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MARINE MAMMAL HARVESTS AND OTHER INTERACTIONS WITH HUMANS

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Abstract. The Arctic is currently undergoing rapid social and environmental changes, and while the peoples of the north have a long history of adapting, the current changes in climate pose unprecedented challenges to the marine mammal–human interactions in the Arctic regions. Arctic marine mammals have been and remain an important resource for many of the indigenous and nonindigenous people of the north. Changes in climate are likely to bring about profound changes to the environment in which these animals live and subsequently to the hunting practices and livelihoods of the people who hunt them. Climate change will lead to reduction in the sea ice extent and thickness and will likely increase shipping through the Northern Sea Route and the Northwest Passage and oil and gas activities in Arctic areas previously inaccessible. Such activities will lead to more frequent interactions between humans and marine mammals. These activities may also change the distribution of marine mammals, affecting the hunters. This paper has three parts. First, an overview of marine mammal harvesting activities in the different circumpolar regions provides a snapshot of current practices and conditions. Second, case studies of selected Arctic regions, indigenous groups, and species provide insight into the manner in which climate change is already impacting marine mammal harvesting activities in the Arctic. Third, we describe how climate change is likely to affect shipping and oil and gas exploration and production activities in the Arctic and describe the possible implications of these changes for the marine mammal populations. We conclude that many of the consequences of climate change are likely to be negative for marine mammal hunters and for marine mammals. Lack of adequate baseline data, however, makes it difficult to identify specific causal mechanisms and thus to develop appropriate conservation measures. Nonetheless, the future of Arctic marine mammals and human uses of them depends on addressing this challenge successfully.

Key words: Arctic; climate change; human interactions; hunting; impacts; marine mammals; offshore activities; shipping.

Introduction

The Arctic is currently undergoing rapid social and environmental changes, and their cumulative effects are felt across the region (e.g., according to the Arctic Human Development Report (AHDR); Einarsson et al. 2004). Environmental and seasonal cycles are an integral part of the coupled human–environment system, and the peoples of the north have a long tradition in adapting to shifting environmental conditions. However, the Arctic Climate Impact Assessment (ACIA) shows that the rapidity and pervasiveness of current and projected climate change pose new challenges to the adaptive capacity of local communities and Arctic societies (ACIA 2005). In this paper, we describe the relationships between climate change, marine mammals, and human activities in the Arctic today and suggest how these interactions might change under a warming climate. The aim is to illustrate the way in which climate change poses unprecedented challenges to marine mammal–human interactions in Arctic regions.

Most Arctic communities interact in some way with marine mammals. The interactions may be direct through, for example, a community's engagement in hunting, whale watching, or fishing activities. Secondary (or indirect) interactions between humans and marine mammals (also) occur in areas where activities such as shipping and oil and gas exploration intersect or overlap with marine mammal habitat (Freeman et al. 1998, Einarsson et al. 2004). Climate change will bring about profound changes to the Arctic sea ice environment, upon which Arctic marine mammals depend for their survival. These changes are likely to negatively affect the health, reproduction, and abundance of marine mammals, which in turn will have consequences for the culture and socioeconomic systems of the peoples who hunt them (see, for example, AMAP 2002).

At the same time, the intensity of human activities such as shipping and oil and gas exploration in northern regions is expected to increase in the future as sea ice cover diminishes in thickness and extent (Brigham and

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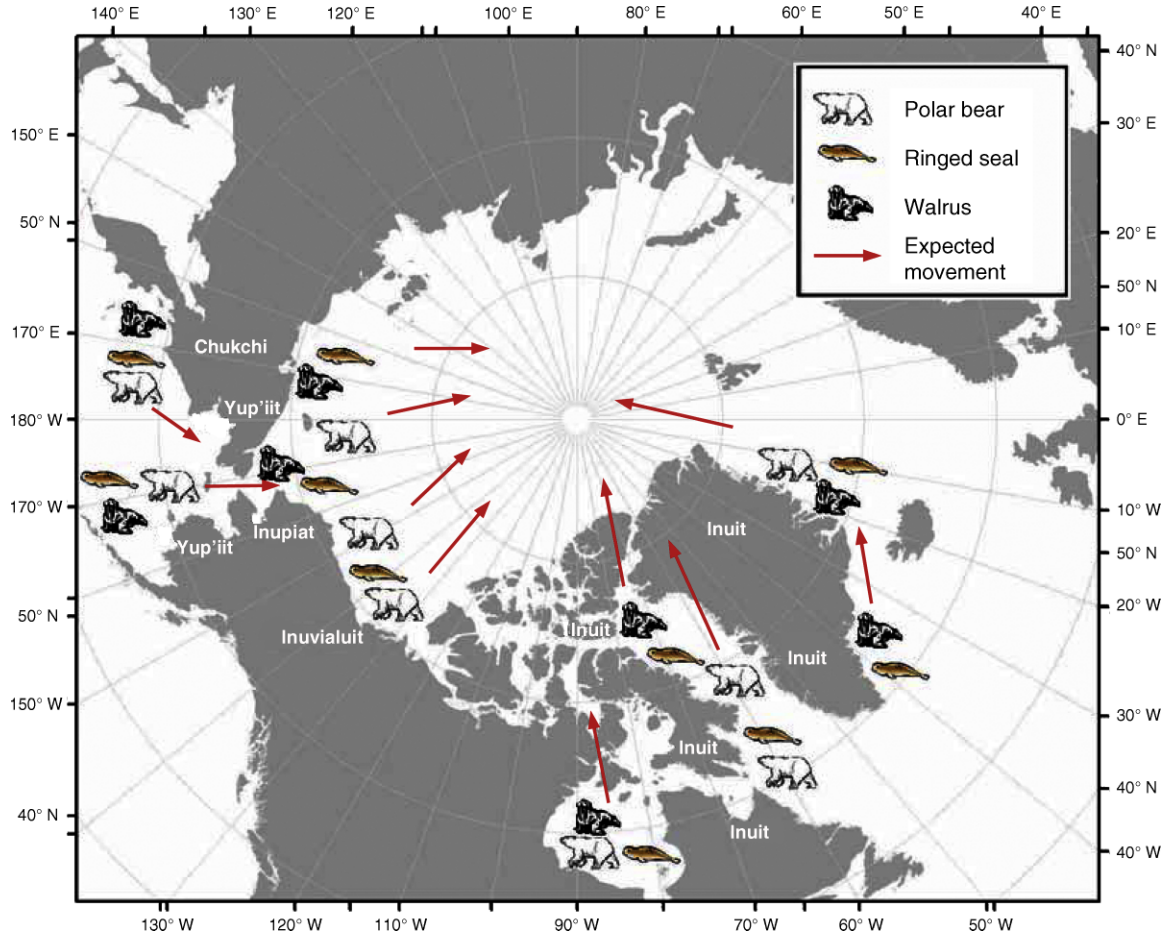

FIG. 1. The general distribution of polar bear (*Ursus maritimus*), ringed seal (*Phoca hispida*), and walrus (*Odobenus rosmarus*), three of the major Arctic marine mammal species harvested by Inuit, Inuvialuit, Yup'iit, and Chukchi (ACIA 2004, Blix 2005). The red arrows indicate the expected northward movement of marine mammals in 2070–2090 following retreating sea ice extent (see Walsh 2008: Fig. 14). Retreating sea ice will impact Arctic marine species as well as the indigenous people who harvest them.

Ellis 2004, ACIA 2005). Growing economic interest in and accessibility to the resources of Arctic areas under future climate scenarios raise concerns about the long-term ecological and socioeconomic viability of Arctic areas.

This paper provides a regional overview of current marine mammal harvesting activities among selected indigenous groups in the circumpolar Arctic, and we discuss how climate change might affect human–marine mammal interactions in the Arctic more generally. We begin by providing an overview of marine mammal harvesting activities in the different circumpolar regions. In the second part, case studies of selected Arctic regions, indigenous groups, and species provide insight into how climate change is already impacting marine mammal harvesting activities in the Arctic. The case studies were selected on the basis of previous knowledge of an area combined with the availability of data. In the final part of the paper, we describe how climate change is likely to affect shipping and oil and gas exploration and production activities in the Arctic and describe the possible implications of these changes for the marine mammal populations.

A number of species of cetaceans and pinnipeds are hunted and utilized in the circumpolar region. We focus here on the core species highlighted throughout this volume: polar bear (*Ursus maritimus*), bowhead whale (*Balaena mysticetus*), beluga (*Delphinapterus leucas*), narwhal (*Monodon monoceros*), walrus (*Odobenus rosmarus*), ringed seal (*Phoca hispida*), and bearded seal (*Erginathus barbatus*). The geographical focus is on the Northwest Territories and Nunavut in Arctic Canada, Greenland, Chukotka, the northwest areas of the Russian Federation, and Alaska, USA (see Figs. 1 and 2).

Overview of Marine Mammal Harvesting Activities by Geographic Region

Nearly four million people live in the Arctic today, including both indigenous and nonindigenous people; some are hunters and herders living on the land, and others are city dwellers (ACIA 2004). Many indigenous

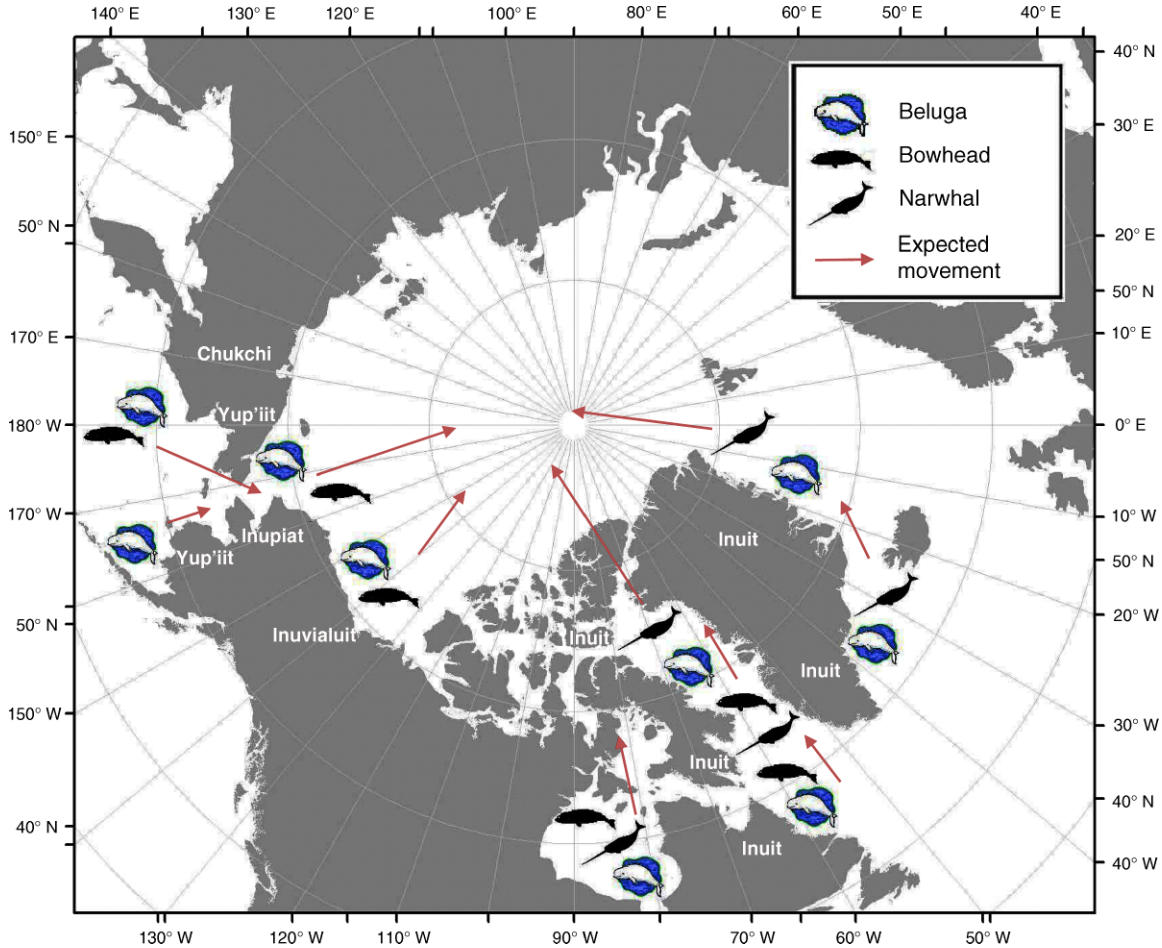

FIG. 2. The general distribution of narwhal (*Monodon monoceros*), beluga (*Delphinapterus leucas*), and bowhead whales (*Balaena mysticetus*), three of the major Arctic marine mammal species harvested by Inuit, Inuvialuit, Yup'iit, and Chukchi (ACIA 2004, Blix 2005). The red arrows indicate the expected northward movement of marine mammals in 2070–2090 following retreating sea ice extent (see Walsh 2008: Fig. 14). Retreating sea ice will impact Arctic marine species as well as the indigenous people who harvest them.

groups are exclusive to the Arctic, such as the Chukchi in the Russian Federation, the Inupiat and Yup'iit in Alaska, USA, the Inuvialuit and Inuit in Arctic Canada, and Greenlanders. Each of these groups continues to practice traditional, natural resource-based activities while simultaneously participating in and adapting to the contemporary world (ACIA 2004).

Many Arctic peoples have always subsisted on the resources of the sea, and they continue this form of livelihood today. Ringed and bearded seals, beluga, bowhead, and narwhal whales, walrus, and polar bears are animals used by Arctic indigenous groups for food, clothing, and other secondary products. These animals figure predominantly in the mixed cash/subsistence economy of local households and communities (Huntington 1992, Nuttall 1992, Hovelsrud-Broda 1999, Caulfield 2000, Dahl 2000). Notably, all of these species depend on sea ice for their survival. Any changes in climatic and sea ice conditions therefore will have consequences for marine mammals and their habitats, with inevitable impacts for the communities that depend on them.

In the context of marine mammal hunting, community vulnerability to climate change is closely linked to the sensitivity and resilience of the harvested animals to such changes. Climate variability has been shown to affect the abundance and availability of marine mammals in the past and will continue to shape the ability of Arctic peoples to harvest and process these animals in the future. Significant changes with respect to the geography of species distribution and composition, animal health, and disease vectors are expected under future climate change (e.g., ACIA 2005). These changes will in turn affect the hunting activities of Arctic indigenous groups.

Participation in marine mammal harvesting among Arctic indigenous groups is not only important for economic purposes but is a crucial factor in the

maintenance of cultural identity and social relationships. The cultural, social, and economic significance of marine mammals varies across cultures and nations. The number and type of species harvested, as well as the methods by which animals are hunted, vary by country, region, and community. Understanding these regional differences is necessary in order to determine potential variations in the consequences of climate change for different groups and is a starting point for considering the specific adaptation needs of each community. Below we discuss the regional differences in marine mammal harvesting activities among various Arctic indigenous groups.

Marine mammal harvesting in Greenland

Greenlandic hunting communities hunt a number of pinniped species (including bearded, hooded [*Cystophora cristata*], ringed, harp [*Phoca groenlandica*], and harbor seals [*Phoca vitulina*], and walrus), polar bears, and whales, including fin (*Balaenoptera physalus*) and minke (*Balaenoptera acutorostrata*) whales, beluga, narwhal, and a number of dolphin species. In general, marine mammals are central to the Greenlandic way of life and are important contributors to the livelihoods, cultural identity, and socioeconomic well-being of Greenlanders. Marine mammals are hunted throughout the year along shores and on ice edges, in the water on ice floes, and on sea ice. Greenlandic hunters travel on ice, on water, or on land to catch desired animals. Larger whales, such as fin and minke, are generally hunted in open water close to the shore, from small vessels equipped with penthrite grenade harpoons and heavy rifles. The generally small size of the vessels limits the range within which hunters are able to travel to catch whales. Walrus are caught on ice floes, on land, and in the water (Caulfield 1997, Hovelsrud-Broda 1997, NAMMCO 2004). Seals are hunted with rifles, in the water, on ice floes from small skiffs, and on sea ice with dog teams or with nets fastened to icebergs. In the open-water season seals are hunted from small boats. The availability of seals and the methods used in seal hunting vary between and within the major regions and between the seasons on Greenland.

During the winter in North Greenland (including Avanersuaq and Qaanaaq), ringed and bearded seals are hunted by their breathing holes in the ice and by netting close to shore. In spring (April to June) seals are hunted while basking on the sea ice, and in summer and early fall (July to September), harp seals appear in the Qaanaaq region and are hunted in the water. Hooded seals have become rare in the Avanersuaq area. This is probably due to the seals moving northward following the decreasing sea ice, which is potentially a result of climate warming (J. Danielson, *personal communication*). In the northern parts of western Greenland, ringed seals are harvested throughout the year, but are the only species hunted in the winter when the hunters travel by dogsled on the ice. Young and adult harp seals appear at the beginning of June and are hunted until November or December. Bearded seals appear during the summer and can be seen until the sea ice appears (NAMMCO 2004). In central western Greenland, harp seals are caught from boats from June to the late fall. They give birth and breed on the sea ice far offshore in spring and are inaccessible to Greenlandic hunters. Hunters in the Maniitsoq region have noted that the frequency of younger harp seals can vary a great deal, depending on ice conditions. Hooded seals appear in April, and newborn seal pups of this species appear on the floe edge or in the drifting ice. The fjords around Sisimiut are no longer covered with ice in the wintertime, and as a consequence, ringed seals are rarely encountered. When the ice conditions in the fjords allow it, ringed seals are caught with nets at the mouth of the fjord. In March and April as the sun grows stronger, numerous seals would be basking in the sun on top of the ice, and until recently they were harvested by hunters walking on the ice or using dog sled. With the sea ice disappearing they are hunted from boats. In southern Greenland, ringed and harp seals are harvested from boats throughout the year, except during their molting period in May and June. Hooded seals frequent the area of Nanortalik from the beginning of April until the end of June.

In east Greenland, bearded and ringed seals are harvested year-round while harp and hooded seals are harvested seasonally. From January until April, ringed seals are caught, at their breathing holes, while basking in the sun on top of the ice, or with nets fastened to sea ice or icebergs (NAMMCO 2004).

Marine mammal harvesting in Arctic Canada

Hunting communities in Nunavut and the Northwest Territories in Arctic Canada harvest a number of seal species, including ringed, bearded, harp, and small numbers of harbor (*Phoca vitulina*) and hooded seals. Polar bears, beluga, narwhal, and occasionally bowhead whale are also important species. In Arctic Canada marine mammal harvesting (along with fishing) provides a considerable source of food for communities, in addition to forming the foundation of indigenous cultures (ACIA 2005). Seal harvesting has always played a central role in Inuit culture, as it sustains traditional sharing customs, maintains knowledge of natural resources and the environment, and ensures the transfer of skills and values from elders to youth. The ringed seal is found throughout the Arctic region but is particularly important to livelihoods in Nunavut, in the eastern Canadian Arctic. The cultural development of the coastal Inuit was supported by the ringed seal because the animal provided a reliable supply of heating oil, meat, and skins. Various hunting techniques are employed to harvest seals, including the stalking of basking seals, harpooning or shooting at breathing holes, and open-water shooting. The majority of seals are shot from a boat in the water. Occasionally, seals are shot while out of the water on ice or rocks. During the

ice-covered seasons, seal harvesting is restricted to ringed and bearded seals.

The bearded seals are permanent residents of the Northwest Territories and are generally found as solitary individuals in areas with moving pack ice, such as leads and polynyas. The availability of benthic feeding areas and pupping areas are crucial to the location of bearded seal populations (NAMMCO 2004). Bearded seals have a tough, flexible hide and are valued for utilitarian purposes, such as lines, traces, kayak coverings, and *kamik* (boot) soles. The meat is also suitable for human and dog food.

Polar bears, beluga, narwhal, and walrus and the occasional bowhead whale are also harvested for food and are an important source of protein for local residents. The Inuit and Inuvialuit harvest whales from the Davis Strait, Baffin Bay, and Foxe Basin–Hudson Bay stocks, although recent tracking indicates that these stocks may be less distinct than previously thought (see Laidre et al. 2008). Traditional hunting methods and modern equipment are combined to make harvests efficient.

Marine mammal harvesting in Chukotka, Russian Federation

Since the break-up of the Soviet Union and subsequent changes to Chukotka's economy and organization, the Chukchi and the Yup'iit peoples of northeastern Russia have resumed some small-scale, sustainable, traditional whaling and sealing activities. The Chukchi have formed their own marine mammal management organization, the Chukotka Marine Mammal Hunting Association, whose goal is "To preserve the aboriginal habitat and traditional subsistence of Chukotka Native peoples" (V. Yetylin, *personal communication*). The main species targeted are gray (*Eschrichtius robustus*), bowhead, and beluga whales, walrus, and bearded, ringed, spotted (*Phoca largha*), and ribbon (*Phoca fasciata*) seals. Narwhal is a protected species in Russia, but is not found in Chukotka.

The main method of seal hunting is netting, both from the ice and in open water. The ringed seal is the most commonly hunted seal and is taken on the ice or in open water at all times of the year. Other seal species appear in the spring when the sea ice breaks up and depart in the late fall when the sea freezes and are harvested when they are present in the hunting areas. Bearded seals are large and very cautious animals and require specialized hunting methods. In the spring and summer, bearded seals haul out on the ice and are hunted by carefully stalking the animal to within firing range. In the fall they haul out on the new ice edge and are hunted from boats (NAMMCO 2004; V. Yetylin, *personal communication*). In the summer seals are shot from boats, floating ice, or hiding places on shore. In the spring and early summer seals are harvested as they lie on the ice by their breathing holes. In the fall and winter seals are hunted from the ice edge or at open water leads. Some hunters also hunt seals at the breathing hole using traditional methods (NAMMCO 2004).

The people of Chukotka harvest the Pacific walrus (*Odobenus rosmarus divergens*) in the Chukchi and the Bering Seas, on the Pacific coast from the spring until the fall, and on the Arctic coast in the summer and in the fall. The walrus come in the spring when the sea ice breaks up and leave in the late fall when the seas start freezing. Walrus hunting methods vary with the seasons. They have been developed over many centuries and are currently maintained by the present generation (NAMMCO 2004). Almost all marine mammal hunting settlements of Chukotka are located near the coastal walrus haul-outs, where the walrus only appear when the ice disappears from the sea. In the Bering Sea the summer coastal haul-outs form in the middle of July, while in the Chukchi Sea the haul-outs form at the end of August and in September. The harvesting season starts in spring when the walrus migrate with the passing ice. Ice haul-outs are the favored resting place of the walrus. They choose mainly the edge of pack ice but sometimes female walrus with calves are found in the center of the pack. In large herds on the ice the walrus tend not to be as alert as when they are in smaller groups. In an ideal situation the hunters will debark onto the ice floe with the walrus or on a neighboring ice floe.

Small numbers of bowhead and beluga whales are taken in Chukotka, most commonly in fall. The bowhead harvest allocation for Chukotka in 2003 was five whales, of which three were harvested.

Marine mammal harvesting in Alaska, USA

Bowhead whales harvested in the United States and in Russia follow a migratory route through the Bering-Chukchi and Beaufort Seas. For Inupiat and St. Lawrence Island Yup'iik whalers, "shorefast ice provides an essential platform for winter and spring hunting, particularly for the bowhead whale during its annual spring migration along the Alaska coast of the Chukchi Sea" (George et al. 2004:363). Successful hunting depends on the hunters' understanding and knowledge of the ice (Nelson 1969, George et al. 2004). Additional communities harvest bowhead whales in the fall in open water (Freeman et al. 1998). In both seasons, whalers use toggle-head harpoons attached by line to floats and black-powder or penthrite grenades. Black-powder grenades were introduced by commercial whalers in the 1800s, whereas penthrite grenades are more recent improvements, using more powerful explosives designed to achieve a faster kill (Øen 1995).

The quota set by the International Whaling Commission for this stock of bowhead whales is a total of 280 for the five-year period 2003–2007, with a maximum harvest in any given year of 140. The quota is shared between Alaska and Chukotka, but most whales are allocated to and caught by Alaskan hunters.

Beluga whales are found in five stocks around Alaska (O'Corry-Crowe et al. 1997), all of which are hunted. Hunting methods vary by region and season and include harpooning from boat and ice edge, netting, and driving whales into shallow water (e.g., Freeman et al. 1998). With the exception of Cook Inlet in southern Alaska (and thus outside the Arctic), there are no restrictions on beluga hunting in Alaska other than that the take not be wasteful. Total harvest of the four stocks in the Bering, Chukchi, and Beaufort seas has been between 200 and 400 animals a year between 1988 and 2004 (K. J. Frost and R. S. Suydam, *unpublished manuscript*).

The bearded seal inhabits areas of the Bering, Chukchi, and Beaufort seas where sea ice forms during the winter. Productive bearded seal hunting begins during late April in the northern Bering Sea area and progressively later at the more northerly villages. In Alaska, ringed seals inhabit the northern Bering, Chukchi, and Beaufort seas. They have been found as far south as the Aleutian Islands. Ringed seals are hunted by Alaska coastal residents from Mekoryuk to Kaktovik. The meat is mainly processed as human food, while the skins are used for clothing, equipment, and crafts. Several thousand seals are harvested annually.

Walrus are hunted from Bristol Bay in the southeastern Bering Sea to Barrow in the northern Chukchi Sea, with the largest harvests occurring in the Bering Strait region. Most hunting occurs on ice floes when boat travel is possible, but some walrus are hunted on land. Open-water hunts are less successful due to the potential for the animal to sink. Walrus are typically shot with a high-powered rifle, and a harpoon and float are attached if possible to reduce the chance of losing the walrus to sinking. Several hundred walrus are taken each year in Alaska (Huntington 1992, NAMMCO 2004).

Climate Change, Marine Mammals, and Humans: Case Studies

The following case studies discuss marine mammal harvesting and other human interactions in the context of existing culture, economy, governance, and management regimes in selected Arctic regions. In the first case study we explore the ways in which climate change is affecting marine mammal habitat in Nunavut, Canada, and the resulting challenges to the culture, diets, economy, and traditional knowledge of Inuit who hunt them. The second case study explores interactions between climate change, bear-harvesting activities, and direct human–bear encounters. In both studies, the emphasis is on how climate change is likely to affect harvesting and other interactions with marine mammals and the potential consequences of these changes for the communities that depend on marine mammals.

Case study 1: Climate change impacts on marine mammal harvesting among the Inuit of Nunavut, Canada

Despite the specialized knowledge held by the contemporary Inuit regarding the ocean and sea ice environment, their knowledge is often absent in discussions of the effects of climate change on marine mammal harvesting. However, there is increasing recognition that indigenous perspectives on climate change complement "scientific" observations and data (ACIA 2005). The inclusion of Inuit perspectives on climate change as a case study in this paper highlights the need for greater integration and feedback between the two knowledge systems. An integrated perspective will enhance the development of credible indicators and measures of climate change and its effects on marine mammal harvesting activities. It will also greatly facilitate the identification and development of effective local adaptation strategies.

The ancestors of today's Inuit, the Sivullirmuit, travelled along the coast of the Bering Strait between Alaska and Greenland, establishing hunting villages where they could most easily access resources. Eventually, these people became known as the Thule, credited with developing the weapons, boats, and skills that were required to hunt larger marine mammals such as bowhead and beluga whales. Innovations in harvesting methods enabled the Thule people to migrate from the north coast of Alaska to inhabit northern Canada, the present geographic home of the Inuit. Although few contemporary Inuit are nomadic and most now live within permanent settlements, the ocean and sea ice environments and activities associated with them continue to provide a source of food and income for Inuit communities and remain vital for the maintenance and continuation of Inuit culture and society (Reid et al. 1994).

Changes in the Arctic ecosystem leading to shifts in the traditional locations and abundance of food supply as a result of climate change will affect all aspects of Inuit community life and well-being (Nickels et al. 2002:304). As pointed out in other papers, the extent of sea ice in Arctic regions has declined considerably over the last century. Such changes have also been documented by the Inuit themselves (see Table 1). The ACIA predicts that the extent of sea ice in the Nunavut region will decline by an additional 10–50% by the year 2100 (ACIA 2004). Although the average annual decrease in sea ice extent is likely to be small, the projected reduction in summer sea ice is significant (ACIA 2004, Walsh 2008). According to Inuit observations, degradation in the quality and extent of the sea ice is already evident in Arctic regions, and these changes are impacting Inuit harvesting activities.

Continued loss of sea ice in the future will pose particular challenges for hunting activities in the spring and fall seasons, disrupting the social, cultural, and economic factors of Inuit community life.

More than 80% of Inuit in the Canadian Arctic hunt, fish, and trap marine mammals and other wildlife (Reid et al. 1994). Following a harvest, marine mammals are normally processed as food. The remaining materials are gathered and utilized to create clothing, tools, and art

TABLE 1. Inuit observations of climate change.

Location	Observation
Arctic Bay	Declines in the number and range of marine mammals, particularly seals.
Arctic Bay [2002] (L. Barnabus, *personal communication*)	"Strong south wind detached mainland ice at the floe edge. Increased personal threat when harvesting marine mammals."
Eastern and northwestern Hudson Bay and the Hudson Strait.	Floe edge melts before breaking up. Beluga whales have decreased in numbers along the coast and have are travelling in currents farther offshore. Walrus have shifted away from the Belcher Islands.

(Nuttall et al. 2005). For example, by-products such as ivory from the tusks of walrus and narwhal are crafted into jewelry and carvings, which drive Nunavut's arts and crafts industry. Other important by-products of marine mammal harvests include sealskin pelts, which in 2002 contributed more than $500 000 (in Canadian dollars) to the economy of Nunavut. Furthermore, the cash revenue earned by hunters from the sale of marine mammal by-products is used in part to finance the cost of future hunts. This helps to maintain the subsistence economy as well as valuable traditional hunting skills.

The household harvesting of marine mammals also has an important nutritional significance. The traditional diet of Inuit includes the consumption of narwhal, beluga, and bowhead whales as well as seal species such as the ringed, bearded, and harbor seals. If climate change reduces access to traditional hunting grounds, there is likely to be a rise in the consumption of foods imported from southern Canada, which could affect the health and well-being of Inuit families (Ford 2005). Using traditional foods is not only regarded by Inuit as healthier, it is also more economical than purchasing commercial foods. This becomes especially relevant to Inuit who are unemployed or have incomes below the poverty line (Nuttall et al. 2005).

In addition to the economic and nutritional implications for communities of reduced access to marine mammals as a result of diminishing sea ice cover, the loss of traditional hunting grounds will affect the transmission of Inuit culture to future generations. A significant amount of the time that Inuit spend hunting is presently devoted to educating younger generations about weather, ice conditions, and the biology of marine species. These skills and attitudes, which are required for the successful harvesting of marine mammals, are transferable to modern community life and are critical to the preservation of Inuit culture and Nunavut's mixed cash and subsistence economy (S. Watt-Cloutier, *unpublished manuscript*). Loss of marine mammal habitat and hunting opportunities as a result of climate change therefore threatens Inuit culture, in addition to household economy and food security.

There is a danger that with continued climate change environmental and sea ice conditions may become unpredictable and hazardous to the point at which traditional knowledge regarding marine mammal harvesting must be supplemented with modern technology. Many narwhal hunters who harvest at the ice edge during the annual spring break-up must now carry small boats on their sleds to avoid being stranded on drifting ice (Ford 2005). As populations of marine mammals decrease and migrate farther north, Inuit hunters must travel further in order to harvest seals in the spring. The added personal risks associated with unpredictable ice, temperatures, and water currents are raising concerns within communities about the viability of continued marine mammal harvesting (Fox 2002). In response to these challenges, many Inuit choose to combine their traditional knowledge of the environment with modern harvesting tools. Some hunters have begun employing global positioning systems, and VHF radios, while other inquire about weather conditions and consult satellite images of the sea ice. Although effective in the short term, it is uncertain what the long-term costs of adaptation to climate change will entail for the Inuit of Nunavut or how equitable the outcomes will be.

Whether for food and clothing for their families, for the creation and sale of modern sealskin clothing, or for cultural reproduction, marine mammals continue to play a crucial role in the socioeconomy of the Inuit in Nunavut. Climate change will introduce change, challenges, and uncertainty to these interactions in the future. Despite these challenges, future socioeconomic development in Nunavut will continue to depend on the sustainable management of the natural resource base upon which marine mammals depend for their survival.

Case study 2: Altered human–bear interactions as a result of climate change

Polar bears are one of the most carefully managed marine mammal species in the circumpolar world and have been the subject of a sustained international conservation effort for the last three decades (Wenzel 2005). Despite these efforts, polar bear populations are facing unprecedented threats as a result of, on the one hand, increasing human activities and development in Arctic regions, which reduce the bears' habitat, and on the other, rapid degradation of prime sea ice habitat brought about by ongoing climate change. This case study discusses how these combined threats are causing problems for polar bear–human interactions in Arctic regions.

TABLE 2. Global polar bear harvest.

Location of population	Mean annual kill
East Greenland (GL)	80
Kane Basin (GL and CA)	11
Baffin Bay (GL and CA)	147
Davis Strait (GL and CA)	68
Arctic Basin (CA)	None reported
Barents Sea (NO and RU)	2+
Beaufort Sea (CA and US)	82
Northern Canada (CA)	329
Siberia and West Alaska (RU and US)†	Unknown
Total	705

Notes: Data adapted from WWF Denmark (2005). Abbreviations are: GL, Greenland; CA, Canada; RU, Russia; NO, Norway; US, USA.

† Includes the Russian and United States populations determined by the International Union for the Conservation of Nature and Natural Resources, Polar Bear Specialist Group: Chukchi, Laptev, and Kara Seas.

Recent climate change scenarios show that the Arctic will experience major changes in the coming decades. Over the past 30 years, the annual average sea ice extent in Arctic regions has decreased by ~8%, or nearly 1×10^6 km^2, and the melting trend is accelerating (ACIA 2004). Furthermore, the sea ice has become thinner, with Arctic-wide average thickness reductions up to 40% between the 1960s and the late 1990s (ACIA 2004). Inuit observations of sea ice conditions support these trends (see Nunavut Tunngavik 2005). Through their continued effects on the sea ice habitat of polar bears, these changes have also resulted in more dangerous encounters between polar bears and humans.

One of the effects of the warming trends highlighted above is that, in general terms, the sea ice is reduced and, in particular, the floe edge ice is now closer to land surfaces than in the past, reducing the extent of viable polar bear habitat. In addition, the timing of the formation and break-up of sea ice has changed compared to that of the past. One outcome is that polar bears are forced into a smaller area, closer to human settlements and camping areas (according to a petition to the Inter American Commission on Human Rights at the Inuit Circumpolar Conference in 2005). Each region is unique when it comes to timing of sea ice and the presence of polar bears. Thus the consequences of sea ice changes on polar bears will vary (Laidre et al. 2008). In Churchill, Manitoba, for example, conservation officers handled more "problem bears" in years when ice break-up occurred earlier in the year (causing bears to be thinner) than in years when break-up was late (Stirling et al. 1999). Piungituq, a hunter of Clyde River, Nunavut, explains the difference between polar bear behavior in the past and today as follows:

> *On the overlapping of the ice packs is where polar bears normally have their hunting grounds. Because the sea ice isn't formed the way it used to be that the polar bears are coming closer. This is why we now have polar bears in the community even before the dark season would start to come. It used to be that when it would start to get dark at night the polar bears would start to come this way, but now they're always around* (ICC 2005:46).

Changing sea ice conditions also affect polar bear–human interactions indirectly by affecting the health, reproduction, and survival of polar bear prey. Following the heavy ice winter of 1974 in the Beaufort Sea, during which time ringed seal productivity plummeted, researchers noted that polar bears were significantly thinner than in earlier years (Kingsley 1979). Two humans were killed and eaten by starving bears as a result (Derocher et al. 2004). These brief examples illustrate how climate change can spur interactions between marine mammals and humans in unexpected and complex ways.

Harvesting and sport hunting

Across the Arctic, but in particular in Greenland, Northern Canada, Northern Russia (Chukotka), and Alaska, polar bears are selectively harvested for subsistence and in some cases for trophy hunting and to remove "problem bears." At present, the documented annual global harvest of polar bears is 705 individuals out of a total population of 21 000–25 000 bears (WWF Denmark 2005; see Table 2).

In northern Canada, sport hunting of polar bears is a relatively recent development. However, Canadian Inuit have the right to assign a part of the annual quota for polar bears in Nunavut to non-Inuit sport hunters. For Inuit who depend on harvesting as their main or entire source of income, sport hunting has become a critical means of ensuring subsistence and enables hunters to meet the general costs of living that are now a part of daily village life (Wenzel 2005).

In contrast to the situation in the northern Canada, Inuit hunters in Greenland and Inupiat hunters in Alaska are permitted to hunt polar bears for subsistence only (Wenzel 2005). In Greenland, polar bears are taken in subsistence hunts for food and for the skin. In Norway, polar bears are protected from all forms of hunting. Russia shares a population of polar bears with the United States; therefore, the two governments, with the participation of native groups in the Russian Far East and Alaska, have drafted and signed an international treaty, ratified by the U.S. Senate, which allows hunting of polar bears by Russian natives, yet places quota restrictions for residents of both countries.

Climate change is likely to increase human–bear interactions in the future, both by reducing polar bear habitat and by rendering the Arctic more permeable to shipping, development, and oil and gas exploration. If climate change continues to threaten the habitat of ice-dependent bears, then polar bear populations will likely be much smaller in the future. Given that continued international pressure for the sustainable management of remaining populations is likely in the future,

TABLE 3. Potential impacts on marine mammals of changes in human activities.

Outcomes of climate change, by activity	Changes in human activity	Impact on marine mammals
Shipping		
Reduction in sea ice extent; thinning sea ice.	Increased shipping activity through the Northwest Passage and Northern Sea Route; longer navigation season; need for recognition of climate change in management regimes.	Increased risk of pollution; increased disturbance of marine mammal habitat.
Hunting		
Changing ice conditions; unpredictable ice and weather conditions; shifting species abundance and distribution; introduction of new species; increased ocean temperature; changes to marine mammal health and reproduction.	Shift in hunting seasons; increased hunting hazards; need for more flexible hunting methods; less reliance on indigenous (local) knowledge; target new species; increased need for cash and more advanced technology; possible reduction in hunting activities; possible socioeconomic changes; more selective hunting.	Shifting hunting pressure to other species; less hunting of ice-dependent species; increased pressure on remaining stocks.
Oil/gas exploration		
Reduction in sea ice extent; increased wave and wind activity; more icebergs.	Increased oil/gas exploration and production; longer production season in some locations; increased shipping; increased infrastructure; development of new technology; increased conflict; need for recognition of climate change in management regimes.	Increased risk of pollution; increased disturbance of and competition for marine mammal habitat.

indigenous communities that depend on hunting polar bears may have to adopt alternative livelihoods. Because the polar bear is a top predator in the Arctic, changes in its distribution or numbers are likely to affect the entire Arctic ecosystem. There is therefore little doubt that polar bear–human interactions will be adversely affected by continued warming in the Arctic.

MARINE MAMMAL INTERACTIONS WITH HUMANS IN THE CONTEXT OF CLIMATE CHANGE

In addition to interacting directly with Arctic marine mammals by harvesting them for food, clothing, and sale, humans interact indirectly with marine mammals by engaging in activities such as shipping and oil and gas exploration in areas that overlap with marine mammal habitat (Table 3).

According to the ACIA report (ACIA 2005), at the observed rate of ice reduction, the Canadian Arctic could experience nearly ice-free summer seasons starting as early as 2050. Previously frozen areas in the Arctic may therefore become seasonally or permanently navigable, increasing the prospects for marine transport through the Arctic and providing greater access to Arctic resources such as fish, oil, and gas.

Shipping and offshore activities

Twenty-five percent of the world's oil reserves are expected to be found in the Arctic region (e.g., ACIA 2005). Most oil and reserves are located in Russia: oil in the Pechora Basin, gas in the lower Ob Basin, and other potential oil and gas fields along the Siberian coast. Canadian oil and gas fields are concentrated in two main basins in the Mackenzie Delta/Beaufort Sea region and in the Arctic Islands. In Alaska, Prudhoe Bay is the largest oil field in North America and other fields have been discovered or remain to be discovered along the Beaufort Sea coast. Oil and gas fields also exist on Greenland's west coast and in Norway's Arctic territories (Huntington and Weller 2005) (see Fig. 3).

In the future, oil and gas activities that were once restricted to the mainland will develop in the Canadian Beaufort Sea, and the oil and gas fields in the Barents Sea will become more accessible (Fig. 4). Other parts of the Arctic are likely to open up for increased exploration, increasing the demand for cargo transport throughout the region.

These reserves represent enormous wealth as well as significant potential for economic growth and development in Arctic regions. However they are also likely to pose challenges for Arctic ecosystems. Increased access to the oil and gas fields due to diminishing sea ice is likely to increase the frequency and intensity of cargo travel through the region, augmenting the risk of oil spills. More icebergs and higher and more wave activity, both a result of diminishing sea ice cover, will create additional challenges for the offshore industry.

Opening of sea routes

Reduction in sea ice extent and thickness will potentially increase the number of days during which polar navigation is possible. The most dramatic impacts will occur in the summer, when sea ice will retreat further and further from Arctic landmasses (ACIA 2004). For example the navigation season for the Northern Sea Route is expected to increase by 70–80 days by the year 2080 (ACIA 2004) (Fig. 4).

Opening of sea routes such as the Northern Sea Route and Northwest Passage could have major implications for marine mammals and for the communities that depend upon them for harvesting. In addition to

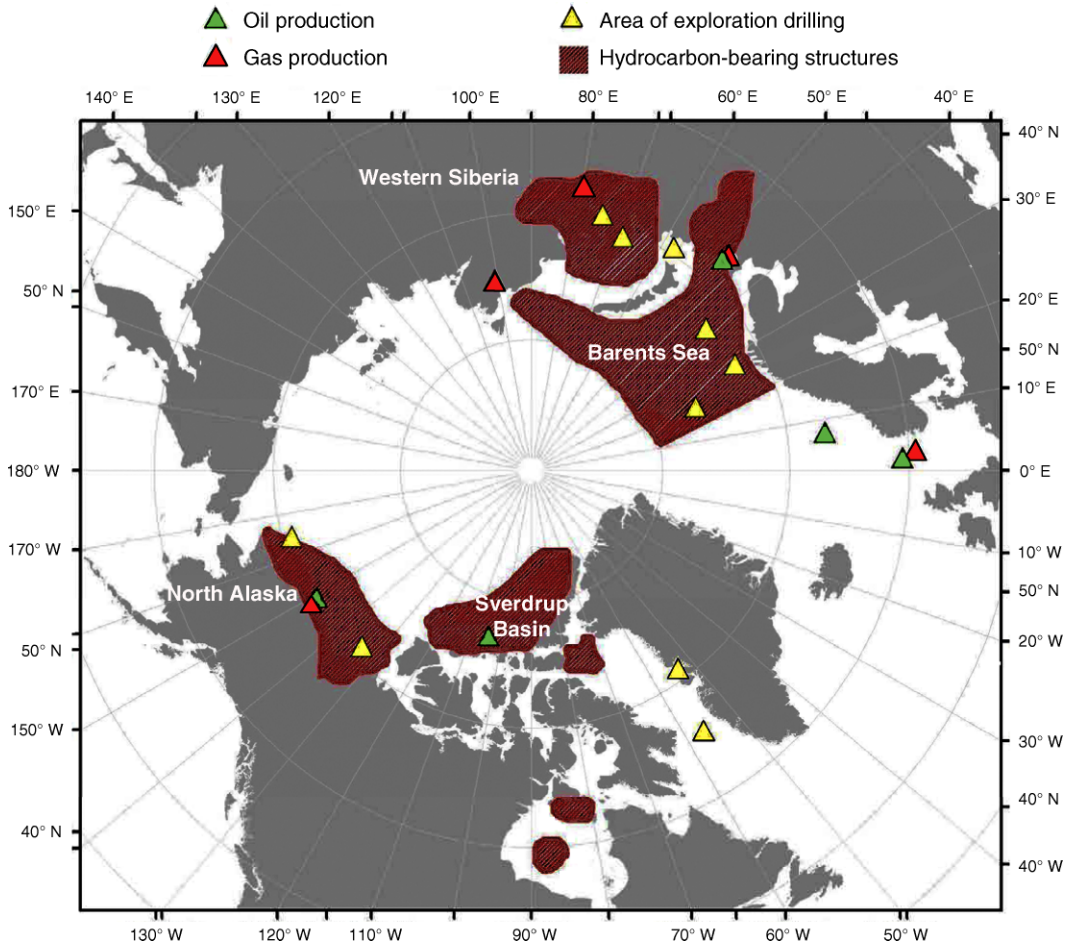

FIG. 3. Major areas of oil and gas development and potential development in the Arctic. Modified from AMAP (1998: Fig. 10.1).

increased shipping, the number of tourism cruises and passenger vessels in Arctic waters is likely to increase as climate change opens waters and communities that were previously isolated from tourism activities.

On the other hand, changes in sea ice cover could make navigation less reliable and bring new challenges to shipping. High intra-annual variability in sea ice conditions has been documented in the Canadian Arctic over the last 30 years, despite the fact that the region as a whole has experienced an overall decrease in the extent of sea ice during September (ACIA 2004). The potential for more multiyear ice and iceberg movement within the northern channels and straits of the Canadian Arctic Archipelago under a warming climate could render shipping conditions even more unreliable and hazardous. Such scenarios are also possible for the Northern Sea Route along the Arctic Russian coast.

At the same time that the Arctic becomes more permeable to human activities, shifts in marine mammal populations as the ice retreats northward are likely, augmenting competition for scarce resources. For example, today in the Northern Sea Route and Northwest Passage the situation is such that

> *commercial fishing, sealing, hunting of marine wildlife by indigenous people, tourism and shipping all compete for use of the narrow straits of these waterways, which are also the preferred routes for marine mammal migration* (ACIA 2004:84).

Shipping and oil and gas exploration activities are likely to continue to encroach on and compete for marine mammal habitat under a warming climate in the future, resulting in more and potentially harmful human–marine mammal interactions. The projected increase in human activities creates a greater need for environmental monitoring, shipping regulations, and regulations governing access in the international arena (ACIA 2005). In addition, national and international management regimes will have a greater need to include the consequences of climate change on marine mammals in the regulations.

The consequences of an increase in multilevel interactions between humans and marine mammals are

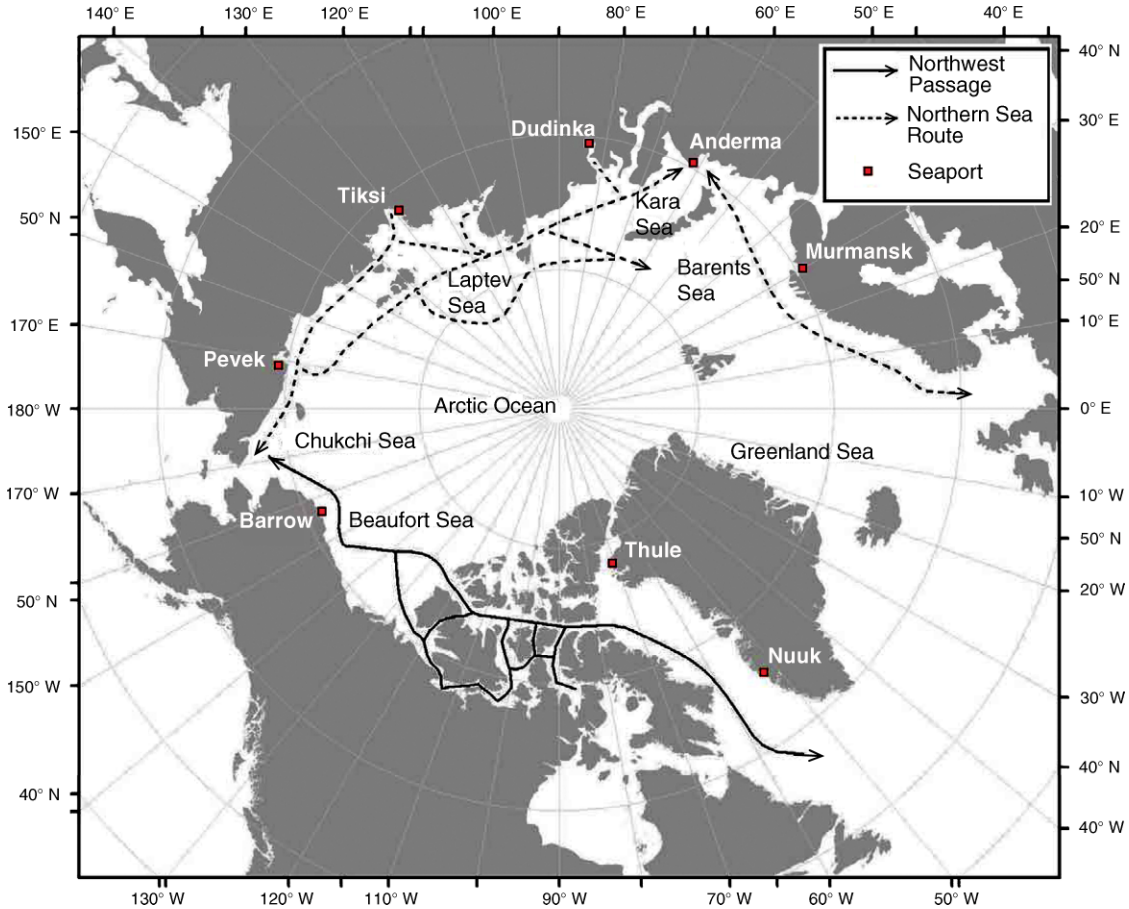

FIG. 4. The general Arctic marine routes. The official Northern Sea Route encompasses all routes across the Russian Arctic coastal seas from Kara Gate to the Bering Strait. The Northwest Passage is the name given to the marine routes between the Atlantic and Pacific oceans along the northern coast of North America that span the straits and sounds of the Canadian Arctic Archipelago. The predicted reduction in Arctic sea ice in all seasons in 2070–2090 is likely to increase marine transport in the Northwest Passage and Northern Sea Route. The thinning and decreasing extent of sea ice will also result in marine transport activity closer to the North Pole in the Arctic Ocean, disrupting the expected movement of marine mammals in 2070–2090.

however virtually unknown. Changes in human activities as a consequence of climate change will need to be assessed in conjunction with the impact of such changes on marine mammals and raise critical questions for further studies: Can we expect compounded impacts on human activities and marine mammals as a result of climate change? Will human activities occur in areas of high abundance of marine mammals in future, and if so, what will be the outcomes? Will marine mammals migrate northwards to the point where interactions between humans and marine mammals become irrelevant? These are questions that will merit continued research in the future.

CONCLUSIONS

Climate change will affect the habitat of marine mammals, with consequences for human activities in Arctic regions. The impacts of these changes may be compounded when they are considered together. Although the full extent and nature of future changes to marine mammal habitat and human activities as a result of climate change are uncertain at this point, the discussion in this paper has illustrated the complexity of these interactions and provided a glimpse at some of the potential impacts of climate change on marine mammal–human interactions in Arctic regions.

Climate change is likely to alter existing harvesting patterns. Some changes may help hunters, but many are likely to decrease access to marine mammals and increase the risks and costs associated with hunting. Less rather than more hunting may be the end result of shifting marine mammal populations due to changing sea ice conditions, and this will undoubtedly alter the socioeconomic system of Arctic hunting communities. However, as local abundances of marine mammals change, hunting pressure may increase on any aggregations remaining near communities. It is possible to envision an increase in hunting pressure on marine species that are less dependent upon ice.

Arctic communities continue to rely on traditional, local knowledge about their environments for traveling and hunting activities as well as for survival. Unfortunately, such knowledge may prove less valuable as ice conditions, weather, and prey distribution become less predictable and more variable and as available species and hunting ranges change. Evidence of increasingly unpredictable sea ice and weather conditions in Arctic regions highlights that hunters are already confronted with increased risks and hazard. In addition to requiring more fuel to reach geographically dispersed prey, adaptation among hunters to climate change may require improved access to advanced technology, larger boats, and new navigational aids such as global positioning systems. These adaptations will require substantial resources and investments on the parts of individual hunters and communities, something that may not be possible given the lack of economic investment and opportunities for the inhabitants of these areas at present. Although Arctic societies have proven to be dynamic and capable of confronting past changes, climate change and its associated effects on marine mammals and human activities present new challenges to the adaptive capacity of Arctic communities.

The net effects of climate change on marine mammal–human interactions in the Arctic are difficult to assess; however, the discussion and case studies presented in this paper highlight that many of the consequences will be negative. Increased shipping and oil and gas activities in the Arctic are likely to increase pollution, noise, and ship strikes and to lead to more frequent interactions between humans and marine mammals. These activities may also change the distributions of marine mammals, affecting hunters. Recognizing trends in population levels and distribution and disentangling local human causes from larger environmental changes (which may be caused in part by human activity elsewhere in the world) will require an extensive monitoring and analysis program. The absence of data generated by such a program, however, will make it difficult or impossible to establish effective conservation measures in the face of combined and interacting pressures from climate change, industrial development, and continued harvests. Nonetheless, the future of Arctic marine mammals and human uses of them depends on addressing this challenge successfully.

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