*HQ*	*Rekdal et al 2014*
	Svalbard-Barents Sea	Atlantic Arctic			Reduced	Unknown	P	Wiig et al 2010
	"- NE Greenland summer component"	*Atlantic Arctic*	*102 (95% CI 32 - 329)*	*2009*	*Reduced*	*Unknown*	*P*	*Boertmann et al 2014*
Ringed seal	Beaufort and Chukchi Seas	Beaufort	1,000,000	Unspecified	Unknown	Unknown	HQ (Russia), H (USA)	Kelly et al 2010
	Bering Sea	Pacific Arctic	340,000	1976-2012	Unknown	Unknown	HQ (Russia), H (USA)	Conn et al 2014
	Hudson and James Bays	Hudson Bay	516,000	1974	Unknown	Unknown	H	Smith 1975
	Baffin Bay	Davis-Baffin, Arctic Archipelago	1,200,000	1990s	Unknown	Unknown	H	Kingsley 1998
	Greenland Sea & Southeast Greenland	Atlantic Arctic	Unknown		Unknown	Unknown	H	
	Svalbard & Barents sea	Atlantic Arctic	Unknown		Unknown	Unknown	H	
	"-Svalbard only, partial"	*Atlantic Arctic*	*7,585 (95% CI 6332-9085)*	*2002-2003*	*Unknown*	*Unknown*	*H*	*Krafft et al 2006*
	White, Barents, Kara & East Siberian seas	Atlantic Arctic, Kara & Laptev	220,000	Unspecified	Unknown	Unknown	HQ (Russia), H (Norway)	Kelly et al 2010
	Labrador	Davis-Baffin	Unknown		Unknown	Unknown	H	
	Arctic Basin	Arctic Basin	Unknown		Unknown	Unknown	P	

Species	Subpopulation/ Stock	CBMP Arctic Marine Area	**Abundance** (with 95% confidence interval (CI) or coefficient of variation (CV) if available)	Year	**Status:** Unknown (U), Reduced (R) or Not Reduced (N)	**Trend:** Unknown(U), Increasing(I), Stable (S), Declining (D)	**Harvest:** harvested without quota (H), harvested with quota (HQ), currently protected (P)	Survey/trend reference from Laidre et al. unless noted
Bearded seal	*E. nauticus* subspecies		Unknown total					
	Bering Sea	Pacific Arctic	>299,000	2012	Unknown	Unknown	HQ (Russia), H (USA)	Conn et al 2014
	Chukchi Sea	Pacific Arctic	27,000	2000	Unknown	Unknown	HQ (Russia), H (USA)	Cameron et al 2010
	Beaufort Sea	Beaufort	Unknown		Unknown	Unknown	H	
	East Siberian Sea	Pacific Arctic	Unknown		Unknown	Unknown	HQ (Russia), H (USA)	
	E. barbatus subspecies		Unknown total				H	
	Eastern Canada and West Greenland	Arctic Archipelago, Davis-Baffin, Hudson Bay			Unknown	Unknown	H	
	"-Canadian waters component"	*Arctic Archipelago, Davis-Baffin, Hudson Bay*	*190,000*	*1958-1979*	*Unknown*	*Unknown*	*H*	*Cleator 1996*
	East Greenland	Atlantic Arctic	Unknown		Unknown	Unknown	H	
	Svalbard & Barents Sea	Atlantic Arctic	Unknown		Unknown	Unknown	H	
	White, Kara & Laptev Seas	Atlantic Arctic, Kara & Laptev	Unknown		Unknown	Unknown	HQ (Russia), H (Norway)	
Ribbon seal	Bering Sea	Pacific Arctic	143,000	2007	Unknown	Unknown	HQ (Russia), H (USA)	Boveng et al. 2013
Harp seal	Northwest Atlantic	Davis-Baffin, Atlantic Arctic	7,420,000 (95% CI 6,360,000 - 8,360,000)	2012	Not Reduced	Stable	H (Greenland), HQ (Canada)	Hammill et al. 2015
	Greenland Sea	Atlantic Arctic	627,410 (95% CI 470,540 – 784,280)	2012	Not Reduced	Increasing	H (Greenland), HQ (Norway)	ICES 2013
	White Sea	Atlantic Arctic	1,419,800 (95% CI 1,266,910-1,572,690)	2013	Reduced	Stable	HQ (Norway) P (Russia)	ICES 2013
Hooded seal	Northwest Atlantic	Davis-Baffin, Atlantic Arctic	593,500 (95% CI 404,400-728,300)	2005	Reduced	Increasing	H (Greenland), HQ (Canada)	Hammil and Stenson 2006
	Greenland Sea	Atlantic Arctic	84,020 (95% CI 68,060–99,980)	2013	Reduced	Decreasing	H (Greenland), P (Norway)	Øigård et al. 2014
Spotted seal	Bering sea	Pacific Arctic	>460,000	2012	Unknown	Unknown	H	Han et al. 2010

Species	**Subpopulation/ Stock**	**CBMP Arctic Marine Area**	**Abundance** (with 95% confidence interval (CI) or coefficient of variation (CV) if available)	**Year**	**Status:** Unknown (U), Reduced (R) or Not Reduced (N)	**Trend:** Unknown(U), Increasing(I), Stable (S), Declining (D)	**Harvest:** harvested without quota (H), harvested with quota (HQ), currently protected (P)	**Survey/trend reference from Laidre et al. unless noted**
Walrus	*O. r. divergens* subspecies (Pacific)							
	Bering-Chukchi Seas	Pacific Arctic	~129,000 (95% CI 55,000–507,000)	2006	Unknown	Unknown	HQ (Russia), H (USA)	Speckman et al. 2011
	Laptev Sea	Kara-Laptev	3,000-5,000	1992	Unknown	Unknown	P	Belikov and Boltunov 2005
	O. r. rosmarus subspecies (Atlantic)							
	North and Central Foxe Basin	Hudson Bay	13,452 (CV=0.43)	2011	Not Reduced	Stable	HQ	Stewart et al. 2013d
	South and East Hudson Bay	Hudson Bay	Low hundreds	2006	Unknown	Unknown	HQ	COSEWIC 2006
	North Hudson Bay-Hudson Strait-Southeast Baffin Island-North Labrador	Hudson Bay, Davis Baffin	Unknown		Unknown	Unknown	H (Canada) or HQ (Greenland)	
	"- Southeast Baffin Island summer aggregation"	*Davis-Baffin*	*2,502 (95% CI 1,660-3,345)*	*2007*	*Unknown*	*Unknown*	*H*	*Stewart et al. 2013b*
	"-North Hudson Bay summer aggregation"	*Hudson Bay*	*1,376*	*1990*	*Unknown*	*Unknown*	*H*	*COSEWIC 2006*
	"-Hudson Strait winter aggregation"	*Hudson Bay*	*6,020 (95% CI 2,485-14,585)*	*2012*	*Unknown*	*Unknown*	*H*	*Elliott et al. 2013*
	"-West Greenland winter aggregation"	*Davis-Baffin*	*1,408 (95% CI 922-2,150)*	*2012*	*Reduced*	*Increasing*	*HQ*	*Heide-Jørgensen et al. 2013*
	West Jones Sound	Arctic Archipelago	503 (95% CI 473-534)	2008	Not Reduced	Stable	HQ	Stewart et al. 2013a
	Penny Strait/Lancaster Sound	Arctic Archipelago	727 (95% CI 623-831)	2009	Not Reduced	Stable	H	Stewart et al. 2013a
	Baffin Bay	Davis-Baffin			Reduced	Increasing	HQ	
	"-Winter (Greenland)"	*Davis-Baffin*	*2,544 (95% CI 1,513-4,279)*	*2014*	*Reduced*	*Increasing*	*HQ*	*Heide-Jørgensen et al. 2016*
	"-Summer (Canada)"	*Davis-Baffin*	*1,251 (95% CL 571-2,477)*	*2009*	*Reduced*	*Increasing*	*H*	*Stewart et al. 2013c*
	East Greenland	Atlantic Arctic	1,429 (95% CI 705-2,896)	2009	Unknown	Stable	HQ	NAMMCO 2015
	Svalbard/Franz Josef Land	Atlantic Arctic			Unknown	Increasing	P	
	"-Svalbard only"	*Atlantic Arctic*	*3,886 (95% CI 3553-4262)*	*2012*	*Unknown*	*Increasing*	*P*	*Kovacs et al. 2014*
	Novaya Zemlya-Eastern Barents-Pechora-White Seas	Atlantic Arctic	3,943 (95% CI 3,605-4,325)	2010	Unknown	Unknown	P	Lydersen et al 2012

Species	Subpopulation/ Stock	CBMP Arctic Marine Area	Abundance (with 95% confidence interval (CI) or coefficient of variation (CV) if available)	Year	Status: Unknown (U), Reduced (R) or Not Reduced (N)	Trend: Unknown(U), Increasing(I), Stable (S), Declining (D)	Harvest: harvested without quota (H), harvested with quota (HQ), currently protected (P)	Survey/trend reference from Laidre et al. unless noted
Polar bear	Arctic Basin	Arctic Basin	Unknown	-	Unknown	Unknown	P	PBSG 2017
	Baffin Bay	Davis-Baffin	2,826 (95% CI 2,059-3,593)	2013	Not Reduced	Unknown	HQ	PBSG 2017
	Barents Sea	Atlantic Arctic	2,644 (95% CI 1899-3592)	2004	Unknown	Unknown	P	PBSG 2017
	Chukchi Sea	Pacific Arctic	Unknown	-	Unknown	Unknown	H	PBSG 2017
	Davis Strait	Davis-Baffin	2,158 (95% CI 1833-2542)	2007	Not Reduced	Stable	HQ	PBSG 2017
	East Greenland	Atlantic Arctic	Unknown	-	Unknown	Unknown	HQ	PBSG 2017
	Foxe Basin	Hudson Bay	2,580 (95% CI 2093-3180)	2010	Not reduced	Stable	HQ	PBSG 2017
	Gulf of Boothia	Arctic Archipelago	1,592 (95% CI 870-2314)	2000	Unknown	Unknown	HQ	PBSG 2017
	Kane Basin	Davis-Baffin	357 (95% CI 221-493)	2014	Not Reduced	Increasing	HQ	PBSG 2017
	Kara Sea	Kara and Laptev Seas	Unknown	-	Unknown	Unknown	P	
	Lancaster Sound	Arctic Archipelago	2,541 (95% CI 1759-3323)	1997	Unknown	Unknown	HQ	PBSG 2017
	Laptev Sea	Kara and Laptev Seas, Pacific Arctic			Unknown	Unknown	P	PBSG 2017
	M'Clintock Channel	Arctic Archipelago	284 (95% CI 166-402)	2000	Unknown	Unknown	HQ	PBSG 2017
	Northern Beaufort Sea	Arctic Basin-Beaufort-Arctic Archipelago	980 (95% CI 825-1135)	2006	Not reduced	Stable	HQ	PBSG 2017
	Norwegian Bay	Arctic Archipelago	203 (95% CI 115-291)	1997	Unknown	Unknown	HQ	PBSG 2017
	Southern Beaufort Sea	Beaufort	907 (95% CI 548-1270)	2010	Reduced	Declining	HQ (Canada), H (USA)	PBSG 2017
	Southern Hudson Bay	Hudson Bay	951 (95% CI 662-1366)	2012	Not reduced	Stable	HQ	PBSG 2017
	Viscount Melville	Arctic Archipelago	161 (95% CI 121-201)	1992	Unknown	Unknown	HQ	PBSG 2017
	Western Hudson Bay	Hudson Bay	1,030 (95% CI 754-1406)	2011	Reduced	Stable	HQ	PBSG 2017

3.6.4 Drivers of observed trends

In a warmer Arctic, endemic marine mammal species are already facing and will continue to face extreme levels of ***habitat change***, most notably a dramatic reduction in sea ice (Laidre et al. 2015, Stern and Laidre 2016). The pattern and timing of sea ice loss is important and will likely result in varied impacts by region and by species. For example, early spring sea ice retreat reduces suitable breeding and pup rearing habitat for ringed seals. Polar bear breeding precedes the ringed seal pupping season and bears depend on hunting seal pups to rebuild energy stores after fasting during their own breeding period. Reduced availability of seal pups will detrimentally affect the polar bear (Bromaghin et al. 2015, Stirling et al. 2016). In Svalbard, changes in ice conditions have been observed to lead to changes in prey composition of bearded seal as estimated by stable isotope signatures (Hindell et al. 2012). Late summer open water (due to seasonal ice retreat north of the continental shelf) limits offshore foraging habitat for Pacific walrus and increases their use of coastal haulouts. Historically, Pacific walrus rested on sea ice located directly over prime feeding areas; use of coastal haulouts results in increased travel time and energy expenditure to access feeding areas and also increased potential of calf mortality due to stampede events (panic exodus of haulouts) (Udevitz et al. 2013). Walrus also depend on winter sea ice adjacent to key feeding areas, notably the St. Lawrence Island polynya, which has high bivalve productivity (primary forage species) and broken ice of sufficient size to provide resting places along with sufficient open water (Jay et al. 2014). Seasonal changes to the polynya may detrimentally affect walrus and in general, changes in the seasonal occurrence and the quality of sea ice in key feeding habitats reduce foraging efficiency of walrus.

In addition to habitat loss, ***physical environmental changes*** (e.g., increased water and air temperatures) alter the forage base of Arctic marine mammals. Such changes may appear as shifts in the density and distribution of prey species, and potentially loss of some fat-rich prey species (Moore et al. 2014). ***Reductions in sea ice*** is already allowing northward movement of temperate species with the possibility of increased competition for food and increased predation by species (i.e., killer whale) formerly unable to access them in areas of extensive sea ice (Laidre et al. 2015). Warmer waters may also bring increased disease risk and increased risks from contaminants (Lefebvre et al. 2016). For some species, notably ice-associated cetaceans, predictions are difficult because the nature of their affiliation with sea ice is not clearly understood. In fact, bowhead whale are doing well, both at the population and individual level, in the increased open-water conditions of the Beaufort and Chukchi Seas (George et al. 2015). In contrast, ice-breeding seals will have marked, or total, breeding-habitat loss in their traditional breeding areas and will certainly undergo distributional changes and likely abundance reductions (Cameron et al. 2010, Kelly et al. 2010). In general, species with fixed traditional spatial and temporal cycles that track historic sea ice and climatic patterns are expected to decline in abundance. It is not certain to what, if any extent such species will be able to adapt their patterns of breeding and habitat use on decadal time scales. Extirpation of some stocks is likely.

Anthropogenic activities that may affect marine mammals in the Arctic are increasing concomitantly with loss of sea ice habitat. The longer and more widespread open water season has already stimulated increases in ship traffic and resource development in the Arctic (Reeves et al. 2014, Laidre et al. 2015). Major shipping routes into the Arctic include the Bering Sea from the Pacific Ocean, Baffin Bay-Davis Strait and Barents Sea from the North Atlantic. Impacts from increased shipping on marine mammal species and the people who depend upon them can come from the direct impact of ship strikes on whales, the loss or disruption of habitat from activities such as icebreaking to clear shipping channels, disturbance from noise generated by ships, and from contamination. The potential for impact will vary by season, dependent in large part on ice conditions.

Noise associated with increasing ship traffic and resource development is also of concern for marine mammal populations. Marine mammals communicate via underwater vocalizations and can be negatively affected by underwater noise from shipping and other industrial activities (Reeves et al. 2014). Bowhead whale, for example, respond to anthropogenic sound in their environment (Southall et al. 2007) and concern that bowhead whale will avoid areas with industrial noise has been the subject of ongoing regulatory discussions of oil and gas operations in the Arctic (NOAA Fisheries 2013). The degree to which bowhead whale respond to noise depends on the activity of the whales; they generally respond less when involved in feeding or social behaviour and more when resting or migrating (Richardson et al. 1999, Richardson 2004). Shipping noise is not anticipated to cause acute physical harm, although many species will likely move away from noise and constant noise may effectively result in habitat loss. In Canada, belugas were observed avoiding ice-breaking vessels at great distances and altering their behaviour for days following the event (Finley et al. 1990). Based on acoustic modelling, noise from an icebreaker is audible to beluga from 35–78 km away, depending upon water depth, and can mask vocalizations over most of that range (Erbe and Farmer 2000). The possibility of noise disturbance is a particular concern to communities and local residents, concerned that key subsistence species may be deflected away from traditional hunting areas (Huntington et al. 2016).

Pollution and the presence of ***toxic chemicals and heavy metals*** are of concern for the health of marine mammals and for the food safety of subsistence communities that depend upon them (Huntington et al. 2016). With increased Arctic oil exploration and shipping, the risk of oil spills from tanker or other shipping accidents has increased. Fuel and heating oil are regularly carried through the region on both destination, and increasingly, inter-ocean voyages. The risk of oil spills to Arctic marine mammals is exacerbated by the lack of effective clean-up techniques and lack of response equipment and capability in remote Arctic regions. Discharge of bilge water, oily sludge, garbage and other materials may be of greater chronic widespread impact than acute accidental spills and as difficult or impossible to clean up.

In addition to the ice-dependent species considered here, under the influence of a warming climate a number of temperate species have extended their distribution range northward and increased the amount of time they spend

Box 3.6.3: Pacific Arctic pinnipeds unusual mortality event

Monitoring seals.
Photo: Josh London, NOAA

In 2011, the emergence of skin lesions and mortality in Arctic seals and walrus on the U.S. Arctic Slope, Pacific Western Arctic, and Bering Strait led to the declaration of an Unusual Mortality Event (UME) by NOAA and the USFWS (NOAA, 2011). In response, a trans-boundary interdisciplinary disease investigative team was assembled to join Indigenous hunters from Alaska, Chukotka, Russia, and the Northwest Territories (NWT) of Canada. No specific cause has been identified, but investigations have ruled out numerous bacteria, viruses, contaminants and algae toxins known to affect marine mammals. Advanced testing for unidentified infectious agents continues as well as testing for other potential causes.

Ice seals and Pacific walrus are key species essential to the Arctic ecosystem and food security for Indigenous subsistence communities (ICC-Alaska, 2015, Raymond-Yakoubian et al., 2014, Gadmus, 2013). At least 60 coastal communities in Alaska, Chukotka and Canada's Northwest Territories are reliant on the non-commercial harvest of local marine wildlife for their nutritional, cultural, and economic well-being. The UME initially identified in northern Alaska ultimately extended to impact communities both westward across the Bering Strait in Chukotka and eastward into the NWT. Thus, food safety and food security aspects are integral components of the response. Disease surveillance continues, including follow-up with surviving animals. NOAA conducted an ice-associated seal research survey in the central Bering Sea in April 2016; nine of the 10 ribbon seals captured had extensive bald patches and are thought to be survivors of the initial disease outbreak. Similar findings of an increased incidence of "black skin" (hairloss patches) and or delayed/incomplete molt have been observed among subsistence harvested ice seal species including, ringed, bearded and spotted seals since 2011. While the outbreak has subsided, such unusual events present food security and public health concern in a region currently experiencing significant environmental and industrial maritime change (Ice Seal Committee 2012).

This was the first UME to be designated in the U.S. Arctic and the first to involve marine mammal species commonly utilized as essential food resources. As such, the event has resulted in important lessons learned to address public health and food security concerns:

Future marine wildlife responses (e.g., for disease outbreaks or contaminant spills) must consider regional public health and food security concerns.

1. Wildlife disease detection in remote coastal areas is likely to be made by people actively engaged in the utilization of resources.
2. Agencies and organizations located in urban centres should successfully integrate with existing regional communication networks (i.e. regional hub organizations, institutions, and Indigenous organisations) to build efficient and comprehensive communications and response capacity.
3. Trans-boundary communication is critical to understanding the status and spread of a disease event occurring in shared wildlife populations.
4. Agencies and communities need wildlife health response networks and response plans with mechanisms to review plans and update contact information on an annual basis.

in the Arctic. Some species that may become important components of the Arctic ecosystem in the future include sperm whales (*Physeter macrocephalus*), northern bottlenose whale (*Hyperoodon ampullatus*), minke whale (*Balaenoptera acutorostrata*), humpback whale, gray whale (*Eschrichtius robustus*), killer whale, pilot whale (*Globicephala melas*), white beaked dolphin (*Lagenorhynchus albirostris*) and harbour porpoise (*Phocoena phocoena*) as well as harbour seal (*Phoca vitulina*) and possibly grey seals (*Halichoerus grypus*). Notably, killer whales have been identified as an increasingly important predator in the Arctic (Ferguson et al. 2010). It is important to monitor temporal and spatial changes in the distribution and seasonal abundance of these species to determine how these changes might impact Arctic ecosystems.

3.6.5 Knowledge and monitoring gaps

The Conservation of Arctic Flora and Fauna (CAFF) has well-developed, basic plans to conduct circumpolar marine biodiversity monitoring (Gill et al. 2011). These plans have not been fully implemented for marine mammals, leaving large knowledge gaps. The first priority for monitoring is therefore to implement the *CBMP Marine Plan* in all Arctic countries.

Specifically, broadly scoped plans have been proposed and circumpolar monitoring plans include those for beluga, ringed seal, and polar bear (e.g., Kovacs (ed) 2014, Simpkins et al. 2009), but the level of implementation of such plans is inadequate (Table 3.6.2). For example, the need for circumpolar monitoring of ringed seal has been recognized as an essential component of any Arctic-monitoring plan. This is the most numerous of the endemic Arctic pinnipeds and a key food resource for polar bear and people in many northern communities. As an ice dependent species, ringed seal are threatened by global warming. Specifically, loss of and changes to sea ice have caused structural changes in their habitat linked to key life history events (Kovacs et al. 2011, 2012). The species is already experiencing serious reductions of breeding habitat; in 2012 a circumpolar CAFF Ringed Seal Network group met in Tromsø, Norway to further develop an initial plan developed in Valencia, Spain in 2008. The primary goals of this workshop were to review current research and monitoring activity, and to select key monitoring parameters that could be consistently collected at key sites across the ringed seal's range. To date, this plan has not been fully implemented.

The cumulative effect of changes in Arctic ecosystems on marine mammals is a key knowledge gap. Arctic ecosystems are undergoing increasing pressure from a variety of major anthropogenic stressors, including increasing shipping activity and resource development, continued increases in human populations, and climate change. By integrating long-term monitoring studies of Arctic marine mammals into research on Arctic change, there is an opportunity to gain a large spatial-scale perspective of ecosystem functioning. Historically, species information has been collected for specific regional concerns or research interests and seldom coordinated across jurisdictions. A notable regional example of coordinated work is the Atlantic Arctic region under the umbrella of NAMMCO and its collaboration with the Canada-Greenland Joint Commission on Narwhal and Beluga. Compiled datasets often provide emergent properties and conclusions that are unanticipated, and consequently can have greater impact on policy decisions and interest to an informed public (Ferguson et al. 2012).

The remote nature of Arctic systems also leads to knowledge gaps, which can be addressed in part through monitoring efforts that engage communities. A successful localized marine mammal monitoring approach, developed independently by a number of circumpolar countries to collect time-series data on Arctic marine mammal health and stock assessment, is community-based monitoring. Long-term monitoring from such programs has provided valuable information for managers and conservation efforts

Box 3.6.4: Local monitoring

Sanikiluaq residents assist research scientists project exploring the effects of climate change on Arctic marine mammals. Photo: Fisheries and Oceans Canada

Fisheries and Oceans, Canada and the Arviat and Sanikiluaq Hunters and Trappers Organization/ Association in Hudson Bay, Canada have developed a cooperative community-based monitoring program. Local Inuit hunters have been provided with sampling equipment and trained to collect biological data from the ringed, bearded, harp, and harbour seals that they harvest. The hunters record the species, sex, date and time, hunter's name, location of harvest and habitat type. They also provide data on total length, axillary girth, hip girth, fat depth at sternum, fat depth at hips, total body weight, and skull weight. Tissues collected by the hunters generally included lower jaw, muscle, blubber, liver, kidney, hair, whiskers, flipper with claws, blood, and reproductive tract. Samples are frozen and shipped to the Fisheries and Oceans Canada at the end of the season. The age of the seal is determined by counting growth layer rings in the teeth and the morphometric measurements are included in various analyses as important indicators of seal health and to determine trends in growth rates and condition over time.

Table 3.6.2. Assessment of monitoring implementation

on several species, including polar bear (e.g., Western Hudson Bay and Southern Beaufort Sea [Stirling et al. 1999, Regehr et al. 2010]), ringed seal (Harwood et al. 2012, 2015), bowhead whale (George et al. 2015), and harp seal (Sjare and Stenson 2010, Stenson et al. 2016). In many of these programs, local peoples assist with collection of data such as tissue samples from hunts or changes in timing or distributions of animals. Ideally, Indigenous and local peoples should be integrally involved in the design and implementation of monitoring programs so that scientific knowledge and TK holders are working collaboratively.

3.6.6 Conclusions and key findings

Climate-induced changes are amplified in the Arctic compared to other areas of the globe. As a result, Arctic marine ecosystems are rapidly changing due to atmospheric and oceanic warming and its impacts on sea ice and associated marine biota, including marine mammals. Other types of anthropogenic activity that exacerbate climate impacts on marine mammal populations include oil and gas exploration and production, commercial fisheries, and both local and global shipping. Marine mammals are highly visible components of Arctic ecosystems, often identified as sentinels of change in the Arctic ecosystem. The prominent use of Arctic marine mammals in generalized descriptions of the changing Arctic is due in part to the great cultural and subsistence value to local peoples and iconic species status at a global level.

Regional differences in our level of understanding of the status of different marine mammal species, populations and stocks compromise our ability to evaluate regional variability in species response to climate warming across the Arctic. To guide data collection and address regional disparities, much effort has gone into developing detailed monitoring plans for the ringed seal, beluga and polar bear, but these plans have not been implemented uniformly across the Arctic. As a result, the level of investment by Arctic governments in monitoring and assessment, and our level of knowledge remain inadequate to understanding impacts of climate and ecosystem change. Communities should be integrally involved in the design and implementation of monitoring programs so that scientific knowledge and TK holders are working collaboratively.

Historically, several marine mammal populations were heavily exploited and reduced to low numbers. Some populations now facing the impacts of Arctic change are still recovering from over-harvest, complicating the interpretation of climate-change effects on population trends. Harvest continues, with many species still an important subsistence resource for indigenous and local peoples across the Arctic. In general, subsistence hunts are managed based on abundance assessments and monitoring of population status, but there are some populations where harvest levels are of concern, for example, narwhal in Melville Bay and East Greenland and walrus in northern Baffin Bay (GINR 2016). Information on harvest levels and status is important to evaluating overall population status and managing hunts. Long-term data sets based on data collected from hunted animals can be an important information source, as they constitute base-line information on demographic parameters during different ecological regimes. The value of collected tissues can be increased even more by subjecting them to modern techniques such as analyses of stable isotopes, providing links to trophic structure of the ecosystem at the time of collection. Similar data series are often collected in different areas/countries and comparative studies across regions further increase the value of individual data sets; provided that approaches for sampling and analyses are comparable.

In summary, Arctic marine ecosystems are under immense cumulative pressure from a variety of factors including climate change, global pollution, shipping, gas-oil exploration and production, and in some areas, hunting and commercial fisheries. Synergistic impacts from the collective pressures can be expressed on individual animals as well as at stock and population levels and are likely to increase the impacts of individual drivers. Major shipping routes are expanding into the Arctic, including the Bering Strait from the Pacific Ocean, Baffin Bay-Davis Strait and Fram Strait/Barents Sea in the North Atlantic, which are also the key areas of marine mammal biodiversity. Ongoing complex spatial-temporal shifts in ecological, and subsequently animal health, suggest that Arctic marine ecosystems are undergoing change. The trends will continue and become more exacerbated with future Arctic climatic warming, particularly with the continued and increasing presence of anthropogenic activities in the Arctic. Reaching an adequate understanding of the responses of marine mammal population to the ongoing environmental changes in Arctic marine ecosystems requires a multidisciplinary and multi-knowledge approach and a high degree of collaboration across borders and between researchers, communities and Arctic governments.

Future indicators that the CBMP Marine Mammal Expert Network plans to collate include health parameters, passive acoustics, habitat changes, and telemetry tracking studies. It is also vital to obtain more knowledge about population sizes, densities, and distributions of marine mammal populations in order to understand the relationships between sea ice loss and climate change and to manage Arctic marine mammal populations in an appropriate manner.

Finally, Laidre et al (2015) identified six recommendations for conservation of Arctic marine mammals in the 21st Century:

1. maintaining and increasing co-management by local, governmental and international entities,
2. understanding that species and populations exhibit variable responses to climate change over time and space,
3. improving monitoring,
4. understanding and mitigating cumulative impacts from industrial activities,
5. recognizing the utility and limitations of protected species legislation in a changing Arctic, and;
6. practicing forward-looking conservation that incorporates scientific evidence on species status with value based-conservation, including the communication of accurate information to the public.

These recommendations are still valid.

References

Allen, B.M., and Angliss, R.P. 2011. Alaska marine mammal stock assessments, 2010. U.S. Department of Commerce, NOAA Technical Memorandum NMFSAFSC-223.

Asselin, N.C., Ferguson, S.H., Richard, P.R. and Barber, D.G. 2012. Results of narwhal (*Monodon monoceros*) aerial surveys in northern Hudson Bay, August 2011. Fisheries and Oceans Canada, Canadian Science Advisory Secretariat Research Document 2012/037.

Belikov, S.E., and Boltunov A.N. 2005. Laptev walruses. Working Paper SC/12/WWG/8, North Atlantic Marine Mammal Commission (NAMMCO), Copenhagen.

Boertmann, D., Kyhn, L.A., Witting, L. and Heide-Jørgensen, M.P. 2015. A hidden getaway for bowhead whales in the Greenland Sea. Polar Biology, 38(8): 1315-1319.

Bogoslovskaya, L. and Krupnik, I. 2014. Climate Change Adaptation – Traditional knowledge of Indigenous Peoples Inhabiting the Arctic and Far North Marine Hunters of Chukotka. UNESCO.

Bogstad, B., Gjøsæter, H., Haug, T. and Lindstrøm, U. 2015. A review of the battle for food in the Barents Sea: cod vs. marine mammals. Frontiers in Ecology and Evolution, 3(29).

Born, E.W., Sonne, C. and Dietz, R. 2010. Research on polar bears in Greenland 2005-2009. *In*: M.E. Obbard, G.W. Thiemann, E. Peacock and T. DeBruyn. (eds.). Proceedings of 15th Working Meeting of the IUCN Polar Bear Specialist Group 29 June- 3 July, Copenhagen, Denmark. Occassional Papers of the IUCN Species Survival Commission No. 43, IUCN Gland, Switzerland and Cambridge, UK: 135-148.

Boveng, P.L., Bengtson, J.L., Cameron, M.F., Dahle, S.P. Logerwell, E.A., London, J.M., Overland, J.E., Sterling, J.T., Stevenson, D.E., Taylor, B.L. and Ziel, H.L. 2013. Status review of the ribbon seal (*Histriophoca fasciata*). U.S. Department of Commerce, NOAA Technical Memorandum NMFS-AFSC-255.

Bromaghin, J. F., McDonald, T.L., Stirling, I., Derocher, A.E., Richardson, E.S., Regehr, E.V., Douglas, D.C., Durner, G.M., Atwood, T. and Amstrup, S.C. 2015. Polar bear population dynamics in the southern Beaufort Sea during a period of sea ice decline. Ecological Applications, 25(3): 634-651.

Buren, A.D., Koen-Alonso, M., Pepin, P., Mowbry, F., Nakashima, B., Stenson, G., Ollerhead, N. and Montevecchi. W.A. 2014. Bottom-up regulation of capelin, a keystone forage species. PLoS ONE, 9(2): e87589.

Burns, J.J. 1981. "Bearded Seal." *In*: S.H. Ridgway and R.J. Harrison (eds.). Handbook of Marine Mammals: Volume 2 Seals. Academic Press, London, pp 145–170.

Cameron, M.F., Bengston, J.L., Boveng, P.L., Jansen, J.K., Kelly, B.P., Dahle, S.P., Logerwell, E.A., Overland, J.E., Sabine, C.L., Waring, G.T. and Wilder, J.M. 2010. Status review of the bearded seal (*Erignathus barbatus*). NOAA Technical Memorandum NMFS-AFSC-211, U.S. Department of Commerce.

Chambellant, M., Stirling, I., Gough, W.A. and Ferguson, S.H. 2012. Temporal variations in Hudson Bay ringed seal (*Phoca hispida*) life-history parameters in relation to environment. Journal of Mammology, 93(1): 267-281.

Cleator, H.J. 1996. The status of the bearded seal, *Erignathus barbatus*, in Canada. Canadian Field Naturalist 110:501-510.

Cochrane, S.K.J., Denisenko, S.G., Renaud, P.E., Emblow, C.S., Ambrose, W.G., Ellingsen, I.H. and Skarðhamar, J. 2009. Benthic macrofauna and productivity regimes in the Barents Sea — Ecological implications in a changing Arctic. Journal of Sea Research, 61(4): 222-233.

Conn, P.B., Ver Hoef, J.M., McClintock, B.T., Moreland, E.E., London, J.M., Cameron, M.F., Dahle, S.P. and Boveng, P.L. 2014. Estimating multispecies abundance using automated detection systems: ice-associated seals in the Bering Sea. Methods in Ecology and Evolution, 5(12): 1280-1293.

Committee on the Status of Endangered Wildlife in Canada (COSEWIC) 2004. COSEWIC assessment and update status report on the beluga whale *Delphinapterus leucas* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

Committee on the Status of Endangered Wildlife in Canada (COSEWIC). 2006. Assessment and update status report on the Atlantic walrus (*Odobenus rosmarus rosmarus*) in Canada. Committee on the status of endangered wildlife in Canada, Ottawa.

Crawford, J.A., Quakenbush, L.T. and Citta, J.T. 2015. A comparison of ringed and bearded seal diet, condition and productivity between historical (1975–1984) and recent (2003–2012) periods in the Alaskan Bering and Chukchi Seas. Progress in Oceanography, 136: 133–150.

Delarue, J., Laurinolli, M. and Martin, B. 2009. Passive acoustic survey of bowhead whales in the Chukchi Sea. The Journal of the Acoustical Society of America, 125(2549).

Derocher, A.E., Lunn, N.J. and Stirling, I. 2004. Polar bears in a warming climate. Integrative and Comparative Biology, 44: 163-176.

Doniol-Valcroze, T. and Hammill, M.O. 2012. Information on abundance and harvest of Ungava Bay beluga. Fisheries and Oceans Canada, Canadian Science Advisory Secretariat Research Document 2011/126.

Durner, G.M. 2015. Using Argos to understand the response of polar bears to a changing Arctic. *In*: Argos, Monitoring the Impacts of Climate Change. Argos Forum, 81: 4-5.

Eamer, J., Donaldson, G.M., Gaston, A.J., Kosobokova, K.N., Lárusson, K.F., Melnikov, I.A., Reist, J.D., Richardson, E., Staples, L. and von Quillfeldt, C.H. 2013. Life Linked to Ice: A guide to sea-ice-associated biodiversity in this time of rapid change. CAFF Assessment Series No. 10. Conservation of Arctic Flora and Fauna, Akureyri, Iceland.

Elliott, R.E., Moulton, V.D., Raborn, S.W. and Davis, R.A. 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, Canada.

Erbe, C. and Farmer, D.M. 2000. Zones of impact around icebreakers affecting beluga whales in the Beaufort Sea. The Journal of the Acoustical Society of America, 108(1332).

Feltz ET, Fay FH. 1966. Thermal requirements in vitro of epidermal cells from seals. Cryobiology, 3: 261-264.

Ferguson, S.H., Berteaux, D., Gaston, A.J., Higdon, J.W., Lecomte, N., Lunn, N., Mallory, M.L., Reist, J., Russell, D., Yoccoz, N.G. and Zhu, X. 2012. Time series data for Canadian arctic vertebrates: IPY contributions to science, management, and policy. Climatic Change 115(1): 235–258.

Ferguson, S.H., Higdon, J.W. and Chmelnitsky, E. 2010. The rise of Killer whales as a major arctic predator. *In*: S.H. Ferguson, 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, pp 117-136.

Finley, K., Bradstreet, M. and Miller, G. 1990. Summer feeding ecology of harp seals (*Phoca groenlandica*) in relation to arctic cod (*Boreogadus saida*) in the Canadian high arctic. Polar Biology, 10(8): 609-618.

Fischbach, A.S., Amstrup, S.C. and Douglas, D.C. 2007. Landward and eastward shift of Alaskan polar bear denning associated with recent sea ice changes. Polar Biology, 30(11): 1395-1405.

Frost, K.J., Lowry, L.F. and Carroll, G. 1993. Beluga whale and spotted seal use of a coastal lagoon system in the northeastern Chukchi Sea. Arctic, 46:8-16.

Gadmus, L. 2013. Linkages between human health and ocean health: a participatory climate change vulnerability assessment for marine mammal harvest. International Journal of Circumpolar Health, 72: 20715.

George, J.C., Druckenmiller, M., Laidre, K.L., Suydam, R. and Person, B. 2015. Bowhead whale body condition and links to summer sea ice and upwelling in the Beaufort Sea. Progress in Oceanography, 136: 250-262.

Gill, M.J., Crane, K., Hindrum, R., Arneberg, P., Bysveen, I., Denisenko, N.V., Gofman, V., Grant-Friedman, A., Guðmundsson, G., Hopcroft, R.R., Iken, K., Labansen, A., Liubina, O.S., Melnikov, I.A., Moore, S.E., Reist, J.D., Sirenko, B.I., Stow, J., Ugarte, F., Vongraven, D. and Watkins, J. 2011. Arctic Marine Biodiversity Monitoring Plan. CAFF Monitoring Series Report No. 3, Conservation of Arctic Flora and Fauna International Secretariat, Akureyri, Iceland.

Givens, G.H., Edmondson, S.L., George, J.C., Suydam, R,. Charif, R.A., Rahaman A., Hawthorne, D., Tudor, B., DeLong, R.A. and Clark, C.W. 2013. Estimate of 2011 Abundance of the Bering-Chukchi-Beaufort Seas Bowhead Whale Population. IWC Paper SC/65a/BRG01.

Gjertz, I., and Wiig Ø. 1994. Distribution and catch of white whales (*Delphinapterus leucas*) at Svalbard. Meddelelser om Grønland, Bioscience 39:93-97.

Glazov D.M., Chernook, V.I., Nazarenko, E.A., Zharikov, K.A., Shpak, O.V. and Mukhametov, L.M. 2010. Summer distribution and abundance of belugas in the White Sea based on aerial survey data (2005-2008). 6th International Marine Mammals of the Holarctic (Kaliningrad, Russia October 11–15, 2010), pp. 134-140.

Gosselin, J.-F., Doniol-Valcroze, T. and Hammill, M.O. 2013. Abundance estimate of beluga in eastern Hudson Bay and James Bay, summer 2011. Fisheries and Oceans Canada, Canadian Science Advisory Secretariat Research Document 2013/016.

Greenland Institute of Natural Resources (GINR). 2016. CITES non detriment findings for havpattedyr i Grønland 2016. Greenland Institute of Natural Resources. CITES Scientific Authority in Greenland.

Grebmeier, J.M. 2012. Shifting Patterns of Life in the Pacific Arctic and Sub-Arctic Seas. Annual Review of Marine Science, 4: 63-78.

Hamilton, C.D., Lydersen, C., Ims, R.A. and Kovacs, K.M. 2015. Predictions replaced by facts: a keystone species' behavioural responses to declining arctic sea-ice. Biology Letters, 11: 20150803.

Hamilton, C.D., Lydersen, C., Ims, R.A., and Kovacs, K.M. 2016. Coastal habitat use by ringed seals *Pusa hispida* following a regional sea-ice collapse: importance of glacial refugia in a changing Arctic. Marine Ecology Progress Series, 545: 261–277.

Hammill, M.O. and Stenson, G.B. 2006. Abundance of Northwest Atlantic hooded seals (1960–2005). Fisheries and Oceans Canada, Canadian Science Advisory Secretariat Research Document 2006/068.

Hammill, M.O., Stenson, G.B., Doniol-Valcroze, T. and Mosnier, A. 2015. Conservation of northwest Atlantic harp seals: Past success, future uncertainty? Biological Conservation, 192: 181-191.

Han, J.B., Sun, F.Y., Gao, X.G., He, C.B., Wang, P.L., Ma, Z.Q. and Wang Z.H. 2010. Low microsatellite variation in spotted seal (*Phoca largha*) shows a decrease in population size in the Liaodong Gulf colony. Annales Zoologici Fennici, 47: 15-27.

Harwood, L.A., Smith, T.G., Auld, J.C., Melling, H. and Yurkowski, D.J. 2015. Seasonal movements and diving of ringed seals, *Pusa hispida*, in the Western Canadian Arctic, 1999-2001 and 2010-11. Arctic, 68(2).

Harwood, L.A., Smith, T.G., Melling, H., Alikamik, J. and Kingsley, M.C.S. 2012. Ringed seals and sea ice in Canada's western Arctic: harvest based monitoring 1992-2011. Arctic, 65: 377–390.

Hay, K., Aglukark, D., Igutsaq, D., Ikkidluak, J. and Mike, M. 2000. Final Report of the Inuit Bowhead Knowledge Study. Nunavut Wildlife Management Board, Iqaluit, Nunavut, Canada.

Heide-Jørgensen M.P. and Laidre K. 2006. Greenland's Winter Whales: the beluga, the narwhal and the bowhead whale. Ilinniusiorfik Undervisningsmiddelforlag, Nuuk, Greenland.

Heide-Jørgensen M.P., Laidre, K.L., Burt, M.L., Borchers, D.L., Hansen, R.G., Rasmussen, M. & Fossette, S. 2010. Abundance of narwhals (*Monodon monoceros*) in Greenland. Journal of Mammalogy, 91:1135-1151.

Heide-Jørgensen, M.P., Laidre, K.L., Fossette, S., Rasmussen, M., Nielsen, N.H. and Hansen R.G. 2013. Abundance of walruses in Eastern Baffin Bay and Davis Strait. NAMMCO Scientific Publications 9.

Heide-Jørgensen M.P., Sinding, M.-H.S., Nielsen, N.H. Rosing-Asvid, A. and Hansen R.G. 2016. Large numbers of marine mammals winter in the North Water Polynya. Polar Biology, 39(9) 1605-1614.

Hindell, M.A., Lydersen, C., Hop, H. and Kovacs, K.M. 2012. Pre-partum diet of adult female bearded seals in years of contrasting ice conditions. PLoS ONE, 7(5): e38307.

Hovelsrud, G.K., McKenna, M. and Huntington, H.P. 2008. Marine mammal harvests and other interactions with humans. Ecological Applications, 18(sp2): S135-S147.

Huntington, H., L. Quakenbush, and M. Nelson. 2016. Effects of changing sea ice on marine mammals and subsistence hunters in northern Alaska from traditional knowledge interviews. Biology Letters 12(8): 20160198.

Ice Seal Committee. 2012. Ice Seal Management Plan. Ice Seal Committee.

Ice Seal Committee. 2014. The Subsistence Harvest of Ice Seals in Alaska-a Compilation of Existing Information, 1960-2012. Ice Seal Committee.

Innes, S., Heide-Jørgensen, M.P., Laake, J.L., Laidre, K.L., Cleator, H.J., Richard, P.R. and Stewart, R.E.A. 2002. Surveys of belugas and narwhals in the Canadian high Arctic in 1996. NAMMCO Scientific Publications, 4:147-190.

International Council for the Exploration of the Sea (ICES). 2013. Report of the Working Group on Harp and Hooded Seals (WGHARP) 26-30 August 2013. ICES CM 2013/ACOM: 20, PINRO, Murmansk, Russia.

International Council for the Exploration of the Sea (ICES). 2016. Report of the ICES/NAFO/NAMMCO Working Group on Harp and Hooded Seals (WGHARP), 26-30 September 2016. ICES CM 2016/ACOM: 21, ICES, Copenhagen, Denmark.

International Union for the Conservation of Nature (IUCN) Polar Bear Specialist Group (PBSG). 2013. Status table for all 19 polar bear subpopulations.

International Union for the Conservation of Nature (IUCN) Polar Bear Specialist Group (PBSG). 2016. IUCN SSC Polar Bear Specialist Group (PBSG), Online.

International Union for the Conservation of Nature (IUCN) Polar Bear Specialist Group (PBSG). 2017. IUCN/Polar Bear Specialist Group - Status table for the world's polar bear subpopulations, Online.

Inuit Circumpolar Council-Alaska (ICC-Alaska). 2015. Alaskan Inuit Food Security Conceptual Framework: How to Assess the Arctic from an Inuit Perspective. Technical Report. Anchorage, Alaska.

Jay, C.V., Grebmeier, J.M., Fischbach, A.S., Mcdonald, T.L., Cooper, L.W. and Hornsby, F. 2014. Pacific walrus (*Odobenus rosmarus divergens*) resource selection in the northern Bering Sea. PLoS ONE, 9(4).

Kalxdorff, S.B. 1997. Collection of local knowledge regarding polar bear habitat use in Alaska. U.S. Fish and Wildlife Service Technical Report MMM 97-2, Anchorage, Alaska.

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

Kingsley, M.C.S. 1998. The numbers of ringed seals (*Phoca hispida*) in Baffin Bay and adjacent waters. *In*: M.P. Heide-Jørgensen and C. Lydersen (eds.). NAMMCO Scientific publications Vol. 1, Tromsø, Norway.

Kochnev, A., Etylin, V.M., Kavry, V.I., Siv-Siv, E.B. and Tanko, I.V. 2003. Traditional knowledge of Chukotka Native Peoples regarding polar bear habitat use. Chukotka Association of Traditional Marine Mammal Hunters, Alaska Nanuuq Commission, and Pacific Fisheries Research Center, Anadyr, Russia.

Kotierk, M. 2010. Elder and Hunter Knowledge of Davis Strait Polar Bears, Climate Change and Inuit Participation. Department of Environment, Government of Nunavut.

Kovacs, K.M. (ed). 2014. Circumpolar Ringed Seal (*Pusa hispida*) Monitoring – CAFF Ringed Seal Monitoring Network. Norwegian Polar Institute Report Series No. 143.

Kovacs, K.M. and Lydersen, C. 2008. Climate change impacts on seals

and whales in the North Atlantic Arctic and adjacent shelf seas. Science Progress, 91(2): 117-150.
Kovacs, K.M., Moore, S., Overland, J.E. and Lydersen, C. 2011. Impacts of changing sea-ice conditions on Arctic marine mammals. Marine Biodiversity, 41(1): 181-194.
Kovacs, K.M., Aguilar, A., Aurioles, D., Burkanov, V., Campagna, C., Gales, N., Gelatt, T., Goldsworthy, S., Goodman, S.J., Hofmeyr, G.J.G., Härkönen, T., Lowry, L., Lydersen, C., Schipper, J., Sipilä, T., Southwell, C., Stuart, S., Thompson, D. and Trillmich, F. 2012. Global threats to pinnipeds. Marine Mammal Science, 28(2): 414-436.
Kovacs, K.M., Aars, J. and Lydersen, C. 2014. Walruses recovering after 60+ years of protection in Svalbard, Norway. Polar Research. 33: 26034.
Kovacs, K.M., Lemons, P., MacCracken, J. and Lydersen, C. 2015. Walruses in a Time of Climate Change. *In*: Arctic Report Card 2015, National Oceanic and Atmospheric Administration.
Krafft, B. A., Kovacs, K. M., Andersen, M., Aars, J., Lydersen, C., Ergon, T. and T. Haug. 2006. Abundance of ringed seals (*Pusa hispida*) in the fjords of Spitsbergen, Svalbard, during the peak molting period. Marine Mammal Science, 22: 394-412.
Laidre, K.L., Stirling, I., Lowry, L.F., Wiig, Ø., Heide -Jørgensen, M.P. and Ferguson, S.H. 2008. Quantifying the sensitivity of Arctic marine mammals to climate induced habitat change. Ecological Applications, 18(sp2): S97-S125.
Laidre, K.L., Stern, H., Kovacs, K.M., Lowry, L., Moore, S., Regehr, E., Ferguson, S., Wig, O., Boveng, P., Angliss, R., Born, E., Litovka, D., Quakenbush, L., Lydersen, C., Vongraven, D. and Ugarte, F. 2015. Arctic marine mammal population status, sea ice habitat loss, and conservation recommendations for the 21st Century. Conservation Biology, 29(3): 1-14.
Lefebvre, K.A., Quakenbush, L., Frame, E., Burek-Huntington, K., Sheffield, G., Stimmelmayr, R., Bryan, A., Kendrick, P., Ziel, H., Goldstein, T., Snyder, J.A., Gelatt, T., Gulland, R., Dickerson, B. and Gill, V. 2016. Prevalence of algal toxins in Alaskan marine mammals foraging in a changing arctic and subarctic environment. Harmful Algae, 55: 13-24.
Litovka D.I. 2013. Ecology of Anadyr stock of Beluga whale *Delphinapterus leucas* (Pallas, 1778). Ph.D. at Voronezh State University (In Russian), September 25, 2013.
Lowry, L. F., Frost, K. J., Zerbini, A., DeMaster, D. and Reeves, R.R. 2008. Trend in aerial counts of beluga or white whales (*Delphinapterus leucas*) in Bristol Bay, Alaska, 1993-2005. Journal of Cetacean Research and Management, 10: 201-207.
Lydersen, C., Chernook, V.I., Glazov, D.M., Trukhanova, I.S. and Kovacs K.M. 2012. Aerial survey of Atlantic walruses (*Odobenus rosmarus rosmarus*) in the Pechora Sea, August 2011. Polar Biology, 35: 1555–1562.
Marcoux, M., Young, B.G., Asselin, N.C., Watt, C A., Dunn, J.B., and Ferguson, S.H. 2016. Estimate of Cumberland Sound beluga (*Delphinapterus leucas*) population size from the 2014 visual and photographic aerial survey. Fisheries and Oceans Canada, Canadian Science Advisory Secretariat Research Document, 2016/037. (Erratum: October 2016)
McKinney, M.A., Iverson, S.J., Fisk, A.T., Sonne, C., Rigét, F.F., Letcher, R.J., Arts, M.T., Born, E.W., Rosing-Asvid, A. and Dietz, R. 2013. Global change effects on the long-term feeding ecology and contaminant exposures of East Greenland polar bears. Global Change Biology, 19(8): 2360-2372.
Moore, S.E. and H. Huntington. 2008. Arctic marine mammals and climate change: impacts and resilience. Ecological Applications, 18(sp2): S157-S165.
Moore, S.E., Logerwell, E., Eisner, L., Farley Jr., E.V., Harwood, L.A., Kuletz, K., Lovvorn, J., Murphy, J.R., and Quakenbush, L.T. 2014. Chapter 11: Marine Fishes, Birds and Mammals as Sentinels of Ecosystem Variabilityand Reorganization in the Pacific Arctic Region. *In*: J.M. Grebmeier and W. Maslowski (eds.). The Pacific Arctic Region: Ecosystem Status and Trends in a Rapidly Changing Environment. Springer, Netherlands, pp 337-392.
North Atlantic Marine Mammal Commission (NAMMCO). 2015. Report of the 22nd Meeting of the NAMMCO Scientific Committee.
North Atlantic Marine Mammal Commission (NAMMCO)/Joint Commission on Conservation and Management of Narwhal and Beluga Scientific Group (JCNB). 2015. Report of the Joint Meeting of the NAMMCO scientific working group on the population status of narwhal and beluga in the North Atlantic and the Canada/Greenland Joint Commission on Conservation and Management of Narwhal and Beluga Scientific Group. "Annex 2" *In:* Report of the 22nd Meeting of the NAMMCO Scientific Committee, pp 94-126.
National Oceanic and Atmospheric Administration (NOAA) Fisheries. 2011. 2011 Arctic Seal Disease Outbreak; Update on Investigation and Findings. NOAA Fisheries, National Oceanic and Atmospheric Administration.
National Oceanic and Atmospheric Administration (NOAA) Fisheries. 2013. Arctic Open Water Meeting Report. NOAA Fisheries, National Oceanic and Atmospheric Administration.
Øigård, T.A., Lindstrom, U., Haug, T. Nilssen, K.T. and Smout, S.2013. Functional relationship between harp seal body condition and available prey in the Barents Sea. Marine Ecology Progress Series, 484: 287-301.
Øigård, T.A., Haug, T. and Nilssen, K.T. 2014. Current status of hooded seals in the Greenland Sea. Victims of climate change and predation? Biological Conservation, 172: 29-36
Polar Bear Range States. 2015. Circumpolar Action Plan: Conservation Strategy for Polar Bears. A product of the representatives of the parties to the 1973 Agreement on the Conservation of Polar Bears.
Polar Bear Technical Committee. 2013. Population status table for North American polar bear subpopulations.
Raymond-Yakoubian, J., Topkok, M., Simonis, O., Pootoogooluk, H., Kowchee, M., Sinnok, J. and Weyapuk, W. 2014. Indigenous Knowledge & Use of Bering Strait Region Ocean Currents. Kawerak, Inc., Alaska.
Reeves, R.R., Ewins, P.J., Agbayani, S., Heidi-Jorgensen, M.P., Kovacs, K.M., Lydersen, C., Suydam, R., Elliott, W., Polet, G., van Dijk, Y. and Blijleven, R. 2014. Distribution of endemic cetaceans in relation to hydrocarbon development and commercial shipping in a warming Arctic. Marine Policy, 44: 375-389.
Regehr, E.V., Hunter, C.M., Caswell, H., Amstrup, S.C. and Stirling, I. 2010. Survival and breeding of polar bears in the southern Beaufort Sea in relation to sea-ice. Journal of Animal Ecology, 79(1): 117–127.
Rekdal S.L, Hansen, R.G., Borchers, D., Bachmann, L., Laidre, K. L., Wiig, Ø., Nielsen, N.H., Fossette, S. Tervo, O. and Heide-Jørgensen, M.P. 2014. Trends in bowhead whales in West Greenland: Aerial surveys vs. genetic capture-recapture analyses. Marine Mammal Science, 31(1): 133-154.
Richard, P.R. 2005. An estimate of the western Hudson Bay beluga population size in 2004. Fisheries and Oceans Canada, Canadian Science Advisory Secretariat Research Document 2005/017.
Richardson, W.J. (ed). 1999. "Monitoring and mitigation". *In:* R.C. Gisiner (ed.). Proceedings/workshop on the effects of anthropogenic noise in the marine environment, Bethesda, MD, Feb. 1998. Office of Naval Research, Arlington, Virginia, pp 97-117.
Richardson, W.J. 2004. Marine mammals versus seismic and other acoustic surveys: introduction to the noise issues. Polarforschung, Bremerhaven, Alfred Wegener Institute for Polar and Marine Research and German Society of Polar Research, 72(2/3): 63-67.
Sandell, H.T., Sandell, B., Born, E.W., Dietz, R. and Sonne-Hansen, C. 2001. Isbjørne i Østgrønland: En interviewundersøgelse om forekomst og fangst. Teknisk rapport nr. 40. Greenland Institute of Natural Resources.
Simpkins, M., Kovacs, K.M., Laidre, K. and Lowry, L. 2009. A framework for monitoring Arctic marine mammals. CAFF CBMP Report No. 16, CAFF International Secretariat, Akureyri, Iceland.
Sjare, B. and G.B. Stenson. 2010. Changes in the Reproductive Parameters of Female Harp Seals (*Pagophilus groenlandicus*)

in the Northwest Atlantic. ICES Journal of Marine Science, 67: 304-315.

Slavik, D. 2012. Inuvialuit Knowledge of Nanuq: Community and Traditional Knowledge of Polar Bears in the Inuvialuit Settlement Region. Inuvialuit Settlement Region Hunters and Trappers Committees, the Wildlife Management Advisory Councils for the North Slope and Northwest Territories and the Inuvialuit Game Council.

Smith, T. G. 1975. Ringed seals in James Bay and Hudson Bay: population estimates and catch statistics. Arctic, 28: 170-182.

Speckman, S.G., Chernook, V.I., Burn, D.M., Udevitz, M.S., Kochnev, A.A. Jay, C.V., Lisovsky, A., Fischbach, A.S. and Benter R.B. 2011. Results and evaluation of a survey to estimated Pacific walrus population size, 2006. Marine Mammal Science, 27: 51-553.

Southall, B.L., Bowles, A.E., Ellison, W.T., Finneran, J.J., Gentry, R.L., Greene Jr., C.R., Kastak, D., Ketten, D.R., Miller, J H., Nachtigall, P.E., Richardson, J.W., Thomas, J.A. and Tyack, P.L. 2007. Marine mammal noise exposure criteria: initial scientific recommendations. Aquatic Mammals, 33(4): 411-522.

Social Science Program. 2014. Indigenous Knowledge and use of Bering Strait Region Ocean Currents. Natural Resources Division, Kawerak Inc.

Stenson, G.B. and Hammill, M.O. 2014. Can ice breeding seals adapt to habitat loss in a time of climate change? ICES Journal of Marine Science, 71(7): 1977-1986.

Stenson, G.B., Buren, A.D. and Koen-Alonso, M. 2016. The impact of changing climate and abundance on reproduction in an ice-dependent species, the Northwest Atlantic harp seal, *Pagophilus groenlandicus*. ICES Journal of Marine Science, 73(2): 250-262.

Stern, H.L. and Laidre, K.L. 2016. Sea-ice indicators of polar bear habitat. The Cryosphere, 10: 2027-2041.

Stewart, R.E.A, Born, E.W., Dunn, J.B., Koski, W.R. and Ryan, A.K. 2013a. Use of multiple methods to estimate walrus (*Odobenus rosmarus rosmarus*) abundance in the Penny Strait-Lancaster Sound and West Jones Sound stocks, Canada. NAMMCO Scientific Publication, 9.

Stewart, R.E.A., Born, E.W., Dietz, R. and Ryan, A.K. 2013b. Estimates of minimum population size for walrus around Southeast Baffin Island, Nunavut. NAMMCO Scientific Publications, 9.

Stewart, R.E.A., Born, E.W., Dietz, R., Heide-Jørgensen, M.P., Rigét, F.F., Laidre, K., Villum Jensen, M., Knutsen, L.Ø., Fossette, S. and Dunn, J.B. 2013c. Abundance of Atlantic walrus in western Nares Strait, Baffin Bay stock, during summer. NAMMCO Scientific Publications, 9.

Stewart, R.E.A., Hamilton, J.W. and Dunn, J.B. 2013d. Results of Foxe Basin walrus (*Odobenus rosmarus rosmarus*) surveys: 2010-2011. Fisheries and Oceans Canada, Canadian Science Advisory Secretary Research Document 2013/017.

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

Stirling, I., Lunn, N.J. and Iacozza, J. 1999. Long-term trends in the population ecology of polar bears in western Hudson Bay in relation to climatic change. Arctic, 52(3): 294–306.

Stirling, I., Spencer, C. and Andriashek, D. 2016. Behavior and activity budgets of wild breeding polar bears (*Ursus maritimus*). Marine Mammal Science, 32(1): 13-37.

Towns, L., Derocher, A.E., Stirling, I., Lunn, N.J. and Hedman, D. 2009. Spatial and temporal patterns of problem polar bears in Churchill, Manitoba. Polar Biology, 32(10): 1529-1537.

Udevitz, M.S., Taylor, R.L., Garlich-Miller, J., Quakenbush, L.T. and Snyder, J. 2013. Potential population-level effects of increased haulout-related mortality of Pacific walrus calves. Polar Biology, 36(2): 291-298.

Vongraven, D., Aars, J., Amstrup, S., Atkinson, S.N., Belikov, S., Born, E.W., DeBruyn, T.D., Derocher, A.E., Durner, G., Gill, M., Lunn, N., Obbard, M.E., Omelak, J., Ovsyanikov, N., Peacock, E., Richardson, E., Sahanatien, V., Stirling, I. and Wiig, O. 2012. A circumpolar monitoring framework for polar bears. Ursus, 23(sp2): 1-66.

Voorhees, H., Sparks, R., Huntington, H.P. and Rode, K.D. 2014. Traditional knowledge about polar bears (*Ursus maritimus*) in Northwestern Alaska. Arctic, 67(4): 523-536.

Voorhees, H. and Sparks, R. 2012. Nanuuq: Local and traditional ecological knowledge of polar bears in the Bering and Chukchi Seas. Alaska Nanuuq Commission, Nome, Alaska.

Wiig, Ø, Bachmann, L., Heide-Jørgensen, M.P., Lindquist, C., Laidre, K.L., Postma, L., Dueck, L., Palsbøll, P. and Bachmann, L. 2011. Recaptures of genotyped bowhead whales (*Balaena mysticetus*) in Eastern Canada and West Greenland. Endangered Species Research, 14: 235-242.

Wiig, Ø., Bachmann, L., Øien, N., Kovacs, K.M. and Lydersen, C. 2010. Observations of bowhead whales (*Balaena mysticetus*) in the Svalbard area 1940-2009. Polar Biology, 33: 979-984.

Tagging narwhal in Greenland.
Photo: Carsten Egevang/ARC-PIC.com