Polar Bear
(Ursus maritimus)

5-Year Review:
Summary and Evaluation

U.S. Fish and Wildlife Service
Marine Mammals Management
Anchorage, Alaska

5-YEAR REVIEW

Polar Bear (*Ursus maritimus*)

I. GENERAL INFORMATION

Purpose of 5-Year Reviews:
The U.S. Fish and Wildlife Service (Service) is required by section 4(c)(2) of the Endangered Species Act (Act) to conduct a status review of each listed species at least once every 5 years. The purpose of a 5-year review is to evaluate whether or not the species' status has changed since it was listed, or since the most recent 5-year review. Based on the 5-year review, the Service recommends whether the species should be removed from the list of endangered and threatened species, be changed in status from endangered to threatened, or be changed in status from threatened to endangered. Our original listing of a species as endangered or threatened is based on the existence of threats attributable to one or more of the five threat factors described in section 4(a)(1) of the Act, and the Service must consider these same five factors in any subsequent consideration of reclassification or delisting of a species. In the 5-year review, the Service considers the best available scientific and commercial data on the species, and focuses on new information available since the species was listed or last reviewed. If the Service recommends a change in listing status based on the results of the 5-year review, the Service must propose to do so through a separate rule-making process defined in the Act that includes public review and comment.

Species Overview:
The polar bear was listed as a threatened species under the U.S. Endangered Species Act of 1973, as amended (16 USC 1531 *et seq*.) (Act) on May 15, 2008 (73 FR 28212). The total circumpolar population is estimated to be 26,000 (95% CI = 22,000 - 31,000) polar bears (Wiig et al. 2015). Polar bears (*Ursus maritimus*) occur in 19 relatively discrete subpopulations (Fig. 1) throughout the seasonally and permanently ice-covered marine waters of the northern hemisphere (Arctic and Subarctic), in Canada, Denmark (Greenland), Norway, Russia and the United States (U.S.). The condition of each of these subpopulations varies (Polar Bear Specialists Group (PBSG) Status Table; http://pbsg.npolar.no/en/status/status-table.html). The U.S. contains portions of two subpopulations: the Chukchi Sea (CS) (also called the Alaska-Chukotka subpopulation in the U.S.–Russia Bilateral Agreement) and the Southern Beaufort Sea (SB) subpopulation.

Methodology used to complete the review:
The 2016 review was prepared by the Marine Mammals Management Program, following guidance issued by Region 7 in June 2015. The Service primarily relied on information from the Polar Bear Conservation Management Plan (Plan), which was released in draft form on July 6, 2015 and finalized on December 20, 2016 (USFWS 2016). This 5-year review contains an analysis of new and updated information on the polar bear's biology and threats, and an assessment of that information compared to that known at the time of listing. The Service focused on current threats to the polar bear that are linked to the Act's five listing factors. The review synthesizes all this information to evaluate the listing status of the polar bear and provide an indication of its progress towards recovery. Finally, based on this synthesis and the threats

identified in the five-factor analysis, the Service recommended a prioritized list of conservation actions to be completed or initiated within the next 5 years.

While the listing incorporates known information on the entire world-wide population of polar bears, the Service has jurisdiction over and manages the only two subpopulations in Alaska, the SB and CS. This document covers the range of the polar bear, but much of the new information presented comes from research conducted on these two populations.

Contact Information:

> **Lead Regional or Headquarters Office:** Drew Crane, Regional Endangered Species Coordinator, Region 7, Anchorage, Alaska: 907-786-3323.
>
> **Lead Field Office:** Hilary Cooley, Polar Bear Team Lead, Marine Mammals Management, Anchorage, Alaska: 907-786-3349.

Federal Register Notice citation announcing initiation of this review:
A notice announcing initiation of the 5-year review of this species and the opening of a 60-day period to receive information from the public was published in the Federal Register on October 13, 2015 (80 FR 61443). The Service received 10 comments in response to this notice, which the Service has considered in preparing this 5-year review.

Listing History:

Original Listing
FR notice: 73 FR 28212
Date listed: May 15, 2008
Entity listed: *Ursus maritimus,* entire
Classification: Threatened

Listed as "depleted" under the Marine Mammal Protection Act of 1972 as amended (MMPA).

Associated Rulemakings:
1. Critical Habitat was finalized on December 7, 2010 (75 FR 76086).
2. A special rule for the polar bear under section 4(d) of the Act was finalized on February 20, 2013 (78 FR 11766).

Review History
A status review and subsequent 12-month finding on the polar bear were completed in 2007 and announced in the Federal Register on January 9, 2007 (72 FR 1064) when the Service published a proposed rule to list the polar bear as threatened on the Federal List of Endangered and Threatened Wildlife in 50 CFR 17.11(h). The listing rule and the 2007 status review are the only formalized reviews that contain a five-factor analysis and conclusions.

Species' Recovery Priority Number at start of 5-year review:
The Recovery Priority Number for polar bear is currently 5C. This number indicates a species that has a high degree of threats and a low recovery potential. The "C" indicates that the species is in conflict with construction or other developmental projects or other forms of economic activity.

Recovery Plan

> **Name of plan or outline**: Polar Bear Conservation Management Plan (Plan)
> **Date issued**: December 20, 2016

Critical Habitat
The Service designated critical habitat for polar bear populations in the United States effective January 6, 2011 (75 FR 76086). The critical habitat designation identified geographic areas that contained features essential for the conservation of the polar bear within Alaska. Polar bear critical habitat included the following habitat types: barrier island habitat, sea ice habitat (both habitats are described in geographic terms), and terrestrial denning habitat (described as a functional determination). Barrier island habitat includes coastal barrier islands and spits along Alaska's coast, which is used for denning, refuge from human disturbance, access to maternal dens, feeding habitat, and travel along the coast. Sea ice habitat is located over the continental shelf, and includes water 300 m (~984 ft) or less in depth. Terrestrial denning habitat includes lands within 32 km (~20 mi) of the northern coast of Alaska between the Canadian border and the Kavik River and within 8 km (~5 mi) of the northern coast of Alaska between the Kavik River and Barrow. The total area designated covers approximately 484,734 sq km (~187,157 sq mi), and is entirely within the lands and waters of the United States.

On January 13, 2013, the U.S. District Court for the District of Alaska issued an order (Alaska Oil and Gas Association and American Petroleum Institute v. Salazar, Case No. 3:11–cv–0025–RRB) that vacated and remanded the polar bear critical habitat final rule to the Service. On February 29, 2016, the 9th Circuit Court Panel reversed the District Court's judgment vacating the Service's designation of critical habitat in Alaska for the polar bear and the original designation has been reinstated.

II. REVIEW ANALYSIS

Application of the 1996 Distinct Population Segment (DPS) policy

The Act defines "species" as including any subspecies of fish or wildlife or plants, and any distinct population segment (DPS) of any species of vertebrate wildlife. This definition of species under the Act limits listing as distinct population segments to species of vertebrate fish or wildlife. The 1996 Policy Regarding the Recognition of Distinct Vertebrate Population Segments under the Act (61 FR 4722) clarifies the interpretation of the phrase "distinct population segment" for the purposes of listing, delisting, and reclassifying species under the Act.

Nineteen polar bear subpopulations are recognized worldwide (Aars et al. 2006; Obbard et al. 2010). In 2008, the Service recognized that genetic diversity is low among subpopulations due to extensive population mixing, and that while genetic analyses support boundaries between some subpopulations, the genetic differences are small and not sufficient to distinguish population segments under the DPS Policy. Since that time, several studies (Crompton et al. 2008; Campagna et al. 2013; Peacock et al. 2015; Malenfant et al. 2016) have found genetic differences between some subpopulations and regions. However, demographic and genetic exchange occurs, (Paetkau et al. 1999; Crompton et al. 2008; Peacock et al. 2015), obscuring evidence of genetic partitioning, and there is no evidence of genetic discontinuities for polar bears that would be consistent with significant periods of genetic isolation. Because of this, the International Union for Conservation of Nature and Natural Resource (IUCN) Red List Assessment (Wiig et al. 2015) concluded that subpopulations cannot be considered as distinct genetic units.

After examining the most current available information for the 5-year Review, the Service has found no new information suggesting morphological or physiological differences across the polar bear's range which would indicate adaptations to environmental variations. Polar bears within different sea ice-affected ecoregions may have minor differences in demographic parameters, behavior, or life history strategies. The Polar Bear Conservation Management Plan relies on those differences along with broad patterns in genetic variation to support the creation of recovery units that correspond to ecoregions. However, those differences do not rise to the level needed to justify distinct population segments. In general, polar bears have a similar dependence upon sea ice habitats, rely upon similar prey, and exhibit similar life history characteristics throughout their range. Therefore, polar bears in the 19 subpopulations do not appear to be markedly separated from one another as a consequence of physical, physiological, ecological, or behavioral factors.

The primary threat to the polar bear's sea ice habitat remains global in scale, and populations continue to be managed collectively by the range countries (domestically and through bi-lateral and multi-lateral agreements). Therefore, the Service does not find that differences in conservation status or management for polar bears across the range countries is sufficient to justify the use of international boundaries to satisfy the discreteness criterion of the DPS policy. The Service concludes that there are no population segments that qualify as a DPS under the Service's DPS policy.

Information of the Species and its Status

Species Biology and Life History

Physical characteristics. Polar bears are the largest living bear species (DeMaster and Stirling 1981), and are characterized by large body size, a stocky form, and have a longer neck and proportionally smaller head than other ursids. Their hair is non-pigmented. Fur color varies between white, yellow, grey, or almost brown, and is affected by oxidation, i.e. exposure to the air, light conditions, and soiling or staining due to contact with fats obtained from prey items (Amstrup 2003). They are sexually dimorphic; females weigh 181 to 317 kilograms (kg) (400 to 700 pounds (lbs) and males up to 654 kg (1,440 lbs).

Adaptations. Polar bears evolved in Arctic sea ice habitats and are evolutionarily well adapted to this habitat. Their unique physical adaptations include: (1) non-pigmented pelage with water-repellent guard hairs and dense underfur; (2) a short, furred snout; (3) small ears with reduced surface area; (4) teeth specialized for a carnivorous rather than an omnivorous diet; and (5) feet with tiny papillae on the underside, which increase traction on ice (Stirling 1988). In addition, they have large, paddle-like feet (Stirling 1988), and claws that are shorter and more strongly curved than brown bear (*Ursus arctos*) claws, and larger and heavier than those of black bears (*Ursus americanus*) (Amstrup 2003) used mainly for clutching prey.

Breeding and Reproduction. Polar bears are a K-selected species, characterized by late sexual maturity, small litter sizes, and extended parental investment in raising young. All of these factors contribute to the species' low reproductive rate (Amstrup 2003). Females generally mature and breed for the first time at 4 or 5 years and give birth at 5 or 6 years of age. Litters of two cubs are most common, but 3-cub litters are seen on occasion across the Arctic (Amstrup 2003). The minimum reproductive interval for adult females is three years.

Females enter a prolonged estrus between March and June, when breeding occurs. Though bears ovulate in the spring, implantation is delayed until autumn. The timing of implantation, and therefore the timing of birth, likely depends on body condition of the female, which is determined by many environmental factors. When foraging conditions are difficult, polar bears may "defer" reproduction in favor of survival (Derocher and Stirling 1992; Eberhardt 2002). Pregnant females that spend the late summer on land prior to denning may not feed for eight months (Watts and Hansen 1987) which coincides with the time when the female gives birth and nourishes new cubs.

Altricial, newborn polar bears have fur, but are blind, and weigh only 0.6 kg (1.3 lb) (Blix and Lentfer 1979). Cubs grow rapidly, and may weigh 10 to 12 kg (22 to 26 lbs) by the time they emerge from the den in the spring. Young bears will stay with their mothers until weaning, which occurs most commonly in early spring when the cubs are 2 1/2 years old. Female bears are available to breed again after their cubs are weaned.

Survival. Polar bears are long-lived and are not generally susceptible to disease or parasites. Due to extended maternal care of young and low reproductive rates, polar bears require high adult survival rates, particularly females, to maintain population levels (Eberhardt 1985; Amstrup and

Durner 1995). Survival rates are generally age dependent, with cubs-of-the-year having the lowest rates and prime age adults (prime reproductive years are between approximately 5 and 20 years of age) having survival rates that can exceed 90 percent (Regehr et al. 2007a). Survival rates exceeding 90 percent for adult females are essential to sustain polar bear populations (Amstrup and Durner 1995).

New studies (Rode et al. 2010a, 2014b) conducted on the SB subpopulation are consistent with previous findings (Regehr et al. 2006) which concluded that declines in body size, body condition, and recruitment in recent decades were associated with declining sea ice availability. Additionally, Regehr et al. (2010) suggested several years of reduced sea ice in the mid-2000s were associated with low breeding probability and survival, leading to negative population growth rate.

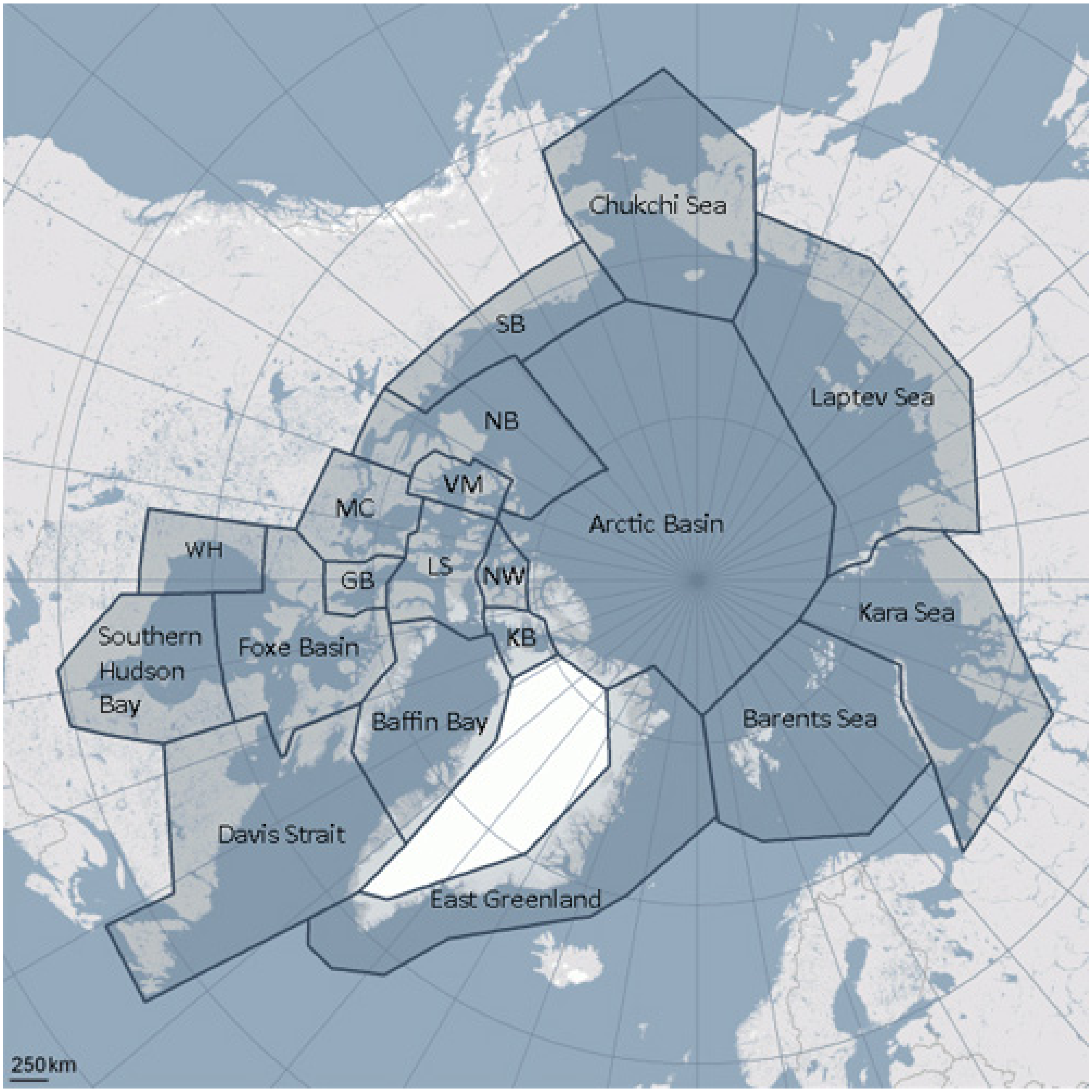
Hunter et al. (2010) used the relationship between sea ice and vital rates estimated during the period 2001-2006 to project the long-term status and survival of the SB subpopulation under future sea ice conditions as forecasted by global climate models. Their models suggested a high probability of significant population declines in the 21st century.

Changes in body condition have been shown to affect bear survival and reproduction, which in turn, can have population-level effects (Regehr et al. 2010; Rode et al. 2010a). Survival of polar bear cubs-of-the-year has been directly linked to their weight and the weight of their mothers, with lower weights resulting in reduced survival (Derocher and Stirling 1996; Stirling et al. 1999). Changes in body condition indices were documented in the Western Hudson Bay subpopulation before a statistically significant decline in that subpopulation was documented (Regehr et al. 2007b). Thus, changes in these indices may serve as an "early warning" that signal a reduction in survival and imminent subpopulation declines.

For the SB subpopulation, Bromaghin et al. (2015) analyzed demographic data through 2010, and found similar evidence to Regehr et al. (2010) for low survival of all sex and age classes of polar bears in the mid-2000s. However, Bromaghin et al. (2015) also found that survival of most sex and age classes of polar bears in the SB population increased during the years 2007-2010, despite continued declines in the availability of sea ice.

Feeding. Polar bears are top predators in the Arctic marine ecosystem. Adult polar bears need to consume approximately 2 kg (4.4 lbs) of fat per day to survive (Stirling 1988). They prey heavily on ice-seals, principally ringed seals (*Phoca hispida*), and to a lesser extent, bearded seals (*Erignathus barbatus*). Bears occasionally take larger animals, such as walruses (*Odobenus rosmarus*) and belugas (*Delphinapterus leucas*) (Kiliaan and Stirling 1978). Research in the Canadian Arctic suggests that, in some areas and under some conditions, terrestrial prey other than seals or carrion may be able to sustain polar bears when seals are unavailable (Stirling and Øritsland 1995; Smith et al. 2010b; Gormezano and Rockwell 2013; Iles et al. 2013). In addition, polar bears are opportunistic feeders and when confined to land for long periods, they will also consume plants and other terrestrial foods (Russell 1975; Derocher et al. 1993; Smith et al. 2010b, Gormezano and Rockwell 2013). However, new studies (Rode et al. 2010b, 2014b, 2015a) confirm previous findings (Derocher et al. 2004) that the relevance of terrestrial foods, such as avian eggs, to the long-term welfare of polar bears is limited by their patchy availability and relatively low nutritional content.

Figure 1. Global distribution of polar bear subpopulations* as defined by the Polar Bear Specialist Group (Obbard et al. 2010; http://pbsg.npolar.no/en/status/population-map.html).



* Subpopulations include the Southern Beaufort Sea (SB), Chukchi Sea , Laptev Sea , Kara Sea, Barents Sea, East Greenland, Northern Beaufort (NB), Kane Basin (KB), Norwegian Bay (NW), Lancaster Sound (LS), Gulf of Boothia (GB), McClintock Channel (MC), Viscount Melville (VM), Baffin Bay, Davis Strait, Foxe Basin, Western Hudson Bay (WH), and Southern Hudson Bay.

Population Delineation and Distribution

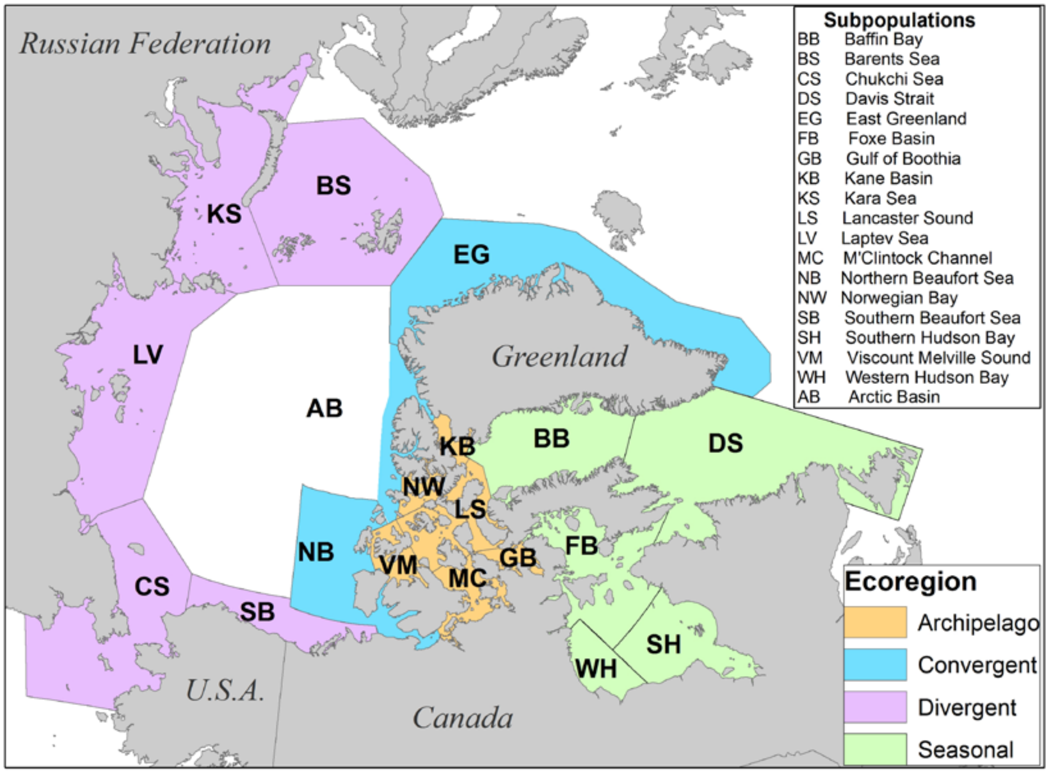
Delineation. Five countries share management responsibilities for polar bears, including Canada, Greenland (an autonomous country within the Danish realm), Norway, Russia, and the United States (the Polar Bear Range States [PBRS]). Both the 2008 listing and this 5-year review are based on the PBSG delineation (Figure 1) which usually, but not always, reflects ecological boundaries. In some cases, boundaries are practical delineations for management purposes.

The Chukchi Sea subpopulation is shared by the U.S. and Russia. The boundaries of this subpopulation are described differently in the *Agreement between the United States of America and the Russian Federation on the Conservation and Management of the Alaska—Chukotka Polar Bear Population*" (Bilateral Agreement) and in Polar Bear Specialist Group (PBSG) publications. The Bilateral Agreement describes the CS subpopulation within a line extending north from the mouth of the Kolyma River and on the east by a line extending north from Point Barrow (Obbard et al. 2010). However, the PBSG describes the northeastern boundary near Icy Cape, Alaska to a western boundary near Chauniskaya Bay, Russia, in the Eastern Siberian Sea (Obbard et al. 2010).

The Southern Beaufort Sea subpopulation is shared by the U.S. and Canada. The western boundary is near Icy Cape, Alaska (Obbard et al. 2010). The eastern boundary was originally determined to be south of Banks Island and east of the Baillie Islands, Canada. Recently, the eastern boundary between the SB and Northern Beaufort subpopulation (NB) has been moved westward, near the community of Tuktoyaktuk, Northwest Territories, Canada (WMAC 2011). The Canadian Inuvialuit Game Council and the North Slope Borough of Alaska adjusted the boundary to 133° W to better align management boundaries with the current distribution of polar bears in this region which was based on radio-tracking data. The shift in the boundary is currently being implemented by the agencies involved in managing the SB and NB subpopulations. However, the new boundary change is currently not recognized by the PBSG.

Distribution. Polar bear subpopulations have been further classified as occurring in one of four ecoregions (Figure 2; Amstrup et al. 2008) based on the spatial and temporal dynamics of sea ice in the subpopulation's range. Subpopulations classified as occurring in the Seasonal Ice Ecoregion share the characteristic that the sea ice in their range fully melts in the summer, during which time bears are forced on shore for extended periods until the sea ice reforms. Subpopulations occurring in the Archipelago Ecoregion are characterized as having heavy annual and multi-year sea ice that fills the channels between the Canadian Arctic Islands. Bears in this ecoregion remain on the sea ice throughout the year. The Divergent Ice Ecoregion is characterized by the formation of annual sea ice that is advected towards the polar basin. Conversely, the Convergent Ice Ecoregion is characterized by annual sea ice that converges towards shoreline allowing bears to access nearshore ice year-round.

Figure 2. Distribution of polar bear ecoregions based on Amstrup et al. (2008).



Population Size Estimates and Trends

Abundance. Accurate estimates of polar bear subpopulation sizes and trends are difficult to obtain due to the species' low densities, the vast and inaccessible nature of their sea ice habitat, the movement of bears across international boundaries, and limited budgets (USFWS 2010a, 2010b). The global population is estimated to be approximately 26,000 (95% CI = 22,000-31,000) throughout the circumpolar arctic (Wiig et al. 2015).

In 2008, of the 19 subpopulations, and excluding the Arctic Basin, two subpopulations were reported to be increasing (M'Clintock Channel and Viscount Melville), five subpopulations were reported as stable (Foxe Basin, Gulf of Boothia, Lancaster Sound, Northern Beaufort Sea, Southern Hudson Bay), five subpopulations were described as declining (Baffin Bay, Kane Basin, Norwegian Bay, SB, Western Hudson Bay), and six were reported as data deficient (Barents Sea, CS, Davis Strait, East Greenland, Kara Sea, and Laptev Sea) (Aars et al. 2006).

Since listing (73 FR 28212), international efforts have been undertaken to more accurately quantify polar bear subpopulations in order to continue to assess the threats of climate change on the species (Table 1). While the type, precision, and time span of data used to estimate trends varies among subpopulations (Wiig et al. 2015), information reported in 2014 (PBSG 2015) now suggests that one subpopulation (M'Clintock Channel) is increasing; six subpopulations are stable (Davis Strait, Foxe Basin, Gulf of Boothia, Northern Beaufort Sea, Southern Hudson Bay, and Western Hudson Bay), three subpopulations are declining (Baffin Bay, Kane Basin, and SB) and 9 are data deficient (Arctic Basin, Barents Sea, CS, East Greenland, Kara Sea, Lancaster Sound, Laptev Sea, Norwegian Bay, and Viscount Melville Sound). (PBSG 2015; http://pbsg.npolar.no/en/status/status-table.html). Since 2008, only the Western Hudson Bay subpopulation has shown a positive change in trend (i.e., from "declining" to "stable"), while the Viscount Melville subpopulation changed from "increasing" to "data deficient" during the same period (Table 1). For the remaining 17 subpopulations, trends either remain unchanged since the time of listing or lack sufficient data for assessment.

Chukchi Sea Subpopulation

Reliable estimates of subpopulation size or status are not available for the Chukchi Sea subpopulation. The most recent quantitative estimate of the size of this subpopulation was 2,000–5,000 polar bears (Belikov 1992), based on incomplete denning surveys in Russian portions of the Chukchi Sea where most of the subpopulation is believed to den (Belikov 1980). In 2005, expert opinion among the PBSG members was that the subpopulation had around 2,000 bears (Aars et al. 2006). This estimate was derived by extrapolating the earlier estimate of Belikov (1992). At the time of the ESA listing in 2008, the PBSG reported this subpopulation at approximately 2,000 animals. Subsequently, the PBSG listed the size of this subpopulation as "unknown," and currently lists the CS subpopulation trend as "data deficient."

Southern Beaufort Sea Subpopulation

The Southern Beaufort Sea subpopulation had an estimated population size of approximately 900 bears in 2010 (Bromaghin et al. 2015). The authors, however, note that suspected biases exist in the abundance estimate. The estimate represents a significant reduction from previous estimates of approximately 1,800 in 1986 (Amstrup et al. 1986), and 1,526 in 2006 (Regehr et al. 2006). In addition, analyses of over 20 years of data on the size and body condition of bears in this subpopulation demonstrated declines for most sex and age classes and significant negative relationships between annual sea ice availability and body condition (Rode et al. 2010a). These lines of evidence suggest that the Southern Beaufort Sea subpopulation is currently declining due to sea ice loss.

Table 1. Polar bear subpopulation trends at the time of listing (2008), their current trends (2016), and changes in trends since listing. Table adapted from Schliebe et al. 2006; Wiig et al. 2015; Aars et al. 2006; PBSG 2015.

	Trend		
Subpopulation	At Time of Listing (2008)	Current (2016)	Change in Trend (Positive/Negative/Unknown)
Arctic Basin	N/A	Data deficient	Unknown
Baffin Bay	Declining	Declining	No change
Barents Sea	Data deficient	Data deficient	Unknown
Chukchi Sea	Data deficient	Data deficient	Unknown
Davis Strait	Data deficient	Stable	Unknown
East Greenland	Data deficient	Data deficient	Unknown
Foxe Basin	Stable	Stable	No change
Gulf of Boothia	Stable	Stable	No change
Kane Basin	Declining	Declining	No change
Kara Sea	Data deficient	Data deficient	Unknown
Lancaster Sound	Stable	Data deficient	Unknown
Laptev Sea	Data deficient	Data deficient	No change
M'Clintock Channel	Increasing	Increasing	No change
Northern Beaufort Sea	Stable	Stable	No change
Norwegian Bay	Declining	Data deficient	Unknown
Southern Beaufort Sea	Declining	Declining	No change
Southern Hudson Bay	Stable	Stable	No change
Viscount Melville Sound	Increasing	Data deficient	Unknown
Western Hudson Bay	Declining	Stable	Positive

<u>Habitat Characteristics and Needs</u>

Pack ice is the primary summer habitat for polar bears in the U.S. (Durner et al. 2009; Rode et al. 2015b; Atwood et al. 2016b). Polar bears depend on sea ice as a platform from which to hunt and feed; to seek mates, breed, and den; to travel to terrestrial maternity denning areas; and to make long-distance movements (Stirling and Derocher 1993). Polar bears prefer certain sea-ice stages, concentrations, forms, and deformation types (Arthur et al. 1996; Mauritzen et al. 2001; Durner et al. 2009; Wilson et al. 2014), and have been shown to prefer the floe ice edge, stable shore-fast ice with drifts, and moving ice (Stirling et al. 1993).

Movements. Polar bear movements are closely tied to seasonal dynamics of sea-ice extent as it retreats northward during summer melt and advances southward during autumn freeze. When the annual sea ice begins to form in shallower water over the continental shelf, polar bears that retreated north of the continental shelf during summer return to shallower shelf waters where seal densities are higher (Durner et al. 2009).

Access to prey. The formation and movement patterns of sea ice strongly influence the distribution and accessibility of ringed and bearded seals (Frost et al. 2004; Ferguson et al. 2005; Cameron et al. 2010). The shore-fast ice zone, where ringed seals construct subnivean (in or under the snow) birth lairs for pupping, is also an important foraging habitat during spring (Stirling et al. 1993). Shore-fast ice is used by polar bears for feeding on seal pups, for movement, and occasionally for maternity denning (Stirling et al. 1993). In protected bays and lagoons, shore-fast ice typically forms in autumn and remains stationary throughout winter. Shore-fast ice usually occurs in a narrow belt along the coast and melts in the summer.

During the winter and spring, when energetic demands are the greatest, nearshore lead systems (i.e., cracks in the ice where bears can hunt hauled-out seals) and polynyas (areas of open sea surrounded by sea ice) are important for seals, and are thus important foraging habitat for polar bears. Polar bears in the SB are thought to reach their peak weights during autumn and early winter (Durner and Amstrup 1996). Thus, availability and accessibility of prey during this time may be critical for survival through the winter months.

Breeding. Polar bears also depend on sea ice as a habitat to seek mates and breed (Stirling and Derocher 1993). Breeding occurs in spring, between March and June (Schliebe et al. 2006). In the Southern Beaufort Sea, the probability that adult females will survive and produce cubs-of-the-year is negatively correlated with ice-free periods over the continental shelf (Regehr et al. 2007a).

In addition, the variable nature of sea ice results in an ever-changing distribution of suitable habitat for polar bears, and eliminates any benefit to defending individual territories (Schliebe et al. 2006). Males must be free of the need to defend territories if they are to maximize their potential for finding mates each year (Ramsay and Stirling 1986; Schliebe et al. 2006).

Denning. Throughout the polar bear's range, most pregnant females excavate dens in snow drifts located on land in the autumn and early winter period (Ramsay and Stirling 1990; Amstrup and Gardner 1994), near the coastline (Durner et al. 2010; Andersen et al. 2012), or, in the case of portions of the SB subpopulation, in snow drifts on pack and shore-fast ice. The key characteristic of all denning habitat is a topographic feature that catches snow on its leeward side in the autumn and early winter as successful denning requires accumulation of sufficient snow for den construction and maintenance (Durner et al. 2003; Liston et al. 2016). Liston et al. (2016) suggested that polar bears need snow drifts that are at least 1.5 meters deep to successfully maintain a maternity den throughout the denning season. In some areas, the majority of polar bear denning occurs in core areas (Harington 1968; Stishov 1991; Ovsyanikov 2005), which show high use over time while in other portions of the species' range, polar bears den in a more diffuse pattern, with dens scattered over larger areas at lower density (Stirling and Andriashek 1992; Amstrup and Gardner 1994; Ferguson et al. 2000).

In Alaska, most polar bear dens occur relatively near the coast along the coastal bluffs and riverbanks of the mainland, on barrier islands, or on the drifting pack ice (Amstrup and Gardner 1994; Amstrup 2003; Durner et al. 2003, 2006, 2010, 2013; USFWS and USGS unpublished data). Denning areas on the North Slope of Alaska are in relatively flat topography (Durner et al.

2003). Currently, approximately 37% (Fischbach et al. 2007) and 10% (Rode et al. 2015b) of pregnant females den on ice in the SB and CS subpopulations, respectively.

Some habitat suitable for denning has been mapped on the North Slope (Durner et al. 2001, 2006, 2013; Blank 2013). The primary denning areas for the CS subpopulation occur on Wrangel Island, Russia, where up to 200 bears per year have denned annually, and the northeastern coast of the Chukotka Peninsula, Russia (Stishov 1991; Ovsyanikov 2005; Obbard et al. 2010).

Five-Factor Analysis

The following five-factor analysis describes and evaluates the threats attributable to one or more of the five listing factors outlined in section 4(a)(1) of the Act.

A. The present or threatened destruction, modification, or curtailment of the species' habitat or range

In the 2008 listing rule (73 FR 28212), the Service found that the primary threat to polar bears was loss of sea ice habitat due to climate change. Polar bears evolved over thousands of years to life in a sea ice environment. They depend on the sea ice-dominated ecosystem to support essential life functions (USFWS 2016). The sea ice ecosystem supports ringed seals, primary prey for polar bears, and other marine mammals that are a part of their prey base (Stirling and Archibald 1977; Smith 1980; Smith 1985; Iverson et al. 2006). New information continues to support that polar bears rely heavily on sea ice for essential life functions (Wilson et al. 2014). Further, there is no new information available suggesting that the threat of climate change has been reduced.

Sea ice is rapidly thinning and retreating throughout the Arctic. Ice conditions that affect polar bear habitat include: (1) fragmentation of sea ice; (2) a dramatic increase in the extent of open water areas seasonally; (3) reduction in the extent and area of sea ice in all seasons; (4) retraction of sea ice away from productive continental shelf areas throughout the polar basin; (5) reduction of the amount of heavier and more stable multi-year ice; and (6) declining thickness and quality of shore-fast ice, if it restricts access to seals. These combined and interrelated events change the extent and quality of sea ice during all seasons, but particularly during the spring-summer period (USFWS 2016).

Climate change will continue to affect Arctic sea ice for the foreseeable future. A further review of new information since 2008 indicates that climate change, resulting in the loss of sea ice habitat for polar bears continues to be the primary threat to the species. Due to the long persistence time of certain greenhouse gases (GHGs) in the atmosphere, the current and projected patterns of GHG emissions over the next few decades and interactions among climate processes, climate changes over the next 40-50 years are already largely set (IPCC 2007; Overland and Wang 2007, 2013). Climate change effects on sea ice and polar bears will continue during this time and likely further into the future (IPCC 2014; Atwood et al. 2015).

The ultimate effect will be that polar bear subpopulations will decline or continue to decline. With a diminished sea ice platform, bear distribution and seasonal onshore abundance will change. Not all subpopulations will be affected evenly in the level, rate, and timing of effects (Atwood et al. 2016a).

A.1. Loss of access to prey

Reduced duration of sea ice over shallow, productive waters of the continental shelf is likely to have significant impacts on the polar bears' ability to access prey, and continued declines in sea ice duration are expected in the future (Durner et al. 2009; Castro de la Guardia et al. 2013; Hamilton et al. 2014). Without sea ice, polar bears lack a platform that allows access to ice seal prey. Longer melt seasons and reduced summer ice extent will likely force bears to increase use of habitats where hunting success will decrease (Derocher et al. 2004; Stirling and Parkinson 2006). Highly-selected summer sea ice habitat by polar bears in the CS subpopulation has declined by 75% in the past 30 years (Wilson et al. 2016). Once sea ice concentration drops below 50 percent, polar bears have been documented to quickly abandon sea ice for land, where access to their primary prey is almost entirely absent. Bears may also retreat northward with the more consolidated pack ice over the polar basin, which may be less productive foraging habitat. In both instances, polar bears are likely to find limited prey items and employ similar energy saving strategies (Whiteman et al. 2015).

The northward retreat is most likely related to reduced hunting success in broken ice with significant open water and need to reduce energetic costs once prey availability and food intake drops below some threshold (Stirling et al. 1999; Derocher et al. 2004). A recent study (Ware et al. in press) found that polar bears are increasingly found on ice over less productive waters in summer, with activity levels indicating that they are not hunting. Similarly, Whiteman et al. (2015) found that bears summering on sea ice had similar metabolic rates to those on land, indicative of fasting. During summer, ice seals typically occur in open water and therefore are virtually inaccessible to polar bears (Harwood and Stirling 1992) although bears have rarely been reported to capture ringed seals in open water (Furnell and Oolooyuk 1980). Thus, hunting in ice-free water will not compensate for the loss of sea ice and the hunting opportunities it affords polar bears (Stirling and Derocher 1993; Derocher et al. 2004).

While observations exist of polar bears eating terrestrial-based foods (Rockwell and Gormezano 2009), the general consensus is that these food items are unlikely to compensate for lost hunting opportunities while on the sea ice (Rode et al. 2015a); with rare exceptions (Miller et al. 2015; Rogers et al. 2015; Whiteman et al. 2015). Further, Rode et al. (2010a) demonstrated that available terrestrial food resources are likely inadequate to offset the nutritional consequences of an extended ice-free period.

Reduced access to preferred prey (i.e., ice seals; Thiemann et al. 2008) is therefore likely to have demographic effects on polar bears. For example, in the SB subpopulation, the period when sea ice is over the continental shelf has decreased significantly over the past decade, resulting in reduced body mass and productivity (Rode et al. 2010a; Rode et al. 2014b) and likely reduced population size (Bromaghin et al. 2015). It should be noted, however, that researchers have documented demographic effects of sea ice loss in only a few of the 19 polar bear subpopulations (Regehr et al. 2007a; Rode et al. 2012). This is highlighted by Rode et al. (2014b) who found that even though sea ice loss during summer had been substantial in the Chukchi Sea, polar bears in that subpopulation did not exhibit concomitant declines in body mass or productivity.

A.2. Increased movements, energy expenditure

The best scientific data available suggest that polar bears are inefficient moving on land and expend approximately twice the average energy when walking compared to other mammals (Best 1982; Hurst 1982). Increased rate and extent of sea ice movements will require polar bears to expend additional energy to maintain their position near preferred habitats (Mauritzen et al. 2003). This may be an especially important consideration for females with small cubs (Durner et al. 2010), who have higher energetic demands due to lactation (Gittleman and Thompson 1988; Ramsay and Dunbrack 1986). As movement of sea ice increases and areas of unconsolidated ice also increase, some bears are likely to lose contact with the main body of ice and drift into unsuitable habitat from which it may be difficult to return (Sahanatien and Derocher 2012). The increased energetic costs to polar bears from increased movements are likely to result in reduced body weight and condition, and a corresponding reduction in survival and recruitment rates (Regehr et al. 2010; Rode et al. 2010a).

Diminished sea ice cover not only increases areas of open water across which polar bears must swim, but may influence the size of wave action. These may result in increases in bear mortality associated with swimming long distances (Monnett and Gleason 2006; Durner et al. 2011; Pagano et al. 2012). In addition, diminished sea ice cover may result in hypothermia for young cubs that are forced to swim for longer periods than at present, although behavioral mechanisms might exist to reduce the probability of this occurring (Aars and Plumb 2010).

A.3. Redistribution of polar bears to where they are more vulnerable to impacts

The continued retraction and fragmentation of sea ice habitats that is projected to occur will alter previous habitat use patterns seasonally and regionally. Recent studies indicate that polar bear movements and seasonal fidelity to certain habitat areas are changing and that these changes are strongly correlated with simultaneous changes in sea ice (Rode et al. 2015b; Atwood et al. 2016b; Wilson et al. 2016). These changes have been documented for a number of polar bear subpopulations, with the potential for large-scale shifts in distribution by the end of the 21st century (Durner et al. 2009).

Gleason and Rode (2009) noted a greater number of bears in open water of the southern Beaufort Sea and on land during surveys in 1997-2005, when sea ice was often absent from their study area, compared to 1979-1996 surveys, when sea ice was a predominant habitat in the area. Schliebe et al. (2008) determined that the number of bears on land in the southern Beaufort Sea region between 2000 and 2005 was higher during years when sea ice retreated further offshore. Their results suggest that a trend of increasing distance between land and sea ice over time would be associated with an increasing number of bears on shore and/or an increase in the duration of time they spend there.

Changes in movements and seasonal distributions caused by climate change can affect polar bear nutrition and body condition (Stirling and Derocher 2012). In Western Hudson Bay, sea ice break-up now occurs approximately 2.5 weeks earlier than it did 30 years ago because of increasing spring temperatures (Stirling et al. 1999; Stirling and Parkinson 2006) which is also correlated with when female bears come ashore and when they are able to return to the ice (Cherry et al. 2013). Similarly, changes in summer sea ice conditions has resulted in an increase in the duration of time spent on shore during the summer, and the proportion of the population using shore in both the SB and CS subpopulations (Rode et al. 2015b; Atwood et al. 2016b). Rode et al. (2015b) also demonstrated that changes in sea ice dynamics have likely resulted in a shift in land use during summer from a mix of coastal use in Alaska and Russia before sea ice loss, to almost exclusive coastal use in Russia after sea ice loss.

Declining reproductive rates, subadult survival, and body mass (weights) have occurred because of longer fasting periods on land resulting from progressively earlier break-ups (Stirling et al. 1999; Derocher et al. 2004). In the Western Hudson Bay (WH) subpopulation, the sea ice-related declines in vital rates have led to reduced population trends and reduced abundance (Regehr et al. 2007b). Similar findings have occurred in other areas. Rode et al. (2010) suggested that declining sea ice has resulted in reduced body size and reproductive rates within the SB subpopulation. They also found that reduced availability of sea ice habitat was correlated with a reduction in the number of yearlings produced per female (Regehr et al. 2007b).

If bears spend more time on land during the open water period, there is potential for increased disease transmission (Kirk et al. 2010; Prop et al. 2015; Wiig et al. 2015), particularly where bears form aggregations at sites where the remains of subsistence harvested whales are deposited (e.g., Barter Island and Cross Island, Alaska). Such aggregations are also more susceptible to the impacts from potential oil spills (BOEM 2014).

Increased use of onshore habitat by polar bears has also led to higher incidences of human-polar bear conflict (Dyck 2006; Towns et al. 2009). In two studies of polar bears killed by humans in northern Canada, researchers found that the majority of polar bears killed in defense-of-life occurred during the open water season (Stenhouse et al. 1988; Dyck 2006). Thus, as more bears come on shore during summer, and spend longer periods of time on land, there is an increased risk of human-polar bear conflict; resulting in the potential for more defense-of-life kills and disruption to industrial, recreational, and subsistence activities.

Seasonal polar bear distribution changes, the negative effect of reduced access to primary prey, and prolonged use of terrestrial habitat are all concerns for polar bears. Although polar bears have been observed using terrestrial foods such as blueberries (*Vaccinium sp*.), snow geese (*Anser caerulescens*), and reindeer (*Rangifer tarandus*), these alternate foods cannot replace the energy-dense diet polar bears obtain from marine mammals (e.g., Derocher et al. 2004; Rode et al. 2010b; Smith et al. 2010b). Polar bears are not known to regularly hunt musk oxen (*Ovibos moschatus*) or snow geese (Lunn and Stirling 1985). Thus, greater use of terrestrial habitats will not offset energy losses resulting from decreased seal consumption. Nutritional stress is a likely result. This conclusion is well-supported by evidence from Western Hudson Bay, as previously cited.

A.4. Impacts to prey species

Polar bear subpopulations are known to fluctuate with prey abundance (Stirling and Lunn 1997). Regional declines in ringed and bearded seal numbers and productivity have resulted in marked declines in certain polar bear subpopulations (Stirling and Øritsland 1995; Stirling 2002). Ringed seal populations are known to exhibit natural fluctuations, but there is concern that longer-term population declines associated with sea ice decline might be overlaid with natural fluctuations (Chambellant et al. 2012). Indeed, ringed seal population dynamics are a complex mix of biotic and abiotic factors (Pilfold et al. 2015), making it difficult to understand the direct influence of sea ice loss on demography.

Accurate population estimates and trends for these seal species are unavailable. In 2012, the National Marine Fisheries Service (NMFS) listed two prey species of polar bears, the Arctic subspecies of ringed seal (*Phoca hispida hispida*) and the Beringia DPS of bearded seal (*Erignathus barbatus nauticus*), as threatened species under the Act (77 FR 76706; 77 FR 76740) due to climate change. Following successful legal challenges to both listings in the District Court, the 9th Circuit Court of Appeals upheld the agency's listing determination for the Beringia Distinct Population Segment of bearded seal on October 24, 2016; NMFS appeal of the Arctic ringed seal decision (March 11, 2016) is still pending.

Diminishing ice and snow cover are the greatest challenges to the persistence of ringed seals. Within the century, snow cover is projected to be inadequate for the formation and occupation of subnivean birth lairs over most of the species' range (Kelly et al. 2010; Iacozza and Fergusson 2014). The thickness of the snow layer surrounding birth lairs is crucial for thermoregulation and hence, the survival of nursing pups when air temperatures are below freezing (Stirling and Smith 2004). Pups in lairs with thin snow roofs are also more vulnerable to predation than pups in lairs with thick roofs (Hammill and Smith 1991; Ferguson et al. 2005). When lack of snow cover has forced birthing to occur in the open, nearly 100% of pups died from predation (Smith and Lydersen 1991; Smith et al. 1991). Additionally, in some populations, ringed seals are thought to be increasing their foraging efforts due to changing environmental conditions with the potential to lead to negative population-level consequences (Hamilton et al. 2015).

Rain-on-snow events during the late winter are increasing and can damage or eliminate snow-covered pupping lairs (ACIA 2005). The pups are then exposed to the elements and risk hypothermia. Damaged lairs or exposed pups are relatively easy prey for polar bears and arctic foxes (*Alopex lagopus*) (Stirling and Smith 2004). Stirling and Smith (2004) postulated that should early season rain become regular and widespread in the future, mortality of ringed seal pups will increase, especially in more southerly parts of their range.

Pupping habitat on landfast ice (McLaren 1958; Burns 1970) and drifting pack ice (Wiig et al. 1999; Lydersen et al. 2004) can be affected by earlier warming and break-up in the spring, which shortens the length of time pups have to grow and mature (Kelly 2001; Smith and Harwood 2001). In addition, high fidelity of ringed seals to birthing sites makes them more susceptible to localized impacts from birth lair snow degradation, harvest, or human activities (Kelly et al. 2006).

Changes in snow and ice conditions can also affect polar bear prey other than ringed seals (Born 2005), and will likely result in a net reduction in the abundance of species such as ribbon seals (*Phoca fasciata*) and bearded seals (MacIntyre et al. 2015). As a result, some polar bear subpopulations likely will not be able to compensate for the reduced availability of ringed seals by increasing their taking of other species (Derocher et al. 2004). Alternatively, walruses at terrestrial haulouts may become more available to polar bears in some areas as polar bear land use increases due to decline of ice extent and duration (Kochnev 2002; Rode et al. 2015b).

A.5. Inadequate conditions for successful denning

Climate change could negatively influence polar bear denning (Derocher et al. 2004). Insufficient snow would prevent den construction or result in use of poor sites where the roof could collapse (Derocher et al. 2004). Changes in the amount and timing of snowfall could also impact the thermal properties of dens (Derocher et al. 2004). Since polar bear cubs are born helpless and need to nurse for three months before emerging from the den, major changes in the thermal properties of dens could negatively impact cub survival (Derocher et al. 2004). Unusual rain events are projected to increase throughout the Arctic in winter (Liston and Hiemstra 2011), and increased rain in late winter and early spring could cause den collapse (Stirling and Smith 2004). The proportion of bears denning on ice has decreased for some subpopulations (Atwood et al. 2016b) and not others, but the consequences of these shifts to cub survival are unknown.

A.6. Loss of access to denning areas

While polar bears can successfully den on land and sea ice (Amstrup and Gardner 1994; Fishbach et al. 2007), for most subpopulations, maternity dens are located on land (Derocher et al. 2004). Recent information indicates that some subpopulations, such as the SB, continue to disproportionately den on land (Rode et al. 2015b). Female polar bears can repeatedly return to specific denning areas on land (Harington 1968; Ramsay and Stirling 1990; Amstrup and Gardner 1994). For bears to access preferred denning areas on land, pack ice must drift close enough or must freeze sufficiently early to allow pregnant females to walk or swim to the area by late October or early November (Derocher et al. 2004). As distance increases between the pack ice edge and coastal denning areas, it will become increasingly difficult for females to access preferred denning locations unless they are already on or near land. Distance to the ice edge is one factor thought to limit denning in western Alaska in the CS subpopulation (Rode et al. 2015b). Increased travel distances could negatively affect denning success and ultimately population size of polar bears (Aars et al. 2006).

Under most climate change scenarios, the distance between the edge of the pack ice and land will increase during summer. Derocher et al. (2004) predicted that under future climate change scenarios, pregnant female polar bears will not be able to reach many of the most important denning areas in the north coast of the central Beaufort Sea. Bergen et al. (2007) found that between 1979 and 2006, the minimum distance polar bears traveled to denning habitats in northeast Alaska increased at an average linear rate of 6–8 km (3.7-5.0 mi) per year and almost doubled after 1992. They projected that travel distances would increase threefold by 2060 (Bergen et al. 2007).

A.7. Loss of mating platform

Moore and Huntington (2008) classify the polar bear as an "ice-obligate" species because the bears rely on sea ice as a platform for breeding as well as resting and hunting. While loss of sea ice may impact mating success due to a reduction in the ability to find females in estrous (Molnár et al. 2011; Owen et al. 2015), polar bear habitat projections indicate a high likelihood of sea ice habitat in spring through at least mid-century (Durner et al. 2009; Castro de la Guardia et al. 2013; Hamilton et al. 2014), indicating that there will likely be suitable ice to serve as a mating platform into the foreseeable future.

B. <u>Overutilization</u>

Overutilization in the form of human-caused removals of bears was not found to be a threat to the population throughout all or a significant portion of its range (73 FR 28212). However, increased mortality from human-bear encounters or other forms of mortality may become a more significant threat in the future, particularly for subpopulations experiencing nutritional stress or declining numbers as a consequence of habitat change.

Subsistence harvest, management harvest (defense of life, mercy killings, and removal of problem bears), and sport harvest (Canada only, using a proportion of subsistence-allocated tags) are currently types of human-caused removals that are allowed throughout all or parts of the polar bear's range. Subsistence harvest accounts for the majority of human-caused removals (Obbard et al. 2010) and is important to indigenous people in many parts of the Arctic for nutritional and cultural purposes, and in some regions provides economic revenue from the sale of polar bear parts or handicrafts.

A review of new information since 2008 indicates that overutilization still does not threaten the species throughout all or a significant portion of its range. This finding is consistent with reviews of circumpolar management of polar bears developed by the IUCN PBSG (Obbard et al. 2010), TRAFFIC North America and World Wildlife Fund Canada (Shadbolt et al. 2012), the Polar Bear Range States (PBRS 2015), the Animals Committee of the Convention on the International Trade of Endangered Species of Fauna and Flora (CITES) 2015 Review of Significant Trade (CITES 2015), and the IUCN Red List Authority (Wiig et al. 2015). Atwood et al. (2015) concluded that sea-ice loss due to anthropogenic climate change was the most important factor in forecasts of the future status of polar bears worldwide, while *in situ* human activities (including human-caused removals) exerted considerably less influence on population outcomes. Harvest management is necessary to ensure that human-caused removals do not reduce abundance to unacceptable levels or reduce the viability of populations (Regehr et al. 2015).

Since 2008, concerns persist about subsistence harvest levels for several subpopulations, particularly those with poor or outdated population data (Obbard et al. 2010; Vongraven et al.

2012). The three polar bear Range States that allow legal harvest -- Canada, Greenland, and the U.S.-- have made progress on the management systems and scientific information used to ensure that harvest does not threaten the species. On a circumpolar level, a primary concern is the potential for future overutilization due to interactions between human-caused removals and negative effects of climate change. For example, if habitat loss leads to an increased number of nutritionally-stressed polar bears on land, human-bear conflicts, and resulting human-caused removals, are expected to increase (PBRS 2015). Harvest management methods that consider the current and future potential effects of habitat loss, the quality of data used to inform management decisions, and the possibility of population thresholds below which increasing conservation efforts would be made to reduce human-caused disturbance and removals, are all important considerations to long-term management of harvest for populations affected by climate change (Regehr et al. 2015; USFWS 2016).

B.1. Management systems and agreements

Human-caused removals are managed in accordance with numerous laws, legislation and regulations among and within the five range state countries. Internationally, the *1973 Agreement on the Conservation of Polar Bears (“Range States Agreement”)* calls for cooperative international management of polar bear populations based on sound conservation practices, prohibits polar bear hunting except by local people using traditional methods, calls for protection of females and denning bears, and bans use of aircraft and large motorized vessels to hunt polar bears (Prestrud and Stirling 1994). The transfer and trade of polar bear parts is regulated by CITES, under which the polar bear is currently listed on Appendix II.

Reviews of international and national management of human-caused removals of polar bears are available in 73 FR 28212, Schliebe et al. (2006), Obbard et al. (2010), Shadbolt et al. (2012), and PBRS (2015).

Canada. In Canada, polar bears are managed under federal, provincial, and territorial legislations. On the federal level, the Species at Risk Act is an important law for managing bears, while multiple land claims agreements play a critical role in polar bear management at the provincial and territorial levels (Shadbolt et al. 2012). There have been several notable changes in Canadian management since 2008. The quota for Nunavut from the WH subpopulation was reduced from 56 bears per year in 2005 to 24 bear per year in 2014 (the quota varied between these years) based on evidence for subpopulation declines due to sea-ice loss (Regehr et al. 2007a; Lunn et al. 2016). A negative non-detriment finding under CITES was issued for the Baffin Bay subpopulation in 2009 due to concerns about over-harvest, followed by an incremental reduction in harvest by 10 bears per year 2010-2014 (Obbard et al. 2010) and completion of a joint population study by Canada and Greenland. A user-to-user agreement has been developed for harvest from the Southern Hudson Bay subpopulation in response to the removal 74 bears in 2011 and the lack of management-specific quotas in Nunavik.

Greenland. Polar bear management in Greenland is governed by *The Greenland Home Rule Act No. 12 of October 29, 1999, on Hunting and Game*. Harvest is primarily for subsistence purposes, and is only permitted by resident, full-time hunters registered with the government of Greenland. Quotas for polar bear harvest were implemented in 2006 along with an improved reporting system (Lønstrup 2006; Born et al. 2011, followed by a phased quota reduction over three-years due to concerns about over-harvest of the Baffin Bay and Kane Basin subpopulations in western Greenland, and lack of current scientific data for the East Greenland subpopulation. A negative non-detriment finding under CITES was issued in 2008 for all polar bears in Greenland. New population studies in western Greenland (see *Canada*) and eastern Greenland were initiated in 2011 and 2015, respectively.

Norway. The *Svalbard Environmental Protection Act* (2002) is the main legal framework for polar bear management in Norway. Because there are no indigenous people in Svalbard, polar bear harvest has been prohibited in Norway since enactment of the 1973 Agreement.

Russia. Russia has prohibited the harvest of polar bears since 1956. Bears can only legally be killed as conflict bears or for scientific purposes. Further, the only permitted removal of bears from their natural environment is the removal of cubs for education (Shadbolt et al. 2012). Russia and the United States signed the *Agreement between the Government of the United States of America and the Government of the Russian Federation on the Conservation and Management of the Alaska-Chukotka Polar Bear Population* (U.S.-Russia Agreement) in 2000, and held the first bilateral meeting in 2009. A sustainable harvest limit of 19 female and 39 males polar bears per year for the Alaska-Chukotka population (also referred to as the CS subpopulation by the PBSG, although management boundaries differ) was identified by the US-Russia Polar Bear Commission in 2010 and has been reaffirmed each year since. The harvest limit is split evenly between Native peoples of Alaska and Chukotka. Russia intends to implement a legal subsistence harvest for indigenous people, in accordance with these limits, once the necessary monitoring and management infrastructures have been established. Since 2008, new amendments have been added to the Criminal Code of the Russian Federation to penalize destruction of critical habitat for animals and plants listed in the Red Data Book of the Russian Federation, including the polar bear.

United States. In 1972, the U.S. passed the MMPA ending polar bear hunting in the U.S. except by coastal dwelling Alaska Natives for subsistence purposes, provided the harvest is not wasteful. The Act also affects harvest management for bears in U.S. jurisdiction. As of the effective date of listing the polar bear as “threatened” under the Act, authorization for the import of sport-hunted polar bear trophies from Canada to the U.S. is no longer available under section 104(c)(5) of the MMPA. In coming years, the U.S. intends to implement the sustainable harvest limits for the CS subpopulation, as identified under the U.S.-Russia Agreement, through a co-management approach between the federal government and an Alaska Native co-management partner. Subsistence harvest in the SB subpopulation is regulated through an agreement between the Inuvialuit of Canada and the Inupiat of Alaska (I-I Agreement; Brower et al. 2002). The current harvest quota is 56 bears, (Alaska 35, Canada 21).

Polar bear harvest in the U.S. is monitored by the Service’s Marking and Tagging Program (MTRP; 75 FR 76086) with the assistance of local taggers in Alaska’s villages. A review of past and current harvest, including other forms of removal, and recommendations for harvest monitoring and management has been developed (Schliebe et al. 2016).

Circumpolar. The five polar bear Range States, as identified in the 1973 Agreement, have become active in recent years to address the emerging threat of climate change, with multilateral meetings of the Range States held in 2009, 2013, and 2015. In 2014, the PBSG was identified as the scientific advisor to the Range States. A Circumpolar Action Plan for the polar bear (PBRS 2015) was developed to synthesize and coordinate management and conservation activities among countries, in conjunction with National Action Plans developed by individual range states.

In 2015, the Trade Working Group of the Range States produced six recommendations to explore mechanisms to counter the threat of poaching and illegal trade in polar bear parts, enhance cooperation among law enforcement agencies, improve the clarity of legal trade data, and improve identification of legally traded specimens. In 2015, the CITES Animals Committee removed the polar bear from a Review of Significant Trade on the basis that the current level of harvest and trade in polar bear parts is not detrimental to the survival of the species in the wild (CITES 2015). This action is expected to result in no change to the polar bear's current listing under Appendix II of CITES. In 2015, the IUCN Red List Authority categorized the polar bear as "vulnerable" (Wiig et al. 2015), similar to the previous categorization (Schliebe et al. 2008), on the basis of the primary threat of habitat loss due to climate change.

Laidre et al. (2015) developed a circumpolar assessment of the status of Arctic marine mammals, including the polar bear, and recommended the following considerations for effective management and conservation: maintain and improve co-management by local, federal, and international partners; recognize spatial and temporal variability in marine mammal subpopulations responses to climate change; implement monitoring programs with clear goals; mitigate cumulative impacts of increased human activity; and recognize the limits of current protected species legislation.

B.2. Subsistence and Sport Harvest

The U.S., Canada, and Greenland are currently the only Range States that allow for the subsistence harvest of polar bears by indigenous people. Polar bear harvest management regimes vary within these countries (73 FR 28212; Obbard et al. 2010; Shadbolt et al. 2012). Polar bear harvest remains an important nutritional, cultural, and economic resource for indigenous people in many parts of the Arctic (e.g., Schliebe et al. 2006; Born et al. 2011; Voorhees et al. 2014; Joint Secretariat 2015). Canada is the only country that allows sport hunting, in Nunavut and the Northwest Territories, through guided hunts that use a portion of the tags allocated for subsistence harvest under existing management agreements.

All forms of human-caused removals are generally included in harvest statistics (noting that some types of removals, such as subsistence harvest and defense-of-life kills, are interrelated such that delineation is difficult). The statistics in this section reflect all reported human-caused removals unless otherwise noted.

Shadbolt et al. (2012) reported that on average 735 polar bears were killed globally per year from 2006-07 to 2010-11 (winter years), which was three to four percent of their estimated global population of 20,000 to 25,000 polar bears (noting that Wiig et al. [2015] suggested a global population size of 26,000 polar bears [95%CI = 22,000-31,000]). For polar bears, removing 4.5% of a population annually has historically been considered sustainable in the sense of not causing populations to decline below the size at which they produce maximum sustainable yield (Taylor et al. 1987). Regehr et al. (2015) corroborated that a 4.5% removal rate is generally reasonable although some subpopulations may support higher rates under favorable environmental conditions, and under some circumstances lower rates may be necessary to avoid accelerating population declines caused by habitat loss due to climate change. Shadbolt et al. (2012) indicated that Canada harvested the most bears of any Range State during this period, with an average of 554 bears per year. Greenland removed an average of 136 bears per year, the U.S. removed an average of 45 bears per year, and Norway removed an average of one bear per year. Information of bears removed in Russia was not available for their analysis, although a new survey of communities in Chukotka provides updated information of the current and historic number of polar bears removed in that region (Kochnev and Zdor 2015; see B.3. Poaching [illegal hunting]).

The mean level of human-caused removal by subpopulation was reported for the period 2005-2009 by Obbard et al. (2010), and updated by the IUCN Polar Bear Specialist Group in 2015 (Table 2; updated versions periodically available at: http://pbsg.npolar.no/en/status/status-table.html). Recent harvest levels have been thought to be sustainable in most subpopulations (Obbard et al. 2010), although concerns exist for some subpopulations due to poor or outdated scientific data, poor or incomplete reporting of human-caused removals, or harvest rates that appear excessive in relation to the best-available estimates of subpopulation size. The 2015 PBSG Status Table categorized knowledge on the current trend of 9 subpopulations as "data deficient." Vongraven et al. (2012) indicated that polar bear harvest is closely monitored in most regions where it occurs, but noted several subpopulations for which improvements to baseline harvest data and sampling are needed. Vongraven et al. (2012) also indicated that, in practice, subsistence harvest levels are based on factors including scientific assessments of status, traditional knowledge information, as well as the level of local interests in harvesting polar bears for nutritional, cultural, and economic purposes. The results of Vongraven et al. (2012) suggest that polar bear subpopulations may respond to various levels of harvest pressure differently depending on multiple factors, and the authors suggest that flexible harvest systems that can adapt to changing conditions may be necessary to mitigate and minimize the relative threat legal harvest poses to polar bear subpopulations.

Regehr et al. (2015) provided a modeling and management framework for harvesting wildlife affected by climate change, applied specifically to polar bears. That framework uses state-dependent (i.e., dependent on current condition) management to identify harvest levels that consider the effects of changes in environmental carrying capacity (e.g., due to sea-ice loss), changes in intrinsic growth rate, the sex and age of removed animals, the quality of population data, timing of management decisions, risk tolerance, and other factors. The authors evaluate the ability of the harvest management strategy relative to its ability to achieve two objectives: (i) maintain a population above its maximum net productivity level relative to a potentially changing carrying capacity, and (ii) minimize the effect of harvest on population persistence. Regehr et al. (2015) demonstrated that harvest adhering to this framework is unlikely to accelerate population declines resulting from habitat loss due to climate change, recognizing that both the harvest level (i.e., number of bears removed annually) and harvest rate (i.e., percent of the population removed annually) may decline for populations negatively affected by climate change.

Table 2. Polar bear population status and trends in relation to human-caused removals by subpopulation from 2010 to 2014 (PBSG 2015: http://pbsg.npolar.no/export/sites/pbsg/en/docs/status-table-2014.pdf) and relative threat to the subpopulation due to harvest (Vongraven et al. 2012).

Subpopulation	Size		Trend		Human-caused removals 2010-2014				Relative threat due to harvest [1]
	Estimate / 95% CI	Year	Relative to historic level	Current	5-yr mean		2014		
					Potential	Actual	Potential	Actual	
Arctic Basin	Unknown		Data Deficient	Data Deficient					Low
Baffin Bay	1546	2004	Data Deficient	**Declining**	144	149	132	137	Declining due to harvest
Barents Sea	2644	2004	Data Deficient	Data Deficient	NA	2	NA	3	None
Chukchi Sea	Unknown		Data Deficient	Data Deficient	58	30 (US), 32 RUS	58	23 (US), 32 (RUS)	Legal quota proposed
Davis Strait	2158	2007	Data Deficient	Stable	99	99	103	105	Low
East Greenland	Unknown		Data Deficient	Data Deficient	62	63	64	65	Sustainability of harvest unknown
Foxe Basin	2580	2009-10	**Not Reduced**	Stable	98	104	71	85	Sustainability of harvest unknown
Gulf of Boothia	1592	2000	**Not Reduced**	Stable	60	58	58	52	Low
Kane Basin	164	1994-97	Data Deficient	**Declining**	11	6	11	5	Declining due to harvest
Kara Sea	Unknown		Data Deficient	Data Deficient		NA		NA	Poaching level unknown
Lancaster Sound	2541	1995-97	Data Deficient	Data Deficient	93	85	102	83	Declining due to harvest
Laptev Sea	Unknown		Data Deficient	Data Deficient		NA		NA	Poaching level unknown
M'Clintock Channel	284	2000	Reduced	**Increasing**	3	3	3	3	Low
Northern Beaufort Sea	980	2006	**Not Reduced**	Stable	65	38	65	43	Low
Norwegian Bay	203	1997	Data Deficient	Data Deficient	4	3	4	3	Declining due to harvest
Southern Beaufort Sea	907	2010	Reduced	**Declining**	76	36	73	43	Harvest mortality additive to negative population growth rate
Southern Hudson Bay	951	2012	**Not Reduced**	Stable	60	62	60	56	High
Viscount Melville Sound	161	1992	Data Deficient	Data Deficient	6	7	6	7	Sustainability of harvest unknown
Western Hudson Bay	1030	2011	Reduced	Stable	23	24	28	32	Harvest mortality additive to negative population growth rate

[1] Referenced from Vongraven et al. 2012

The U.S. harvest management system for the SBS subpopulation is described in section B.1. Management systems and agreements. For the most recent 10-year period 2006-2015, an average of 19 bears per year (Figure 3) were removed from the U.S. portion of the SBS subpopulation. The average sex composition of removals during this period was 27% female, 50% male, and 22% unknown.

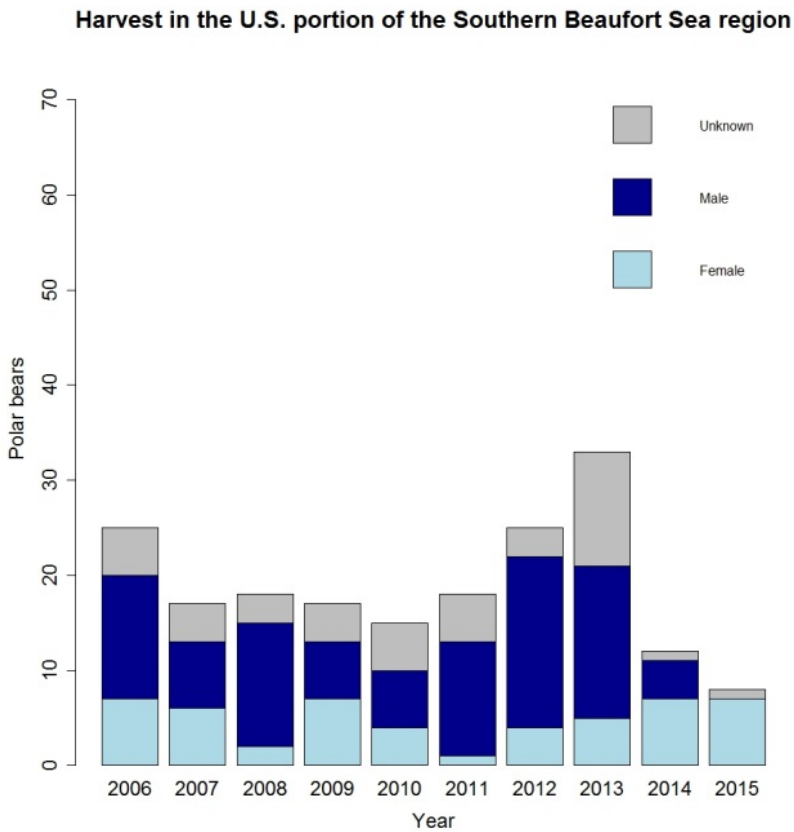


Figure 3. Polar bear harvest in the U.S. portion of the Southern Beaufort Sea subpopulation 2006-2015.

The U.S. harvest management system for the CS subpopulation is described in section B.1. Management systems and agreements. For the most recent 10-year period 2006-2015, an average of 30 bears per year (Figure 4) were removed from the U.S. portion of the CS subpopulation, calculated relative to the boundary near Icy Cape, Alaska, as recognized by the PBSG (Obbard et al. 2010). The average sex composition of removals during this period was 29% female, 57% male, and 14% unknown.

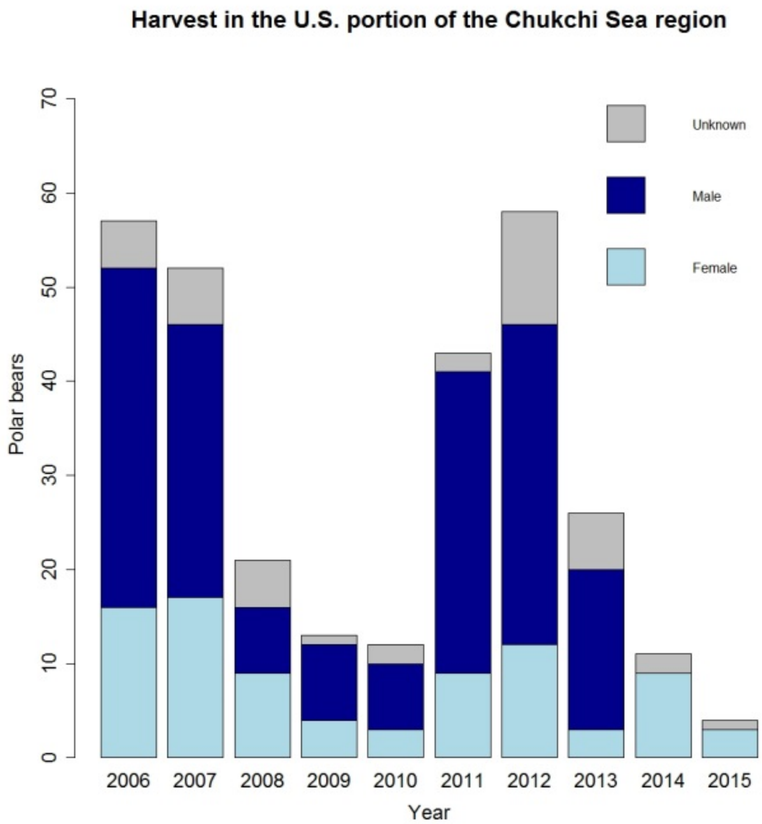


Figure 4. Polar bear harvest in the U.S. portion of the Chukchi Sea subpopulation 2006-2015.

B.3. Poaching (illegal hunting)

Given the remoteness of human habitation throughout polar bear range, poaching is hard to record and quantify. During the 2008 review, the Service found limited evidence to suggest that poaching is a concern in the subpopulations within the Range States of Canada, Norway, Greenland, and the U.S. However, poaching may be an issue for the subpopulations within Russia. The level of poaching is unknown in the Kara Sea and Laptev Sea subpopulations (Vongraven et al. 2012) even though polar bear hunting has been prohibited in Russia since 1956. Poaching appeared to increase in northeast Russia (Chukotka) after the collapse of the Soviet Union affecting the CS subpopulation. The level of illegal killing was estimated to be high enough to be unsustainable and to pose a serious threat to the CS subpopulation in the 1990s (Obbard et al. 2010). Kochnev (2004) suggested that illegal hunting in eastern Russia may have been as high as 100 to 200 bears between 1999 and 2003.

Kochnev and Zdor (2015) suggest that illegal hunting of polar bears in the CS subpopulation removed approximately 32 bears per year recently, based on community interviews conducted between 2010 and 2011. This represents a likely decline from the estimated 209 bears killed annually from 1994 to 2003. Environment Canada reports that illegal hunting in Canada is a rare event (Environment Canada 2010). There is little documentation of illegal hunting in Greenland although two men were charged with use of illegal equipment in 2011 (Shadbolt et al. 2012). No documented cases of illegal hunting exist for Norway (Svalbard). In the U.S., from 2008 to 2015, only one known bear was illegally taken from the CS subpopulation in 2013. Wiig et al. (2015) reported that range-wide illegal hunting of polar bears is not thought to be a major concern.

B.4. Defense-of-life removals

Human-bear interactions and defense-of-life kills may increase under projected climate change scenarios where more bears are on land and in contact with humans (Derocher et al. 2004). Polar bears are inquisitive animals and often investigate novel odors or sights. This trait can lead to polar bears being killed when they investigate human activities (Herrero and Herrero 1997). Since the late 1990s, the timing of freeze-up in the autumn has occurred later and later, resulting in an increased amount of time polar bears spend on land in some areas (Rode et al. 2015b). This can increase the probability of human-bear interactions. With projections indicating that the Arctic Ocean may be largely ice free in the summer in the next few decades (Overland and Wang 2013), human-polar bear conflicts are expected to increase as bears are forced on shore and closer to people (Dyck 2006; Regehr et al. 2007b; Towns et al. 2009). Understanding and addressing human-bear conflicts will ultimately help reduce the necessity to lethally remove a polar bear in defense of a human life.

Since 2008, human-polar bear conflict reduction has become an important issue for many circumpolar communities. In recent years, these efforts have increased and have incorporated multiple groups. Non-government organizations (NGOs) have been working with government agencies and local communities throughout the Arctic to provide information and training, remove attractants from villages, provide bear-proof storage containers for food, provide electric fencing, and fund polar bear patrols (Voorhees and Sparks 2012; York et al. 2014). These initiatives strive to minimize human-bear conflicts and create safe communities; however, much work remains. Reducing human-bear conflicts through attractants management, such as managing human food and garbage or managing natural attractants (i.e., whale carcass sites) in or near human settlements continues to be an important and challenging issue for Arctic communities and wildlife managers (Koopmans 2011; Aerts 2012; ANC 2013; York et al. 2014).

Polar bear patrols in coastal communities are another effective technique to reduce human-bear conflicts through deterrence and education. These structured programs enable trained, local residents to deter polar bears from entering communities using a variety of non-lethal techniques (ANC 2013). While deterrence may not be effective for every bear, it does provide a non-lethal option for keeping bears out of communities in the majority of cases. Established polar bear patrols now occur in the U.S., Canada, Greenland, and Russia.

Since the listing in 2008, in Alaska, two defense-of-life removals from the SB subpopulation by non-Alaska Natives occurred with humans engaged in recreational activities. The first incident occurred in August 2014 at Bullen Point and the second occurred a week later in the Arctic National Wildlife Refuge.

B.5. Other removals

Other forms of removal include take associated with accidental mortality during scientific research, during industrial activities and placement of orphaned cubs into public display facilities. These sources of mortality are generally included in estimates of total removals provided previously. In 2008, these levels of take were sufficiently low that the Service determined they were insignificant and had no effect on population status. New information summarized below indicates this is still an accurate assessment.

Research

Research activities may cause short-term effects to individual polar bears targeted in survey and capture efforts (Thiemann et al. 2013) and may incidentally disturb those nearby. In rare cases, research efforts may lead to injury or death of polar bears. Between 1967 and 2012, there were around 4,401 capture events of polar bears in Alaska with at least 19, and perhaps as many as 27, deaths (a capture mortality rate ranging from 0.4 – 0.6% since 1967). In 2001 the USGS began an intensive capture/mark/recapture project in the southern Beaufort Sea that is ongoing and mortality has been low (3 research related mortalities resulting from 1,260 captures, or 0.24%). Capture efforts in the southern Beaufort Sea, however, have not resulted in any long-term effects on body condition, reproduction, or cub survival (Rode et al. 2014a)

Orphaned Cubs
In the U.S., two orphaned cubs-of-the year have been removed from their natural environment since 2008. In 2011, one orphaned female cub from the SB subpopulation was recovered in an industrial area after apparently being separated from its mother. It was subsequently sent to a public display facility. In 2013, one orphaned male cub of the year that was recovered from the CS subpopulation as a stranded animal after its mother was harvested. It was subsequently sent to a public display facility for long term care and maintenance. No other recent information on orphaned cubs has been documented from other countries.

Industrial Activities
Climate change is expected to increase accessibility to natural resources in the Arctic, effectively increasing industrial activities and its support infrastructure in the circumpolar regions. Industries, such as mineral extraction, shipping, and petroleum exploration and development, are all expected to increase in the future.

Three polar bear removals have occurred from the SB subpopulation since the listing as a result of industry activities, and one removal occurred as a result of deterrence activities. In 2011, an oil company security guard accidently shot and killed a female polar bear during a deterrence action. In 2012, one adult female and her two-year old male cub were found dead on an island near industry facilities. Their deaths are assumed to be related to the chemical substances found in and on the bears. In 2012, an additional lethal removal from the SB subpopulation occurred during a deterrence action of a community bear patrol. Since 2008, no other recorded removals as a result from industrial activities have been documented. Industrial activities are further discussed in Section E.1.

C. Disease and Predation

In the Final Rule for listing polar bears under the Act (73 FR 28212), the Service examined the best available scientific information on disease and determined that diseases do not threaten the species throughout all or any significant portion of its range. A further review of new information since 2008 indicates that disease and predation continue to pose little threat to the species.

C.1. Disease

Polar bears are not generally susceptible to disease and parasites (73 FR 28212). The Service noted in 2008 that the potential for disease outbreaks, an increased possibility of pathogen exposure from changing diets, increased susceptibility of polar bears to existing pathogens, or the occurrence of new pathogens that have moved northward with a warming environment all warrant continued monitoring and may become more significant threat factors in the future for polar bear populations experiencing nutritional stress or declining numbers (73 FR 28212).

Fagre et al. (2015) conducted a literature review of existing papers describing infectious diseases that have been reported in polar bears. They noted that in reports where wild polar bears have been exposed to various bacteria, fungi, parasites and viruses, limited information on health effects were reported. They also documented that the majority of diseases found in captive polar bears do not occur in the Arctic environment and thus may have limited value for understanding the importance of these diseases in wild bear populations.

C.2. Emergence of new pathogens in polar bears

Whether polar bears are more susceptible to new pathogens due to their lack of previous exposure to diseases and parasites is unknown. As the effects of climate change become more prevalent, there are concerns with the expansion of existing pathogens from southern latitudes moving into the polar bears' range (Weber et al. 2013). New pathogens may expand their range northward from more southerly areas under projected climate change scenarios (Harvell et al. 2002). Further, the potential for pathogens crossing human-animal boundaries (e.g. giardia), and new threats from existing pathogens that may be able to establish in immuno-compromised/stressed individuals is also a concern. Many different pathogens and viruses have been found in seal species that are polar bear prey, so the potential exists for transmission of these diseases to polar bears

Patyk et al. (2015) suggested that due to the predicted effects of climatic warming and the synergistic effects of pollutants on polar bears' resistance to disease and parasites, establishing good baseline data for the most common diseases in different populations of polar bears and by tracking temporal trends in prevalence for each disease could help future research and monitoring.

C.3. Intraspecific Competition

While cannibalism has been documented among polar bears (Derocher and Wiig 1999; Amstrup et al. 2006; Stirling and Ross 2011) and infanticide by male polar bears have been documented (Taylor et al. 1985; Derocher and Wiig 1999; Stone and Derocher 2007), there is no indication that these stressors have resulted in population level effects.

C.4. Interspecific competition

One form of interspecific competition is cross-breeding, or hybridization. The ranges of polar bears and grizzly bears overlap only in portions of northern Canada, Chukotka (Russia), and northern Alaska. The first documented case of cross-breeding in the wild was a first generation male hybrid harvested on Banks Island, Canada in 2006 (Doupé et al. 2007). Since then, two additional hybrids have been harvested on Victoria Island and multiple sightings have been confirmed in Canada, one of which is considered a "second generation" hybrid, the result of a female grizzly-polar hybrid mating with a male grizzly bear (Species at Risk Committee [SARC] 2012). Further, in April 2012, an adult female polar bear was harvested with two older first generation hybrid cubs (SARC 2012). Cross-breeding in the wild is thought to be rare, but cross-breeding may pose concerns for subpopulations and species viability in the future should the rate of occurrence increase. Based on the harvest and sighting locations, polar bears affected by cross-breeding with grizzly bears presumably are part of the NB and Viscount Melville subpopulations.

Along Alaska's northern coast, polar bears compete with brown bears for food sources. Results from a study conducted in 2005-2007 (Miller et al. 2015) indicate that brown bears are socially dominant and frequently displace polar bears from an annual bowhead whale carcass food source. The physiological effects of these interactions on individual polar bears are not fully determined.

D. <u>Inadequacy of existing regulatory mechanisms</u>

In the Final Rule (73 FR 28212), the Service reviewed existing regulatory mechanisms and determined that potential threats to polar bears from direct take, disturbance by humans, and incidental or harassment take are, for the most part, adequately addressed by existing regulatory mechanisms. However, there are no known regulatory mechanisms in place at the national or international level that directly and effectively address the primary threat to polar bears—the range-wide loss of sea ice habitat within the foreseeable future (73 FR 28212).

As noted above, since 2008, there have been no new mechanisms that effectively regulate greenhouse gas emissions, which are contributing to global climate change and associated modifications to polar bear habitat. However, governments and concerned organizations are trying to address climate change impacts on a global level. Recently, at the Paris Climate Conference held in December 2015, 195 countries adopted the first universal global climate agreement. This agreement presents a global action plan that is meant to limit global warming to below 2°C by the end of the century (European Commission 2016;

http://ec.europa.eu/clima/policies/international/negotiations/paris/index_en.htm). On April 22, 2016, all five polar bear range state countries signed the Paris Agreement.

E. Other Natural or Manmade Factors Affecting the Polar Bear's Continued Existence

In the Final Rule for listing polar bears under the Act (73 FR 28212), the Service examined the best available scientific information on other natural or manmade factors affecting polar bears' continued existence, such as 1) contaminants; 2) shipping and transport; and 3) ecotourism, and determined that they did not threaten the species throughout all or any significant portion of its range. A further review of new information since 2008 indicates that these factors still do not threaten the polar bear throughout its range, but have the potential to pose a more significant risk in the future.

E.1. Contaminants

Although loss of sea ice is the greatest threat to polar bears, contaminants can exacerbate the effects of this and other threats. Understanding the potential effects of contaminants on polar bears in the Arctic is confounded by the wide range of contaminants present, each with different chemical properties and biological effects, and their differing geographic, temporal, and ecological exposure regimes. In the Final Rule, the Service identified three main groups of contaminants in the Arctic that present the greatest potential threats to polar bears and other marine mammals: persistent organic pollutants (POPs), heavy metals, and petroleum hydrocarbons. The Service concluded that contaminant concentrations were not thought to have population level effects on most polar bear populations, but also noted that contaminants may become a more significant threat in the future, especially for polar bear subpopulations experiencing declines related to nutritional stress brought on by sea ice loss and environmental changes.

E.1.a. Persistent Organic Pollutants (POPs)

Persistent organic pollutants are organic chemicals resistant to biodegradation that can remain in the environment for a long period of time. They are of particular concern to apex species such as polar bears that have low reproductive rates and high lipid levels because POPs tend to bioaccumulate and biomagnify in fatty tissues. The presence and persistence of these contaminants is dependent on factors such as transport routes, distance from source, and quantity and chemical composition of their releases.

In the Final Rule, the Service noted that the Barents Sea (BS), East Greenland (EG), Kara Sea (KS), and some Canadian polar bear subpopulations have the highest overall contaminant concentrations. While the levels of some contaminants, such as polychlorinated biphenyls (PCBs), generally seem to be decreasing in polar bears, others, such as hexachlorocyclohexanes (HCHs), were relatively high, and newer compounds, such as, polybrominated diphenyl ethers (PBDEs) and perflouro-octane sulfonates (PFOS), posed a potential future risk to polar bears. The effects of these contaminants at the population level were considered to be largely unknown. New information regarding contaminant effects on polar bears is summarized below.

Sonne (2010) conducted a review to assess the health effects from a combination of POPs, specifically, organochlorines (OCs), polybrominated diphenyl ethers (PBDEs) perfluorinated compounds (PFCs) and mercury (a heavy metal) on polar bears. Effects on immune and reproductive systems, the brain stem, as well as bone density reduction seemed to occur, but that threshold levels for oral exposure and tissue concentrations could not be specifically estimated.

Letcher et al. (2010) summarized data on the biological effects of a subgroup of POPs known as organohalogen contaminants (OHCs) to evaluate risks on Arctic biota, including polar bears. They found that polar bears in the Southern Hudson Bay (SH), (EG), (BS), and WH subpopulations have the highest potential risk of POP/OHC exposure. Subsequently, Dietz et al. (2015) conducted a risk assessment of OHCs levels found in polar bears during 1999-2008 from 11 subpopulations to assess reproductive effects, immunotoxicity, and carcinogenicity. Results indicated that all subpopulations were at risk for OHC additive effects and that PCBs were the highest contributor to risk.

In EG polar bears, Dietz et al. (2013b) found that, although 18 out of 19 legacy organochloride contaminant levels (including PCBs) decreased between 1983 and 2010, relatively high levels still persist. Several additional studies support previous findings that PCBs and PCB metabolites (e.g., OH-PCBs) can affect the reproductive potential of polar bears in combination with natural stressors and other contaminants (Gustavson et al. 2015; Sonne et al. 2015) and thyroid health (Grønning 2013). Pederson et al. (2015) found that bears from EG have perfluoroalkyl substances (PFAs) at levels that could affect cognitive processes and motor functions. Similarly, Bytingsvik et al. (2012) found levels of PFAs in polar bears in the Svalbard region that pose a health concern for the BS subpopulation, but direct health effects were not identified.

Regarding brominated compounds, McKinney et al. (2011) analyzed samples collected in 2005-2008 from 11 subpopulations of polar bears for flame retardants (as well as legacy contaminants). They found that PBDE levels were highest in EG, BS, WH, and SH subpopulations. Dietz et al. (2013a) reported a significantly increasing trend in concentrations of brominated contaminants between 1983 and 2010, particularly for sub-adult polar bears, that are causing health effects to the EG subpopulation. Subsequently, Vorkamp et al. (2015) found evidence of exposure to 5 novel brominated flame retardants in Greenland polar bears, but noted that concentrations were low.

Additional research from fatty acid analysis indicates that increasing contaminant burdens in polar bears may be a result of dietary shifts resulting from climate induced sea ice changes. For example, in WH polar bears, in years when earlier sea ice breakup occurred, a higher proportion of polar bears' diet consisted of open-water seals (harbor seals) than ice-associated seals (ringed seals) (McKinney et al. 2009). Similar trends were observed in EG polar bears (McKinney et al. 2013); these shifts may affect polar bears because subarctic seals may have higher contaminant loads than Arctic seal species.

In Alaska, contaminant levels in polar bear subpopulations at the time of listing were considered relatively low compared to other subpopulations. A study by Bentzen et al. (2008) showed that the variation in contaminant levels in polar bears may be due to variation in diet and biomagnification of organochlorines in relation to sex, age, and trophic position. Alaskan subpopulations continue to have some of the lowest concentration of PCBs, chlorinated pesticides, and flame retardants of all the polar bear subpopulations (McKinney et al. 2011).

E.1.b. Metals

In the Final Rule, the Service noted that mercury is the element of greatest concern to polar bears, and that the highest concentrations have been found in the Viscount Melville Sound and SB subpopulations. The Service noted that, although mercury found in marine mammals often exceed levels that have caused effects in terrestrial mammals; most marine mammals appear to have evolved mechanisms that allow tolerance of higher concentrations of mercury (AMAP 2005).

Since the listing, spatial and temporal trends of mercury exposure have been studied in various polar bear populations. In one study of 10 different subpopulations in Alaska, Canada, and East Greenland in 2005-2008, concentrations of mercury, selenium and arsenic were highest in the Beaufort Sea area and lowest in Hudson Bay and the Chukchi/Bering seas (Routti et al. 2011). A recent increase in mercury in East Greenland polar bears was also noted in that study. Another analysis of temporal mercury trends in Northwest Greenland polar bear hair found that mercury increased 1.6–1.7% each year from 1892 to 2008; the two most recent median concentrations were 23–27-fold higher than the pre-industrial baseline level in the same region (Dietz 2011).

Mercury levels are expected to continue to increase over time in Arctic due to several climate-related factors. Climate warming will likely accelerate the mobilization of mercury from thawing permafrost, as observed by Rydberg et al. (2010). A study of mercury export from the Yukon River Basin in Alaska documented a large amount of organic-carbon associated mercury exported from that system (a particularly bioavailable mercury fraction), which was likely attributed to permafrost thaw and other climate-related factors (Schuster et al. 2011). Liver mercury levels in polar bears from Canada, Alaska and Greenland, combined with carbon isotope data, suggested that polar bear food webs rich in river-exported carbon may lead to elevated total mercury concentrations in polar bears (Routti et al. 2012). Reduction in the length of the sea-ice season can also influence bioaccumulative contaminant concentrations in polar bears due to prey switching behavior (McKinney et al. 2009). Thus, the ecological impacts of climate change on mercury exposures are a complex interplay of factors such as sea ice dynamics, atmospheric loading of contaminants, permafrost melt, and predator-prey dynamics (McKinney et al. 2015).

The biological implications of increased mercury exposure to polar bear health are an important area of study. The effects of mercury on neurological health and reproduction have been well studied in a few mammalian species and in human epidemiological studies, but less is known about dose-response relationships in polar bears. Krey et al. (2014) studied neurochemical parameters related to mercury in brains of polar bears and found that the current environmental exposure levels do not appear to have an effect on polar bears from northern Canada.

While some contaminants have decreased in overall levels, indicating that international regulations can be effective in reducing contaminants, slow declines of some legacy pollutants like PCBs, coupled with exposure to "new" chemicals, continue to be a concern to polar bear health (McKinney et al. 2009), especially in Greenland and Norway. Since mercury is known to impact the neurological and reproductive health in other mammals, and is expected to continue to increase in polar bear populations over time, mercury should continue to be an important focus of future polar bear monitoring efforts and toxicological studies. Although population-level effects are still widely un-documented for most polar bear subpopulations, increasing exposure to contaminants may become a more significant threat in the future, especially for declining polar bear subpopulations and/or bears experiencing nutritional stress. Therefore, contaminants should continue to be closely monitored.

E.1.c. Petroleum hydrocarbons

Petroleum hydrocarbons can be introduced into polar bear habitat from industrial development and shipping. As noted in the Final Rule, polar bears overlap with both active and planned oil and gas operations throughout their range. Impacts on polar bears from industrial activities, such as oil and gas development, may include: disturbance from increasing human-bear interactions, resulting in direct displacement of polar bears, preclusion of polar bear use of preferred habitat (most notably, denning habitat); and/or displacement of primary prey. Also, increases in circumpolar Arctic oil and gas development, coupled with increases in shipping due to the lengthening open water season, increase the potential for an oil spill to impact polar bears and their habitat.

<u>Industrial Development</u>

Oil and gas activities have occurred in every polar bear Range State, either in the onshore or offshore environment. At the time of listing, the greatest level of oil and gas activity occurring within polar bear habitat was in the United States (Alaska). The Service determined that direct impacts on polar bears from oil and gas exploration, development, and production activities had been minimal and did not threaten the species overall. This conclusion was based primarily on: 1) the relatively limited and localized nature of the development activities; 2) existing mitigation measures that were in place; and 3) the availability of suitable alternative habitat for polar bears. The Service also noted that data on direct quantifiable impacts to polar bear habitat from oil and gas activities was lacking.

Petroleum development is cyclic in nature and susceptible to market demands. Currently, oil and gas exploration, development and production throughout the Arctic has declined since the time of the listing.

Canada. While approval has been given for construction of a natural gas pipeline from the Mackenzie Delta to southern Canada that could affect denning polar bears from the SB subpopulation (Obbard et al. 2010), the project is moving slowly due to environmental and aboriginal concerns and no construction has been initiated (Wilson 2016). Earlier interests in offshore exploration in the Lancaster Sound region had the potential to affect marine mammals including the Lancaster Sound subpopulation, however, permits were recently relinquished (Murray 2016).

Greenland. Since listing, Greenland's government published Greenland's Oil and Mineral Strategy 2014-2018, which encourages oil and gas development as well as focusing on mitigating environmental impacts (Government of Greenland 2014). West Greenland waters were opened for hydrocarbon exploration in 2008; subsequent environmental assessments for oil and gas development in the Baffin Bay and Davis Strait areas resulted in an overall conclusion that development would have little to moderate effects on polar bears; however, polar bears are sensitive to oiling and effects and a worst case scenario oil spill could have serious effects on polar bears (Mosbech et al. 2007; Boertmann et al. 2009a). Exploration has also occurred in waters offshore from northeast Greenland, potentially affecting the EG subpopulation; an environmental analysis assessed similar moderate effects, with oil spills posing a more serious concern (Boertmann et al. 2009b). Despite increasing oil and gas interests, production is likely still 15-20 years away (Thorup 2014).

Norway. While previously most oil and gas activities have occurred in the southern portions of the Barents Sea that is relatively ice free, the Norwegian government recently opened up an additional area further north toward the Arctic sea ice (Agence France-Presse 2016).

Russia. Oil and gas exploration in the Kara Sea has been postponed indefinitely (Pinchuk and Astakhova 2015); however, some interest in offshore exploration and development continues (Gurzu 2016) Offshore production of the Prirazlomnoye field in the Pechora Sea began in 2013, within the range of the KS polar bear subpopulation. While significant environmental concerns have been raised about this project (Barents Observer 2015), no known effects to polar bears have been reported.

United States. In 2006 oil exploration interests expanded into the Chukchi Sea within range of the CS polar bear subpopulation. Since listing, lease sales have been held in both the Beaufort and Chukchi seas, and high value polar bear habitat was identified in the Chukchi Sea lease area (Wilson et al. 2014). However, since 2014, market mechanisms, such as a decline in the value of oil, have led to a decline in pursuing petroleum development at this time in both the Beaufort and Chukchi seas. This has also resulted in cancellation of future lease sales (USDOI 2015) and the relinquishment of lease holding by companies back to the U.S. government.

Ongoing oil and gas production continues in central Beaufort Sea, within range of the SB subpopulation. Two new offshore developments have begun producing oil since the time of listing. Additionally, another offshore development initiated the permit process to develop an oil field in the Beaufort Sea (BOEM 2015).

All oil and gas activities continue to be evaluated and regulated in the United States. Potential effects on polar bears are mitigated through: 1) development of activity-specific human-bear interaction plans (to avoid disturbance), 2) safety and deterrence training for industry staff, 3) bear monitoring and reporting requirements, and 4) implementation of project-specific protection measures (e.g., 1 mile buffers around den sites). In 2015, the Department of the Interior released additional proposed regulations for future, offshore exploratory drilling activities in the U.S. Arctic (USDOI 2015). These regulations are intended to improve operational standards from mobilization to transport, drilling, and emergency response in a manner that the entire exploration operation can be conducted in a safe manner. Additionally, a review of potential impacts, including cumulative effects, is conducted every five years through the Service's Incidental and Intentional Take Program; the most recent reviews (in 2016 and 2013 for the Beaufort and Chukchi seas, respectively) include "findings of no significant impact" to polar bears.

Oil Spills

Oil spills were identified as a primary concern for polar bears throughout their range in the Final Rule. The primary threats to polar bears from an oil spill are: 1) inability to effectively thermoregulate when their fur is oiled, 2) ingestion of oil from grooming or eating contaminated prey, 3) habitat loss or precluded use of preferred habitat; and 4) oiling and subsequent reduction of prey. Spilled oil present in the autumn or spring during formation or breakup of ice presents a greater risk than in open water or ice-covered seasons because of the difficulties associated with cleaning oil in mixed, broken ice, and the presence of bears and other wildlife in prime feeding areas over the continental shelf during this period.

At the time of listing, no major oil spills had occurred in the marine environment within the range of polar bears and the Service had determined that the probability of a large scale oil spill occurring in polar bear habitat and affecting the species range wide was low. The Service also noted that, in Alaska: 1) past history in the Beaufort and Chukchi seas has demonstrated that operations can be conducted safely, and effects on wildlife and the environment minimized; 2) regulations are in place that provide for pollution prevention and control, as well as marine mammal monitoring and avoidance measures; and 3) plans are reviewed by both leasing and wildlife agencies prior to any activity so that protective measures specific for polar bears can be put into place with any new activity. However, the Service also noted that increased circumpolar Arctic oil and gas development, coupled with increased shipping, increased the potential for an oil spill, and if a large spill were to occur, it could have significant impacts to polar bears and their prey, depending on the size, location, and timing of the spill, and the number of animals affected.

Since the 2008 listing, the level of information and number of entities generating information on oil spill preparedness has been increasing in the Arctic (Holland-Bartels and Pierce 2011). For example, at the circumpolar level, the Arctic Council's Protection of the Arctic Marine Environment (PAME) working group produced the Arctic Marine Shipping Assessment 2009 Report (AMSA Report) which identified oil spill prevention as the highest priority in the Arctic for environmental protection. The PAME working group is functioning to enhance cooperation in the field of oil spill prevention, and support research and technology that helps prevent release of oil into Arctic waters (www.pame.is). Additionally, in 2014, the member nations of the Arctic Council signed a Cooperative Agreement to strengthen cooperation, coordination, and mutual assistance regarding oil pollution preparedness and response in the Arctic and to protect the marine environment from oil pollution (www.arcticcouncil.org/eppr/). These initiatives will help countries be better prepared for oil spills, thereby benefitting polar bears if a spill were to occur.

Since the listing, several key reports have also been published regarding oil spill response in the U.S. Arctic. An effort to assess risks, challenges and potential consequences of oil spills in the U.S. Arctic was undertaken by the U.S. Arctic Program, Pew Environment Group (Pew 2010). The authors noted that, while very large spills and well blowouts are low-probability events, the consequences can be disastrous, and even a moderate spill in a sensitive area could have devastating effects.

A report prepared by the U.S. Geological Survey (Holland-Bartels and Pierce 2011) noted that "a significant coordinated international effort by industry and governments is taking place to develop safe and effective infrastructure and technologies to access energy resources in ice-covered Arctic waters." They also noted that while management, spill response, and science communities are actively engaged in developing essential decision-making and ocean- observing systems, most of these efforts are not fully funded, operational, or tested in Arctic waters. They also concluded that better data, and better coordination of data, is needed to optimize oil spill response in the Arctic.

In Alaska, the Oil Spill Risk Analysis process continues to be used by federal managers to identify where natural resources might be exposed to oil under various spill scenarios. For example, as part of the lease sale process, the Bureau of Land Management (BLM) and Bureau of Ocean Energy Management (BOEM) modeled the likelihood of spills occurring during exploration and development in both the National Petroleum Reserve-Alaska (NPR-A) (BLM 2012) and in the Beaufort and Chukchi Sea planning areas (BOEMRE 2011, BOEM 2014). Large (greater than 1,000 bbl) or very large spills (greater than 120,000 bbl) were considered unlikely to occur during oil and gas exploration (BOEM 2014). They also concluded that while a very large oil spill is a highly unlikely event, if one did occur it could result in the loss of large numbers of polar bears and could have a significant impact on the SB and CS polar bear subpopulations.

In terms of response measures, a planning tool known as the Net Environmental Benefit Analysis has been developed that can be used as a decision-making process to identify spill response methods that are most likely to reduce environmental threats in the Arctic (Potter et al. 2012). Additionally, new detection tools, such as, laser fluorosensors and unmanned aircraft systems, have been tested and used to detect and track oil in snow and ice, and they appear to have applications to minimize oil impacts to polar bears (EPPR 2015).

Further, considerable research has been conducted on the use of in-situ burning (ISB), dispersants, and chemical herders as response tools for cleaning up oil in the ice environment, some with promising results (Brandvik et al. 2010; Sørstrøm et al 2010; Potter et al. 2012). Recent technology developments include: better fire resistant boom, use of herding agents in conjunction with ISB, improvements to dispersant formulas, and better equipment and delivery systems (Potter et al. 2012). Significant data gaps still exist in terms of understanding the toxicity from chemical herders and dispersant to Arctic species (Holland-Bartels and Pierce 2011).

The Service has identified minimizing risk of contamination from oil spills as a high priority conservation and recovery action in the Polar Bear Conservation Management Plan (USFWS 2016). We have also been working with various partners to increase response capabilities for polar bears if an oil spill were to occur. While the Service's response strategy emphasizes preventative measures, significant steps have been taken in the last five years to improve response capabilities for treating a small number of oiled polar bears. For example, the Service has joined other response partners to form a marine mammal working group to improve communication and planning among response partners for marine mammals and conduct field drills. The Service has also recently updated the *Oil Spill Response Plan for Polar Bears in*

Alaska (USFWS 2015). The plan classifies response activities for polar bear protection into primary, secondary and tertiary strategies. Primary response involves keeping spilled oil away from polar bears and physical protection of areas most important to polar bears. Primary response strategies also include guidance on the removal of oiled carcasses from the environment to prevent scavenging/ingestion by polar bears. Secondary response is designed to prevent polar bears from entering oiled areas. Tertiary response involves the capture, handling, transport, and treatment of oiled bears, and either their return to the environment or placement in a designated facility.

Some significant progress has been made toward increasing capacity to treat a small number of oiled polar bears in Alaska, including the design and construction of specialized equipment such as washing tables, transport cages, and a collapsible polar bear holding pen (Miller 2016). In addition, two experiments were conducted in 2012 to determine how best remove oil from polar bear fur, with promising results (S. Jensen unpublished data).

The Service is currently conducting an analysis that involves developing a model that will help anticipate how an oil spill might affect polar bear populations. The study involves simulating oil spill trajectories at various locations in the Chukchi and Beaufort seas, corresponding to existing or planned areas of development (McCay et al. 2016). Spill trajectories will be overlain with biological data on annual movement patterns and habitat use patterns of polar bears (Wilson et al. 2014). This will help the Service predict how many animals are likely to be exposed to oil during a spill event.

Although the risk of a large enough oil spill affecting a significant portion of the world-wide polar bear population remains unlikely, the potential consequences warrant continued monitoring and mitigation of industries that have the potential to spill oil into the Arctic environment. Progress is continuing at local, national and international levels on planning, response operations specific to polar bears.

E.2 Shipping and Transportation

In the Final Rule, the Service noted that a decline in Arctic sea ice has resulted in an increase in the navigation season within Arctic waters, and identified increased shipping as an emerging issue for polar bear conservation. Previously ice-covered sea routes are now opening up in summer, allowing access for commercial shipping. Increased shipping along the Northern Sea Route (part of the Northeast Passage that follows Norway and Russia's coast down into the Chukchi and Bering seas), and the Northwest Passage **(**which follows Canada's eastern coast north along Canada and Alaska's Beaufort Sea coast) could result in increased fragmentation of sea ice habitat and disturbance/injury to marine mammals, increased human-bear encounters, and the introduction of waste/ litter, and toxic pollutants into the marine environment (PBRS 2015). A primary concern associated with increased shipping is the increased potential for oil spills to occur.

While no population level effects from increased shipping were identified at the time of listing, the IUCN Polar Bear Specialist Group recommended that the Range States take appropriate measures to monitor, regulate, and mitigate ship traffic impacts on polar bear populations and their habitat (Aars et al. 2006).

Since the listing, increased attention on shipping as an emerging Arctic issue has occurred at the circumpolar level. For example, the Arctic Council completed a comprehensive Arctic marine shipping assessment report (AMSA Report) that focused on ship uses of the Arctic Ocean and their potential impacts on humans and the Arctic marine environment (Arctic Council 2009). The AMSA Report includes a comprehensive estimate of how many ships (excluding naval vessels) operated in the Arctic during a given year, and identified Arctic natural resource development and regional trade as the key drivers of future Arctic marine activity. The release of oil was identified as one of the most significant environmental threats related to shipping. The report included a specific recommendation for Arctic countries to address impacts on marine mammals from shipping, and work with the International Maritime Organization (IMO) to develop and implement mitigation strategies.

Since then, significant advancements have been made to implement the recommendations set forth in the AMSA Report. For example, several reports that identify Arctic marine areas of special ecological and cultural importance have been published (Smith et al. 2010a), and voluntary guidelines to reduce underwater noise to avoid adverse impacts on marine biota have been developed (Arctic Council 2015). Additionally, vessel routing and speed restrictions have been recognized as effective measures to mitigate impacts on marine mammals (Brigham and Sfraga 2010). In 2015, the IMO adopted the environmental provisions of the Polar Code, a significant achievement for addressing marine environmental protection which includes standardized safety procedures such as use of designated ship lanes. The Polar Code is expected to enter into force in January 2017 (IMO 2016). In the U.S., steps are being taken to establish designated shipping routes in the Bering Strait and Chukchi Sea (79 FR 72157), areas known for their biological (and cultural) importance (Huntington et al. 2015).

Potential impacts from shipping on polar bears continue to warrant attention. At present, ongoing circumpolar efforts to improve marine safety and environmental protection are positive steps toward addressing potential impacts on marine mammal species, including polar bears.

E. 3. Ecotourism

Polar bear viewing and photography are popular forms of tourism that occur primarily in Churchill, Canada; Svalbard, Norway; and the north coast of Alaska (the communities of Kaktovik and Barrow). In the Final Rule, the Service noted that, while it is unlikely that properly regulated tourism will have a negative effect on polar bear subpopulations, increasing levels of public viewing and photography in polar bear habitat may lead to increased human-polar bear interactions. Tourism can also result in inadvertent displacement of polar bears from preferred habitats, or alter natural behaviors (Lentfer 1990; Dyck and Baydack 2004, Eckhardt 2005). If increased human-bear conflicts lead to polar bears being killed in defense of life, this could also lead to reduced opportunities for subsistence harvest. Conversely, tourism can have the positive effect of increasing the worldwide constituency of people with an interest in polar bears and their conservation.

Since the listing, the human dimension aspect and role of stakeholders in polar bear viewing has increased. It has been noted that wildlife tourism conservation activities have a greater potential for success if local people take part in developing and implementing programs (Lemelin and Dyck 2008).

In Canada, polar bear tourism is growing in the Torngat Mountains National Park, located in northern Labrador where polar bears from the Davis Strait subpopulation occur in this region (Lemelin and Maher 2009). Bear viewing management includes use of Inuit guides, attractant management, passive and active deterrents, and education/codes of conduct that minimize human-bear interactions and facilitate understanding of the unique viewing situation in this area (Lemelin and Maher 2009). In 2008, polar bears from the WH subpopulation were recognized as threatened under the Manitoba Endangered Species Act, and since then, all tourism flights into core maternity denning areas have been discontinued (Lunn et al. 2010).

In Norway, tourism activities are also increasing (Vongraven et al. 2010) and there is concern that polar bears are disturbed in sensitive areas during sensitive periods; however, no quantitative studies have been conducted to determine whether impacts are significant.

In Alaska, tourism is increasing because of the opportunity to observe polar bears near the community of Kaktovik during autumn (Service unpublished data). Since listing, the Service has worked with the community of Kaktovik to reduce human-bear conflicts by establishing professional viewing practices that promote both human safety and polar bear conservation under provisions of the MMPA. Additionally, community-based guidelines request that visitors use trained guides, obey local laws and ordinances related to polar bear viewing. The effects of ecotourism on polar bears have not been reported from Russia or Greenland.

Increasing polar bear tourism does not appear to have emerged as a significant threat to the world wide population of polar bears, and may contribute positively to polar bear conservation. Negative effects may occur in areas where regulations and involvement from local stakeholders is lacking. Cooperative relationships that develop between managers and community residents will become increasingly important if tourism to observe polar bears continues to grow.

III. RECOVERY CRITERIA

Recovery plans provide guidance to the Service, States, and other partners and interested parties on ways to minimize threats to listed species, and on criteria that may be used to determine when recovery goals are achieved. There are many paths to accomplishing the recovery of a species and recovery may be achieved without fully meeting all recovery plan criteria. For example, one or more criteria may have been exceeded while other criteria may not have been accomplished. In that instance, the Service may determine that, overall, the threats have been minimized sufficiently, and the species is robust enough, to downlist or delist the species. In other cases, new recovery approaches and/or opportunities unknown at the time the recovery plan was finalized may be more appropriate ways to achieve recovery. Likewise, new information may change the extent that criteria need to be met for recognizing recovery of the species. Overall, recovery is a dynamic process requiring adaptive management, and assessing a species' degree of recovery is likewise an adaptive process that may, or may not, fully follow the guidance provided in a recovery plan. The Service focused our evaluation of species status in this 5-year review on progress that has been made toward recovery since the species was listed (or since the most recent review) by eliminating or reducing the threats discussed in the five-factor analysis. In that context, progress towards fulfilling recovery criteria serves to indicate the extent to which threat factors have been reduced or eliminated.

A Conservation Management Plan for polar bears was finalized and became effective on December 20, 2016 (USFWS 2016). The Plan requires that to be considered recovered under the ESA, polar bears must meet three levels of criteria – fundamental, demographic, and threats-based. At this point, all the criteria are not met. The criteria for assessing recovery of polar bear are as follows:

Fundamental Criteria

Fundamental Criterion 1: the worldwide probability of persistence is at least 95% over 100 years.

Fundamental Criterion 2: the probability of persistence in each recovery unit (ecoregion) is at least 90% over 100 years.

Demographic Criteria

Demographic Criterion 1: The mean adult female survival rate (at a density corresponding to maximum net productivity level and in the absence of direct human-caused removals) in each recovery unit is at least 93-96%, both currently and as projected over the next 100 years.

Demographic Criterion 2: The ratio of yearlings to adult females (at a density corresponding to maximum net productivity level) in each recovery unit is at least 0.1-0.3, both currently and as projected over the next 100 years.

Demographic Criterion 3: The carrying capacity, distribution, and connectivity in each recovery unit, both currently and as projected over the next 100 years, are such that the probability of persistence over 100 years is at least 90%.

Demographic Criterion 4: Total direct human-caused removals in each recovery unit do not exceed a rate *h* (relative to the population size in the recovery unit) that maintains the population above its maximum net productivity level relative to carrying capacity.

Threats-based Criteria

Threats-based Criterion 1 (Sea ice): In each recovery unit, either (a) the average annual ice-free period is expected not to exceed 4 months over the next 100 years based on model projections using the best available climate science, or (b) the average annual ice-free period is expected to stabilize at longer than 4 months over the next 100 years based on model predictions using the best available climate science, and there is evidence that polar bears in that recovery unit can meet ESA Demographic Criteria 1, 2, and 3 under that longer ice-free period.

> **Threats-based Criterion 2 (human-caused removals):** For each recovery unit, the total level of direct, lethal removals of polar bears by humans, in conjunction with other factors, does not reduce the probability of persistence below 90% over 100 years.

IV. SYNTHESIS

Polar bears evolved to utilize the Arctic sea ice niche and are distributed throughout most ice-covered seas of the Northern Hemisphere. However, polar bear habitat, principally sea ice, is declining throughout the species' range and this decline is expected to continue for the foreseeable future. In 2008, the Service determined that the polar bear was threatened throughout its range by habitat loss (i.e., sea ice recession) (73 FR 28212). Additionally, the Service found no known regulatory mechanisms in place at the national or international level that directly and effectively address the primary threat to polar bears which is the range-wide loss of sea ice habitat. The Service determined that overutilization did not threaten the species, but that it was exacerbating the effects of habitat loss for several populations and may become a more significant threat within the foreseeable future. The Service determined that disease and predation and contaminants did not threaten the species, but may become more significant threat factors for polar bear populations, especially those experiencing nutritional stress or declining population levels, within the foreseeable future.

New data indicate that the global threat of habitat loss identified in the 2008 listing decision remains. Sea ice continues to rapidly thin and retreat throughout the Arctic (Stroeve et al. 2012) and there remain no mechanisms in place to address this threat. The year 2015 was the warmest year since records have been kept from 1880 to 2015 with a globally-averaged land surface temperature of 2.39°F (1.33°C) above the 20th century average (NCEI 2015). As reported by Wiig et al. (2015), arctic sea ice loss has thus far progressed faster than most climate models have predicted (Stroeve et al. 2007) with September sea extent declining at a linear rate of 14% per decade from 1979 through 2011 (Stroeve et al. 2012, 2014). Multiple combined and interrelated events have changed the extent and characteristics of sea ice during all seasons, but particularly during summer. Arctic warming is likely to continue for several decades given the current trends in global greenhouse gas emissions (IPCC 2014), the long persistence time of certain greenhouse gas in the atmosphere (Moore and Braswell 1994), and the lag times associated with global climate processes attaining equilibrium (Mitchell 1989; Hansen et al. 2011). Hence, climate change effects on sea ice and polar bears and their prey will very likely continue for several decades or longer unless greenhouse gases in the atmosphere can be held at suitable levels, primarily by reducing greenhouse gas emissions. Recently, Atwood et al. (2015) corroborated the climate threat by determining through Bayesian network modeling that the most influential driver of adverse polar bear outcomes in the future will be declines in the sea-ice conditions, and secondarily declines in marine prey base.

Atwood et al. (2015) found that compared to sea-ice loss, mortality from in situ anthropogenic factors such as, hunting and defense of life will exert considerably less influence on future polar bear population outcomes. Harvest, increased bear-human interaction levels, defense of life take, illegal take, and take associated with scientific research programs are still occurring regionally for some populations and will benefit from continued management effort. However, the level has not changed significantly since the previous evaluation, and laws, regulations, and agreements for most management programs encourage sustainable harvest levels. The Service found no new information suggesting that any of the remaining stressors such as trans-Arctic shipping, industrial development, and point-source pollution threaten polar bears (Atwood et al. 2015).

Given these factors, the species remains vulnerable due to its limited range and ongoing threat, the range-wide loss of sea ice habitat. Therefore, the Service concludes that *Ursus maritimus* continues to meet the definition of threatened, and the Service recommends no status change at this time.

V. RESULTS

Recommended Classification:

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist (*Indicate reasons for delisting per 50 CFR 424.11):*

____ Extinction
____ Recovery
____ Original data for classification in error

_X_ **No change is needed**

New Recovery Priority Number and Brief Rationale:

The polar bear recovery number should remain "5C". After thorough data review and analysis, we concluded that the polar bear (*Ursus maritimus*) continues to meet the definition of threatened, as a result, we recommend no status change at this time. New information continues to support that polar bears rely heavily on sea ice for essential life functions and that increasing atmospheric levels of greenhouse gases are contributing to Arctic warming and continued loss of sea ice habitat. Although the global population of polar bears is currently estimated to be approximately 26,000, we anticipate that the continued loss of sea ice will cause the population to decline.

VI. RECOMMENDATIONS FOR FUTURE ACTIONS

Establishment of a Recovery Implementation Team
The Polar Bear Conservation Management Plan identifies several actions that will promote recovery of this species. Among these is the establishment of a Recovery Implementation Team to coordinate and assess implementation of the plan. This is a very important step to ensure success of the plan.

Limit global atmospheric levels of greenhouse gases to levels appropriate for supporting polar bear recovery and conservation, primarily by reducing greenhouse gas emissions
Because the FWS cannot regulate GHG, actions will focus on developing a communication strategy that articulates the consequences to polar bears and their habitat of the likely effects of the current baseline GHG emissions scenario compared to one that reflects an aggressive approach to curtailing emissions worldwide.

Support international conservation efforts through the Range States relationships
Work closely with the other Range States to implement the conservation actions outlined in the Circumpolar Action Plan for polar bears range-wide that are consistent with national priorities and in alignment with statutory responsibilities. In Alaska, pursue targeted conservation efforts with Canada and Russia by sharing resources and expertise.

Manage human-bear conflicts
Develop and communicate an overarching strategy and best management practices to prevent, monitor, and manage human-polar bear conflicts in the United States with input from local residents, conservation partners, and invited experts.

Collaboratively manage subsistence harvest
Collaborate with the North Slope Borough, local communities, and others on implementation of robust and sustainable subsistence management strategies for the Chukchi Sea and Southern Beaufort Sea subpopulations in the context of existing agreements.

Protect denning habitat
Continue den detection, mapping, and habitat work in polar bear habitat in the United States. Work with partners to minimize development and disturbance on barrier islands (where denning habitat is most limited) and to mitigate the loss of denning habitat.

Minimize risks of contamination from spills

Pursue several avenues to minimize the risk of marine spills and, should a spill occur, to improve the ability of responders to minimize harm to polar bears and their prey. Examples of specific actions include continuing to provide feedback on oil exploration plans and compliance documents; ensuring that responders and companies have current information on seasonal bear movements, aggregations and important habitat areas; and developing standard operating procedures for deterrence, rescue, and handling of oiled bears.

Conduct strategic monitoring and research
Identify areas of research and monitoring methods to evaluate the effectiveness of recovery efforts. Develop an adaptive management plan for updating and revising the conservation and recovery criteria.

U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of the Polar Bear *(Ursus maritimus)*

Current Classification: "Threatened"

Recommendation resulting from the 5-Year Review:

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist
_X_ No change needed

Appropriate Listing/Reclassification Priority Number, if applicable:

Review Conducted By: Marine Mammals Management Office – Polar Bear Team

FIELD OFFICE APPROVAL:

Lead Field Supervisor, Fish and Wildlife Service

Approve ______________________ Date 1/11/17

The lead Field Office must ensure that other offices within the range of the species have been provided adequate opportunity to review and comment prior to the review's completion. The lead field office should document this coordination in the agency record.

REGIONAL OFFICE APPROVAL:

The Regional Director or the Assistant Regional Director, if authority has been delegated to the Assistant Regional Director, must sign all 5-year reviews.

Lead Regional Director, Fish and Wildlife Service

Approve Gregory E Siekaniec Date 3 February 2017

The Lead Region must ensure that other regions within the range of the species have been provided adequate opportunity to review and comment prior to the review's completion. Written concurrence from other regions is required.

Cooperating Regional Director, Fish and Wildlife Service

_____Concur _____ Do Not Concur

Signature NA Date_______

REFERENCES

Aars, J., N. J. Lunn, and A. E. Derocher. 2006. Polar Bears: Proceedings of the 14th Working Meeting of the IUCN/SSC Polar Bear Specialist Group 20–24 June 2005, Seattle, Washington. Seattle, Washington, USA.

Aars, J., and A. Plumb. 2010. Polar bear cubs may reduce chilling from icy water by sitting on mother's back. Polar Biology 33:557-559.

ACIA. 2005. Arctic Climate Impact Assessment. Cambridge University Press.

Aerts, L. 2012. Polar bear diversionary feeding workshop report. Report prepared by LAMA Ecological, Anchorage, Alaska.

Agence France-Presse. 2016. Arctic oil drilling: Outcry as Norway opens new areas to exploration. The Guardian. Guardian News and Media Limited, https://www.theguardian.com/world/2016/may/19/norway-arctic-new-oil-drilling-licences.

AMAP. 2005. AMAP Assessment 2002: Persistent Organic Pollutants in the Arctic. Arctic Monitoring and Assessment Programme, Oslo, Norway.

Amstrup, S. C. 2003. Polar Bear (*Ursus maritimus*). Pages 587-610 *in* G. A. Feldhamer, B. C. Thompson, and J. A. Chapman, editors. Mammals of North America: Biology, Management, and Conservation. John Hopkins University Press, Baltimore, Maryland, USA.

Amstrup, S. C., and G. M. Durner. 1995. Survival rates of radio-collared female polar bears and their dependent young. Canadian Journal of Zoology 73:1312-1322.

Amstrup, S. C., and C. Gardner. 1994. Polar bear maternity denning in the Beaufort Sea. Journal of Wildlife Management 58:1-10.

Amstrup, S. C., B. G. Marcot, and D. C. Douglas. 2008. A Bayesian network modeling approach to forecasting the 21st century worldwide status of polar bears.*in* E. T. DeWeaver, C. M. Bitz, and L.-B. Tremblay, editors. Arctic Sea Ice Decline: Observations, Projections, Mechanisms, and Implications. American Geophysical Union, Washington, D.C., USA.

Amstrup, S. C., I. Stirling, and J. W. Lentfer. 1986. Past and present status of polar bears in Alaska. Wildlife Society Bulletin 14:241-254.

Amstrup, S. C., I. Stirling, T. S. Smith, C. Perham, and G. W. Thiemann. 2006. Recent observations of intraspecific predation and cannibalism among polar bears in the southern Beaufort Sea. Polar Biology 29:997-1002.

ANC. 2013. Polar bear deterrence workshop, December 3-4, 2012, Anchorage, Alaska. Report prepared by the Alaska Nanuuq Commission.

Andersen, M., A. E. Derocher, Ø. Wiig, and J. Aars. 2012. Polar bear (*Ursus maritimus*) maternity den distribution in Svalbard, Norway. Polar Biology 35:499-508.

Arctic Council. 2009. Arctic marine shipping assessment 2009 report. http://www.pame.is/images/03_Projects/AMSA/AMSA_2009_report/AMSA_2009_Report_2nd_print.pdf.

Arctic Council. 2015. Status on implementation of the AMSA 2009 report recommendations. http://www.pame.is/images/03_Projects/AMSA/AMSA_Documents/Progress_Reports/AMSArecommendations2015_Web.pdf.

Arthur, S. M., B. F. J. Manly, L. L. McDonald, and G. W. Garner. 1996. Assessing habitat selection when availability changes. Ecology 77:215-227.

Atwood, T. C., B. G. Marcot, D. C. Douglas, S. C. Amstrup, K. D. Rode, G. M. Durner, and J. F. Bromaghin. 2015. Evaluating and ranking threats to the long-term persistence of polar bears. U.S. Geological Survey Open-File Report 2014-1254.

Atwood, T. C., B. G. Marcot, D. C. Douglas, S. C. Amstrup, K. D. Rode, G. M. Durner, and J. F. Bromaghin. 2016a. Forecasting the relative influence of environmental and anthropogenic stressors on polar bears. Ecosphere 7:e01370.

Atwood, T. C., E. Peacock, M. A. McKinney, K. Lillie, R. Wilson, D. C. Douglas, S. Miller, and P. Terletzky. 2016b. Rapid environmental change drives increased land use by an arctic marine predator. Plos One 11:e0155932.

Barents Observer. 2015. Modernization of Prirazlomnaya will fivefold oil production. Norwegian Barents Secretariat, http://barentsobserver.com/en/energy/2015/10/modernization-prirazlomnaya-will-fivefold-oil-production-12-10.

Belikov, S. E. 1980. Distribution and structure of dens of female polar bears in Wrangel Island. Bears: Their Biology and Management:117-117.

Belikov, S. E. 1992. Number, distribution, and migrations of the polar bear in the Soviet Arctic. Krupnye Khishniki (Big Predators). Moskva, CNIL Glavokhoty RSFSR:74-84.

Bentzen, T. W., E. H. Follmann, S. C. Amstrup, G. S. York, M. J. Wooller, D. C. G. Muir, and T. M. O'Hara. 2008. Dietary biomagnification of organochlorine contaminants in Alaskan polar bears. Canadian Journal of Zoology-Revue Canadienne De Zoologie 86:177-191.

Bergen, S., G. M. Durner, D. C. Douglas, and S. C. Amstrup. 2007. Predicting movements of female polar bears between summer sea ice foraging habitats and terrestrial denning habitats of Alaska in the 21st century: Proposed methodology and pilot assessment. Report Administrative Report, U.S. Geological Survey, Alaska Science Center, Reston, Virginia.

Best, R. C. 1982. Thermoregulation in resting and active polar bears. Journal of comparative physiology 146:63-73.

Blank, J. J. 2013. Remote identification of maternal polar bear (*Ursus maritimus*) denning habitat on the Colville River Delta, Alaska. M.S. thesis. University of Alaska Anchorage.

Blix, A. S., and J. W. Lentfer. 1979. Modes of thermal protection in polar bear cubs - at birth and on emergence from the den. American Journal of Physiology-Regulatory, Integrative and Comparative Physiology 236:R67-R74.

BLM. 2012. National Petroleum Reserve-Alaska final integrated activity plan/environmental impact statement. U.S. Department of the Interior, Bureau of Land Management, Anchorage, Alaska.

BOEM. 2014. Alaska Outer Continental Shelf Chukchi Sea Planning Area oil and gas lease sale 193 in the Chukchi Sea, Alaska, final second supplemental environmental impact statement, Volume 1. OCS EIS/EA BOEM 2014-669, Bureau of Ocean Energy Management, Alaska OCS Region, Anchorage, Alaska.

BOEM. 2015. BOEM seeks public comment on Liberty Prospect development and production plan. Bureau of Ocean Energy Management, http://www.boem.gov/press09182015/.

BOEMRE. 2011. Alaska Outer Continental Shelf Chukchi Sea planning area: Oil and gas lease sale 193 in the Chukchi Sea, Alaska. Final supplemental environmental impact statement OCS EIS/EA BOEMRE 2011-041, U.S. Department of the Interior, Bureau of Ocean Energy Managment, Regulation and Enforcement, Alaska OCS Region, Anchorage, Alaska.

Boertmann, D., A. Mosbech, D. Schiedek, and K. Johansen, editors. 2009a. The eastern Baffin Bay. A preliminary strategic environmental impact assessment of hydrocarbon activities in the KANUMAS West area. NERI Technical report no. 720. National Environmental Research Institute, Aarhus University, Denmark.

Boertmann, D., A. Mosbech, D. Schiedek, and K. Johansen, editors. 2009b. The western Greenland Sea. A preliminary strategic environmental impact assessment of hydrocarbon activities in the KANUMAS East area. NERI Technical report no. 719. National Environmental Research Institute, Aarhus University, Denmark.

Born, E. W. 2005. Robben and Eisbären in der Arktis: Auswirkung von Erderwärmung und Jagd (Arctic pinnipeds and polar bears: effects of warming and exploitation). Pages 152–159 *in* J. L. Lozán, H. Grassl, H. W. Hubberten, P. Hupfer, L. Karbe, and D. Piepenburg, editors. Warnsignale aus den Polarregionen (Warning signals from the polar regions). Wissenschaftliche Auswertungen, Hamburg, Germany.

Born, E. W., A. Heilmann, L. K. Holm, and K. L. Laidre. 2011. Polar Bears in Northwest Greenland: An Interview Survey about the Catch and the Climate. Museum Tusculanum Press, Copenhagen, Denmark.

Brandvik, P. J., P. S. Daling, L.-G. Faksness, J. Fritt-Rasmussen, R. L. Daae, and F. Leirvik. 2010. Experimental oil release in broken ice - a large-scale field verification of results from laboratory studies of oil weathering and ignitability of weathered oil spills. JIP Report No. 26, SINTEF Materials and Chemistry, Trondheim, Norway.

Brigham, L. W., and M. P. Sfraga, editors. 2010. Considering a roadmap forward: The Arctic Marine Shipping Assessment. Workshop Report for October 22-24, 2009, University of Alaska Fairbanks and the University of the Arctic Institute for Applied Circumpolar Policy.

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

Brower, C. D., A. Carpenter, M. L. Branigan, W. Calvert, T. Evans, A. S. Fischbach, J. A. Nagy, S. Schliebe, and I. Stirling. 2002. The Polar Bear Management Agreement for the Southern Beaufort Sea: an evaluation of the first ten years of a unique conservation agreement. Arctic 55:362-372.

Burns, J. J. 1970. Remarks on the distribution and natural history of pagophilic pinnipeds in the Bering and Chukchi Seas. Journal of Mammalogy 51:445-454.

Bytingsvik, J., S. P. J. van Leeuwen, T. Hamers, K. Swart, J. Aars, E. Lie, E. M. E. Nilsen, Ø. Wiig, A. E. Derocher, and B. M. Jenssen. 2012. Perfluoroalkyl substances in polar bear mother-cub pairs: A comparative study based on plasma levels from 1998 and 2008. Environment International 49:92-99.

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

Campagna, L., P. J. V. de Groot, B. L. Saunders, S. N. Atkinson, D. S. Weber, M. G. Dyck, P. T. Boag, and S. C. Lougheed. 2013. Extensive sampling of polar bears (*Ursus maritimus*) in the Northwest Passage (Canadian Arctic Archipelago) reveals population differentiation across multiple spatial and temporal scales. Ecology and Evolution 3:3152-3165.

Castro de la Guardia, L., A. E. Derocher, P. G. Myers, A. D. T. van Scheltinga, and N. J. Lunn. 2013. Future sea ice conditions in western Hudson Bay and consequences for polar bears in the 21st century. Global Change Biology 19:2675-2687.

Chambellant, M., N. J. Lunn, and S. H. Ferguson. 2012. Temporal variation in distribution and density of ice-obligated seals in western Hudson Bay, Canada. Polar Biology 35:1105-1117.

Cherry, S. G., A. E. Derocher, G. W. Thiemann, and N. J. Lunn. 2013. Migration phenology and seasonal fidelity of an Arctic marine predator in relation to sea ice dynamics. Journal of Animal Ecology 82:912-921.

CITES. 2015. Evaluation of the review of significant trade [Decision 13.67 (Rev. COP14)]. AC28 Doc. 9.1, Report prepared by the co-chairs of the Advisory Working Group (AWG) on the Evaluation of the Review of Significant Trade, Convention on International Trade in Endangered Species of Wild Fauna and Flora, twenty-eighth meeting of the Animals Committee, Tel Aviv, Israel, August 30-September 3, 2015.

Crompton, A. E., M. E. Obbard, S. D. Petersen, and P. J. Wilson. 2008. Population genetic structure in polar bears (Ursus maritimus) from Hudson Bay, Canada: Implications of future climate change. Biological Conservation 141:2528-2539.

DeMaster, D. P., and I. Stirling. 1981. *Ursus maritimus*. Polar bear. Mammalian Species 145:1-7.

Derocher, A. E., D. Andriashek, and I. Stirling. 1993. Terrestrial foraging by polar bears during the ice-free period in Western Hudson Bay. Arctic 46:251-254.

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

Derocher, A. E., and I. Stirling. 1992. The population dynamics of polar bears in Western Hudson Bay. Pages 1150-1159 *in* D. R. McCullough and R. H. Barrett, editors. Wildlife 2001: Populations. Elsevier Applied Science, London.

Derocher, A. E., and I. Stirling. 1996. Aspects of survival in juvenile polar bears. Canadian Journal of Zoology 74:1246-1252.

Derocher, A. E., and Ø. Wiig. 1999. Infanticide and cannibalism of juvenile polar bears (*Ursus maritimus*) in Svalbard. Arctic 52:307-310.

Dietz, R., E. W. Born, F. Riget, A. Aubail, C. Sonne, R. Drimmie, and N. Basu. 2011. Temporal trends and future predictions of mercury concentrations in northwest Greenland polar bear (ursus maritimus) hair. Environmental Science & Technology 45:1458-1465.

Dietz, R., K. Gustayson, C. Sonne, J. P. Desforges, F. F. Riget, V. Pavlova, M. A. McKinney, and R. J. Letcher. 2015. Physiologically-based pharmacokinetic modelling of immune, reproductive and carcinogenic effects from contaminant exposure in polar bears (*Ursus maritimus*) across the Arctic. Environmental Research 140:45-55.

Dietz, R., F. F. Riget, C. Sonne, E. W. Born, T. Bechshoft, M. A. McKinney, R. J. Drimmie, D. C. G. Muir, and R. J. Letcher. 2013a. Three decades (1983-2010) of contaminant trends in East Greenland polar bears (*Ursus maritimus*). Part 2: Brominated flame retardants. Environment International 59:494-500.

Dietz, R., F. F. Riget, C. Sonne, E. W. Born, T. Bechshoft, M. A. McKinney, and R. J. Letcher. 2013b. Three decades (1983-2010) of contaminant trends in East Greenland polar bears (*Ursus maritimus*). Part 1: Legacy organochlorine contaminants. Environment International 59:485-493.

Doupé, J. P., J. H. England, M. Furze, and D. Paetkau. 2007. Most northerly observation of a grizzly bear (*Ursus arctos*) in Canada: Photographic and DNA evidence from Melville Island, Northwest Territories. Arctic 60:271-276.

Durner, G. M., and S. C. Amstrup. 1996. Mass and body-dimension relationships of polar bears in northern Alaska. Wildlife Society Bulletin 24:480-484.

Durner, G. M., S. C. Amstrup, and K. J. Ambrosius. 2001. Remote identification of polar bear maternal den habitat in northern Alaska. Arctic 54:115-121.

Durner, G. M., S. C. Amstrup, and A. S. Fischbach. 2003. Habitat characteristics of polar bear terrestrial maternal den sites in northern Alaska. Arctic 56:55-62.

Durner, G. M., D. C. Douglas, R. M. Nielson, and S. C. Amstrup. 2006. Model for autumn pelagic distribution of adult female polar bears in the Chukchi Seas, 1987-1994. U. S. Geological Survey, Anchorage, Alaska.

Durner, G. M., D. C. Douglas, R. M. Nielson, S. C. Amstrup, T. L. McDonald, I. Stirling, M. Mauritzen, E. W. Born, O. Wiig, E. DeWeaver, M. C. Serreze, S. Belikov, M. Holland, J. A. Maslanik, J. Aars, D. A. Bailey, and A. E. Derocher. 2009. Predicting 21st-century polar bear habitat distribution from global climate models. Ecological Monographs 79:25-58.

Durner, G. M., A. S. Fischbach, S. C. Amstrup, and D. C. Douglas. 2010. Catalogue of polar bear (*Ursus maritimus*) maternal den locations in the Beaufort Sea and neighboring regions, Alaska, 1910–2010. U.S. Geological Survey Data Series 568.

Durner, G. M., K. Simac, and S. C. Amstrup. 2013. Mapping polar bear maternal denning habitat in the National Petroleum Reserve - Alaska with an IfSAR digital terrain model. Arctic 66:197-206.

Durner, G. M., J. P. Whiteman, H. J. Harlow, S. C. Amstrup, E. V. Regehr, and M. Ben-David. 2011. Consequences of long-distance swimming and travel over deep-water pack ice for a female polar bear during a year of extreme sea ice retreat. Polar Biology 34:975-984.

Dyck, M. G. 2006. Characteristics of polar bears killed in defense of life and property in Nunavut, Canada, 1970-2000. Ursus 17:52-62.

Dyck, M. G., and R. K. Baydack. 2004. Vigilance behaviour of polar bears (*Ursus maritimus*) in the contect of wildlife-viewing activities at Churchill, Manitoba, Canada. Biological Conservation 116:343-350.

Eberhardt, L. L. 1985. Assessing the dynamics of wild populations. Journal of Wildlife Management 49:997-1012.

Eberhardt, L. L. 2002. A paradigm for population analysis of long-lived vertebrates. Ecology 83:2841-2854.

Eckhardt, G. 2005. The effects of ecotourism on polar bear behavior. University of Central Florida, Orlando, Florida.

Environment Canada. 2010. MANAGEMENT AND INTERNATIONAL TRADE OF POLAR BEAR FROM CANADA. Information document CoP15 Inf. 11, Convention on International Trade in Endangered Species of Wild Fauna and Flora, fifteenth meeting of the Conference of the Parties, Doha, Qatar, March 13-25, 2010.

EPPR. 2015. Guide to oil spill response in snow and ice conditions. Emergency Prevention, Preparedness and Response working group of the Arctic Council.

European Commission. 2016. Climate action, Paris Agreement, policy. European Commission, http://ec.europa.eu/clima/policies/international/negotiations/paris_en#tab-0-0.

Fagre, A. C., K. A. Patyk, P. Nol, T. Atwood, K. Hueffer, and C. Duncan. 2015. A review of infectious agents in polar bears (*Ursus maritimus*) and their long-term ecological relevance. Ecohealth 12:528-539.

Ferguson, S. H., I. Stirling, and P. McLoughlin. 2005. Climate change and ringed seal (*Phoca hispida*) recruitment in Western Hudson Bay. Marine Mammal Science 21:121-135.

Ferguson, S. H., M. K. Taylor, A. Rosing-Asvid, E. W. Born, and F. Messier. 2000. Relationships between denning of polar bears and conditions of sea ice. Journal of Mammalogy 81:1118-1127.

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

Frost, K. J., L. F. Lowry, G. Pendleton, and H. R. Nute. 2004. Factors affecting the observed densities of ringed seals, *Phoca hispida*, in the Alaskan Beaufort Sea, 1996-99. Arctic 57:115-128.

Furnell, D. J., and D. Oolooyuk. 1980. Polar bear predation on ringed seals in ice-free water. The Canadian Field Naturalist 94:88-89.

Gittleman, J. L., and S. D. Thompson. 1988. Energy allocation in mammalian reproduction. American zoologist 28:863-875.

Gleason, J. S., and K. D. Rode. 2009. Polar bear distribution and habitat association reflect long-term changes in fall sea ice conditions in the Alaskan Beaufort Sea. Arctic 62:405-417.

Gormezano, L. J., and R. F. Rockwell. 2013. What to eat now? Shifts in polar bear diet during the ice-free season in western Hudson Bay. Ecology and Evolution 3:3509-3523.

Government of Greenland. 2014. Greenland’s oil and mineral strategy 2014-2018. FM 2014/133, IASN-2013-093824, Government of Greenland.

Grønning, H. M. 2013. Combined effects of persistent organic pollutants and biological variables on vitamin D in polar bears. Norwegian University of Science and Technology, Trondheim, Norway.

Gurzu, A. 2016. Economic pain pushes Russia to drill in high Arctic. Politico. Politico SPRL, http://www.politico.eu/article/economic-pain-pushes-russia-to-drill-in-high-arctic-oil-energy-natural-gas/.

Gustavson, L., T. M. Ciesielski, J. Bytingsvik, B. Styrishave, M. Hansen, E. Lie, J. Aars, and B. M. Jenssen. 2015. Hydroxylated polychlorinated biphenyls decrease circulating steroids in female polar bears (*Ursus maritimus*). Environmental Research 138:191-201.

Hamilton, C. D., C. Lydersen, R. A. Ims, and K. M. Kovacs. 2015. Predictions replaced by facts: A keystone species' behavioural responses to declining Arctic sea-ice. Biology Letters 11:6.

Hamilton, S. G., L. Castro de la Guardia, A. E. Derocher, V. Sahanatien, B. Tremblay, and D. Huard. 2014. Projected polar bear sea ice habitat in the Canadian Arctic Archipelago. Plos One 9:e113746.

Hammill, M. O., and T. G. Smith. 1991. The role of predation in the ecology of the ringed seal in Barrow Strait, Northwest-Territories, Canada. Marine Mammal Science 7:123-135.

Hansen, B. B., R. Aanes, I. Herfindal, J. Kohler, and B. E. Sæther. 2011. Climate, icing, and wild arctic reindeer: past relationships and future prospects. Ecology 92:1917-1923.

Harington, C. R. 1968. Denning habits of the polar bear (*Ursus maritimus* Phipps). Report Series 5, Candian Wildlife Service, Ottawa, Ontario, Canada.

Harvell, C. D., C. E. Mitchell, J. R. Ward, S. Altizer, A. P. Dobson, R. S. Ostfeld, and M. D. Samuel. 2002. Climate warming and disease risks for terrestrial and marine biota. Science 296:2158-2162.

Harwood, L. A., and I. Stirling. 1992. Distribution of ringed seals in the southeastern Beaufort Sea during late summer. Canadian Journal of Zoology-Revue Canadienne De Zoologie 70:891-900.

Herrero, J., and S. Herrero. 1997. Visitor safety in polar bear viewing activities in the Churchill region of Manitoba, Canada. Report prepared by BIOS Environmental Research and Planning Associates Ltd. for Manitoba Natural Resources and Parks Canada, Calgary, Alberta, Canada.

Holland-Bartels, L., and B. Pierce, editors. 2011. An evaluation of the science needs to inform decisions on Outer Continental Shelf energy development in the Chukchi and Beaufort Seas, Alaska. U.S. Geological Survey Circular 1370, Reston, Virginia.

Hunter, C. M., H. Caswell, M. C. Runge, E. V. Regehr, S. C. Amstrup, and I. Stirling. 2010. Climate change threatens polar bear populations: a stochastic demographic analysis. Ecology 91:2883-2897.

Huntington, H. P., R. Daniel, A. Hartsig, K. Harun, M. Heiman, R. Meehan, G. Noongwook, L. Pearson, M. Prior-Parks, M. Robards, and G. Stetson. 2015. Vessels, risks, and rules: Planning for safe shipping in Bering Strait. Marine Policy 51:119-127.

Hurst, R. J., N. A. Øritsland, and P. D. Watts. 1982. Metabolic and temperature responses of polar bears to crude oil. Pages 263–280 *in* P. J. Rand, editor. Land and Water Issues Related to Energy Development; Proceedings of the 4th Annual Meeting of the International Society of Petroleum Industry Biologists, Denver, Colorado, September 22-25, 1981. Ann Arbor Science.

Iacozza, J., and S. H. Ferguson. 2014. Spatio-temporal variability of snow over sea ice in western Hudson Bay, with reference to ringed seal pup survival. Polar Biology 37:817-832.

Iles, D. T., S. L. Peterson, L. J. Gormezano, D. N. Koons, and R. F. Rockwell. 2013. Terrestrial predation by polar bears: Not just a wild goose chase. Polar Biology 36:1373-1379.

IMO. 2015. Polar Code environmental provisions adopted. International Maritime Organization, http://www.imo.org/en/MediaCentre/PressBriefings/pages/18-Polar-Code-MEPC.aspx.

IPCC. 2007. Climate change 2007: The physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom, and New York, New York, USA.

IPCC. 2014. Climate change 2014: Impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom, and New York, New York, USA.

Iverson, S. J., I. Stirling, and S. L. C. Lang. 2006. Spatial and temporal variation in the diets of polar bears across the Canadian arctic: Indicators of changes in prey populations and environment. Pages 98-117 *in* I. L. Boyd, S. Wanless, and C. J. Camphuysen, editors. Top Predators in Marine Environments. Cambridge University Press, United Kingdom.

Joint Secretariat. 2003. The Inuvialuit harvest study: Data and methods report 1988–1997. The Joint Secretariat, Inuvik, Northwest Territories, Canada.

Kelly, B. P. 2001. Climate change and ice breeding pinnipeds. Pages 43-55 *in* G.-R. Walther, C. A. Burga, and P. J. Edwards, editors. “Fingerprints” of Climate Change: Adapted

Behaviour and Shifting Species Ranges. Kluwer Academic/Plenum Publishers, New York, New York.
Kelly, B. P., O. H. Badajos, M. Kunnasranta, and J. Moran. 2006. Timing and re-interpretation of ringed seal surveys. OCS Study MMS 2006-013, Final report prepared by Coastal Marine Institute, School of Fisheries and Ocean Sciences, University of Alaska, Fairbanks, Alaska, for U.S. Department of the Interior, Minerals Management Service, Alaska OCS Region.
Kelly, B. P., J. L. Bentson, P. L. Boveng, M. F. Cameron, S. P. Dahle, J. K. Jansen, E. A. Logerwell, J. E. Overland, C. L. Sabine, G. T. Waring, and J. M. Wilder. 2010. Status review of the ringed seal (*Phoca hispida*). NOAA Technical Memorandum NMFS-AFSC-212, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center.
Kiliaan, H. P. L., and I. Stirling. 1978. Observations on Overwintering Walruses in the Eastern Canadian High Arctic. Journal of Mammalogy 59:197-200.
Kirk, C. M., S. Amstrup, R. Swor, D. Holcomb, and T. M. O'Hara. 2010. Morbillivirus and toxoplasma exposure and association with hematological parameters for southern Beaufort Sea polar bears: Potential response to infectious agents in a sentinel species. Ecohealth 7:321-331.
Kochnev, A., and E. Zdor. 2015. Harvest and Use of Polar Bear in Chukotka: Results of Research Conducted in 1999–2012. WWF-Russia, Moscow, Russia.
Kochnev, A. A. 2002. Autumn aggregations of polar bears on the Wrangel Island and their importance for the population. Proceedings of the Marine Mammals of the Holarctic meeting, September 10–15, 2002, Baikal, Russia.
Kochnev, A. A. 2004. Polar bear in Chukotka: concerns and hopes (in Russian, English translation). Wildlife Conservation 3:7-14.
Koopmans, F. 2011. Human-polar bear conflicts in East Greenland: Lessons learned from the circumpolar Arctic. Master's of Science report prepared for Wageningen University and WWF.
Krey, A., M. Kwan, and H. M. Chan. 2014. In vivo and in vitro changes in neurochemical parameters related to mercury concentrations from specific brain regions of polar bears (*Ursus maritimus*). Environmental Toxicology and Chemistry 33:2463-2471.
Laidre, K. L., H. Stern, K. M. Kovacs, L. Lowry, S. E. Moore, E. V. Regehr, S. H. Ferguson, Ø. Wiig, P. Boveng, R. P. Angliss, E. W. Born, D. Litovka, L. Quakenbush, C. Lydersen, D. Vongraven, and F. Ugarte. 2015. Arctic marine mammal population status, sea ice habitat loss, and conservation recommendations for the 21st century. Conservation Biology 29:724-737.
Lemelin, H., and P. Maher. 2009. Nanuk of the Torngats: human–polar bear interactions in the Torngat mountains National Park, Newfoundland and Labrador, Canada. Human dimensions of wildlife 14:152-155.
Lemelin, R. H., and M. Dyck. 2008. New frontiers in marine wildlife tourism: an international overview of polar bear tourism management strategies. Pages 361-379 *in* J. Higham and M. Lück, editors. Marine wildlife and tourism management: Insights from the natural and social sciences. CABI, Oxfordshire, U.K.
Lentfer, J. W. 1990. Workshop on measures to assess and mitigate the adverse effects of Arctic oil and gas activities on polar bears. PB91-127241, Final report preapared for the Marine Mammal Commission, Washington, D.C.

Letcher, R. J., J. O. Bustnes, R. Dietz, B. M. Jenssen, E. H. Jorgensen, C. Sonne, J. Verreault, M. M. Vijayan, and G. W. Gabrielsen. 2010. Exposure and effects assessment of persistent organohalogen contaminants in arctic wildlife and fish. Science of the Total Environment 408:2995-3043.

Liston, G. E., and C. A. Hiemstra. 2011. The changing cryosphere: Pan-arctic snow trends (1979-2009). Journal of Climate 24:5691-5712.

Liston, G. E., C. J. Perham, R. T. Shideler, and A. N. Cheuvront. 2016. Modeling snowdrift habitat for polar bear dens. Ecological Modelling 320:114-134.

Lønstrup, J. 2006. Polar bear management in Greenland. Pages 133–134 *in* J. Aars, N. J. Lunn, and A. E. Derocher, editors. Polar Bears: Proceedings of the 14th Working Meeting of the IUCN/SSC Polar Bear Specialist Group, 20–24 June 2005, Seattle, Washington, Seattle, Washington, USA.

Lunn, N. J., M. Branigan, L. Carpenter, J. Justus, D. Hedman, D. Larsen, S. Lefort, R. Maraj, M. E. Obbard, E. Peacock, and F. Pokiak. 2010. Pages 87–114 *in* M. E. Obbard, G. W. Thiemann, E. Peacock, and T. D. DeBruyn, editors. Polar Bears: Proceedings of the 15th Working Meeting of the IUCN/SSC Polar Bear Specialist Group, 29 June - 3 July, 2009, Copenhagen, Denmark.

Lunn, N. J., S. Servanty, E. V. Regehr, S. J. Converse, E. Richardson, and I. Stirling. 2016. Demography of an apex predator at the edge of its range: impacts of changing sea ice on polar bears in Hudson Bay. Ecological Applications 26:1302-1320.

Lunn, N. J., and I. Stirling. 1985. The significance of supplemental food to polar bears during the ice-free period of Hudson Bay. Canadian Journal of Zoology 63:2291-2297.

Lydersen, C., O. A. Nost, K. M. Kovacs, and M. A. Fedak. 2004. Temperature data from Norwegian and Russian waters of the northern Barents Sea collected by free-living ringed seals. Journal of Marine Systems 46:99-108.

MacIntyre, K. Q., K. M. Stafford, P. B. Conn, K. L. Laidre, and P. L. Boveng. 2015. The relationship between sea ice concentration and the spatio-temporal distribution of vocalizing bearded seals (*Erignathus barbatus*) in the Bering, Chukchi, and Beaufort Seas from 2008 to 2011. Progress in Oceanography 136:241-249.

Malenfant, R. M., C. S. Davis, C. I. Cullingham, and D. W. Coltman. 2016. Circumpolar genetic structure and recent gene flow of polar bears: a reanalysis. Plos One 11:25.

Mauritzen, M., S. Belikov, E., A. N. Boltunov, A. E. Derocher, E. Hansen, R. A. Ims, Ø. Wiig, and N. Yoccoz. 2003. Functional responses in polar bear habitat selection. Oikos 100:112-124.

Mauritzen, M., A. E. Derocher, and Ø. Wiig. 2001. Space-use strategies of female polar bears in a dynamic sea ice habitat. Canadian Journal of Zoology 79:1704-1713.

McCay, D. F., R. Balouskus, J. Ducharme, M. S. Gearon, Y. Kim, S. Zamorski, Z. Li, and J. Rowe. 2016. Simulation of oil spill trajectories during the broken ice period in the Chukchi and Beaufort Seas. Project Number: 2015-067, Final report prepared by RPS ASA, South Kinstown, Rhode Island, for U.S. Fish and Wildlife Service, Marine Mammals Management, Anchorage, Alaska.

McKinney, M. A., S. J. Iverson, A. T. Fisk, C. Sonne, F. F. Riget, R. J. Letcher, M. T. Arts, E. W. Born, A. Rosing-Asvid, and R. Dietz. 2013. Global change effects on the long-term feeding ecology and contaminant exposures of East Greenland polar bears. Global Change Biology 19:2360-2372.

McKinney, M. A., R. J. Letcher, J. Aars, E. W. Born, M. Branigan, R. Dietz, T. J. Evans, G. W. Gabrielsen, E. Peacock, and C. Sonne. 2011. Flame retardants and legacy contaminants in polar bears from Alaska, Canada, East Greenland and Svalbard, 2005-2008. Environment International 37:365-374.

McKinney, M. A., E. Peacock, and R. J. Letcher. 2009. Sea ice-associated diet change increases the levels of chlorinated and brominated contaminants in polar bears. Environmental Science & Technology 43:4334-4339.

McKinney, M. A., S. Pedro, R. Dietz, C. Sonne, A. T. Fisk, D. Roy, B. M. Jenssen, and R. J. Letcher. 2015. A review of ecological impacts of global climate change on persistent organic pollutant and mercury pathways and exposures in arctic marine ecosystems. Current Zoology 61:617-628.

McLaren, I. A. 1958. The biology of the ringed seal (*Phoca hispida* Schreber) in the eastern Canadian Arctic. 118:1-97.

Miller, S. 2016. Increasing oil spill response capabilities for polar bears in Alaska. Poster presented at the 24th International Conference on Bear Research and Management, Anchorage, Alaska.

Miller, S., J. Wilder, and R. R. Wilson. 2015. Polar bear–grizzly bear interactions during the autumn open-water period in Alaska. Journal of Mammalogy gyv140.

Mitchell, J. F. B. 1989. The "greenhouse" effect and climate change. Reviews of Geophysics 27:115-139.

Molnár, P. K., A. E. Derocher, T. Klanjscek, and M. A. Lewis. 2011. Predicting climate change impacts on polar bear litter size. Nature Communications 2:186.

Monnett, C., and J. S. Gleason. 2006. Observations of mortality associated with extended open-water swimming by polar bears in the Alaskan Beaufort Sea. Polar Biology 29:681-687.

Moore, B., and B. H. Braswell. 1994. The lifetime of excess atmospheric carbon dioxide. Global Biogeochemical Cycles 8:23-38.

Moore, S. E., and H. P. Huntington. 2008. Arctic marine mammals and climate change: impacts and resilience. Ecological Applications S18:157-165.

Mosbech, A., D. Boertmann, and M. Jespersen. 2007. Strategic environmental impact assessment of hydrocarbon activities in the Disko West area. NERI technical report no. 618, National Environmental Research Institute, University of Aarhus, Denmark.

Murray, N. 2016. Shell relinquishes exploration permits near Lancaster Sound in eastern Arctic. CBC/Radio-Canada, http://www.cbc.ca/news/canada/north/shell-lancaster-sound-permits-1.3620681.

NCEI. 2015. State of the climate: Global analysis for annual 2015, published online January 2016. National Oceanic and Atmospheric Administration, National Centers for Environmental Information, http://www.ncdc.noaa.gov/sotc/global/201513.

Obbard, M. E., G. W. Thiemann, E. Peacock, and T. D. DeBruyn, editors. 2010. Polar Bears: Proceedings of the 15th Working Meeting of the IUCN/SSC Polar Bear Specialist Group, 29 June - 3 July, 2009, Copenhagen, Denmark.

Overland, J. E., and M. Wang. 2013. When will the summer Arctic be nearly sea ice free? Geophysical Research Letters 40:2097-2101.

Overland, J. E., and M. Y. Wang. 2007. Future regional Arctic sea ice declines. Geophysical Research Letters 34.

Ovsyanikov, N. G. 2005. Research and conservation of polar bears on Wrangel Island. Pages 167-171 *in* Proceedings of the 14th Working Meeting of the IUCN/SSC Polar Bear

Specialist Group, June 2005, Seattle, Washington, USA. Gland, Switzerland and Cambridge, United Kingdom, Seattle, Washington, USA.

Owen, M. A., R. R. Swaisgood, C. Slocomb, S. C. Amstrup, G. M. Durner, K. Simac, and A. P. Pessier. 2015. An experimental investigation of chemical communication in the polar bear. Journal of Zoology 295:36-43.

Paetkau, D., S. C. Amstrup, E. W. Born, W. Calvert, A. E. Derocher, G. W. Garner, F. Messier, I. Stirling, M. K. Taylor, O. Wiig, and C. Strobeck. 1999. Genetic structure of the world's polar bear populations. Molecular Ecology 8:1571-1584.

Pagano, A. M., G. M. Durner, S. C. Amstrup, K. S. Simac, and G. S. York. 2012. Long-distance swimming by polar bears (*Ursus maritimus*) of the southern Beaufort Sea during years of extensive open water. Canadian Journal of Zoology 90:663-676.

Patyk, K. A., C. Duncan, P. Nol, C. Sonne, K. Laidre, M. Obbard, O. Wiig, J. Aars, E. Regehr, L. L. Gustafson, and T. Atwood. 2015. Establishing a definition of polar bear (*Ursus maritimus*) health: A guide to research and management activities. Science of the Total Environment 514:371-378.

PBRS. 2015. Circumpolar action plan: Conservation strategy for the polar bear. A product of the representatives of the parties to the 1973 Agreement on the Conservation of Polar Bears (Polar Bear Range States).

PBSG. 2015. Summary of polar bear population status per 2014. Polar Bear Specialist Group, pbsg.npolar.no/en/status/status-table.html.

Peacock, E., S. A. Sonsthagen, M. E. Obbard, A. Boltunov, E. V. Regehr, N. Ovsyanikov, J. Aars, S. N. Atkinson, G. K. Sage, A. G. Hope, E. Zeyl, L. Bachmann, D. Ehrich, K. T. Scribner, S. C. Amstrup, S. Belikov, E. W. Born, A. E. Derocher, I. Stirling, M. K. Taylor, O. Wiig, D. Paetkau, and S. L. Talbot. 2015. Implications of the Circumpolar Genetic Structure of Polar Bears for Their Conservation in a Rapidly Warming Arctic. Plos One 10:30.

Pedersen, K. E., N. Basu, R. Letcher, A. K. Greaves, C. Sonne, R. Dietz, and B. Styrishave. 2015. Brain region-specific perfluoroalkylated sulfonate (PFSA) and carboxylic acid (PFCA) accumulation and neurochemical biomarker responses in east Greenland polar bears (*Ursus maritimus*). Environmental Research 138:22-31.

Pew Environment Group. 2010. Policy recommendations: Oil spill prevention and response in the U.S. Arctic Ocean.

Pilfold, N. W., A. E. Derocher, I. Stirling, and E. Richardson. 2015. Multi-temporal factors influence predation for polar bears in a changing climate. Oikos 124:1098-1107.

Pinchuk, D., and O. Astakhova. 2015. Exclusive: Russia's Rosneft unlikely to resume Kara Sea drilling before 2018 - sources. Reuters. Reuters, http://www.reuters.com/article/us-russia-rosneft-kara-sea-idUSKBN0OR16H20150611.

Potter, S., I. Buist, K. Trudel, D. Dickins, and E. Owens. 2012. Spill response in the Arctic offshore.

Prestrud, P., and I. Sterling. 1994. The International Polar Bear Agreement and the current status of polar bear conservation. Aquatic Mammals 20:113-113.

Prop, J., J. Aars, B.-J. Bårdsen, S. A. Hanssen, C. Bech, S. Bourgeon, J. de Fouw, G. W. Gabrielsen, J. Lang, and E. Noreen. 2015. Climate change and the increasing impact of polar bears on bird populations. Frontiers in Ecology and Evolution 3:33.

Ramsay, M. A., and R. L. Dunbrack. 1986. Physiological constraints on life history phenomena: The example of small bear cubs at birth. American Naturalist 127:735-743.

Ramsay, M. A., and I. Stirling. 1986. On the mating system of polar bears. Canadian Journal of Zoology 64:2142-2151.

Ramsay, M. A., and I. Stirling. 1990. Fidelity of female polar bears to winter-den sites. Journal of Mammalogy 71:233-236.

Regehr, E. V., S. C. Amstrup, and I. Stirling. 2006. Polar bear population status in the southern Beaufort Sea. U.S. Geological Survey Open-File Report 2006-1337.

Regehr, E. V., C. M. Hunter, H. Caswell, S. C. Amstrup, and I. Stirling. 2007a. Polar bears in the southern Beaufort Sea I: survival and breeding in relation to sea ice conditions, 2001-2006. U.S. Geological Survey Administrative Report, Anchorage, Alaska, USA.

Regehr, E. V., C. M. Hunter, H. Caswell, S. C. Amstrup, and I. Stirling. 2010. Survival and breeding of polar bears in the southern Beaufort Sea in relation to sea ice. Journal of Animal Ecology 79:117-127.

Regehr, E. V., N. J. Lunn, S. C. Amstrup, and I. Stirling. 2007b. Supplemental materials for the analysis of capture-recapture data for polar bears in western Hudson Bay, Canada, 1984-2004. U.S. Geological Survey Data Series 304.

Regehr, E. V., R. R. Wilson, K. D. Rode, and M. C. Runge. 2015. Resilience and risk--a demographic model to inform conservation planning for polar bears. Open-File Report 2015–1029, U.S. Geological Survey, Reston, Virginia.

Rockwell, R. F., and L. J. Gormezano. 2009. The early bear gets the goose: Climate change, polar bears and lesser snow geese in western Hudson Bay. Polar Biology 32:539-547.

Rode, K. D., S. C. Amstrup, and E. V. Regehr. 2010a. Reduced body size and cub recruitment in polar bears associated with sea ice decline. Ecological Applications 20:768-782.

Rode, K. D., A. M. Pagano, J. F. Bromaghin, T. C. Atwood, G. M. Durner, K. S. Simac, and S. C. Amstrup. 2014a. Effects of capturing and collaring on polar bears: findings from long-term research on the southern Beaufort Sea population. Wildlife Research 41:311-322.

Rode, K. D., E. Peacock, M. Taylor, I. Stirling, E. W. Born, K. L. Laidre, and Ø. Wiig. 2012. A tale of two polar bear populations: Ice habitat, harvest, and body condition. Population Ecology 54:3-18.

Rode, K. D., E. V. Regehr, D. C. Douglas, G. Durner, A. E. Derocher, G. W. Thiemann, and S. M. Budge. 2014b. Variation in the response of an Arctic top predator experiencing habitat loss: feeding and reproductive ecology of two polar bear populations. Global Change Biology 20:76-88.

Rode, K. D., J. D. Reist, E. Peacock, and I. Stirling. 2010b. Comments in response to "Estimating the energetic contribution of polar bear (Ursus maritimus) summer diets to the total energy budget" by Dyck and Kebreab (2009). Journal of Mammalogy 91:1517-1523.

Rode, K. D., C. T. Robbins, L. Nelson, and S. C. Amstrup. 2015a. Can polar bears use terrestrial foods to offset lost ice-based hunting opportunities? Frontiers in Ecology and the Environment 13:138-145.

Rode, K. D., R. R. Wilson, E. V. Regehr, M. S. Martin, D. C. Douglas, and J. Olson. 2015b. Increased land use by Chukchi Sea polar bears in relation to changing sea ice conditions. Plos One 10:e0142213.

Rogers, M. C., E. Peacock, K. Simac, M. B. O'Dell, and J. M. Welker. 2015. Diet of female polar bears in the southern Beaufort Sea of Alaska: Evidence for an emerging alternative foraging strategy in response to environmental change. Polar Biology 38:1035-1047.

Routti, H., R. J. Letcher, E. W. Born, M. Branigan, R. Dietz, T. J. Evans, A. T. Fisk, E. Peacock, and C. Sonne. 2011. Spatial and temporal trends of selected trace elements in liver tissue from polar bears (*Ursus maritimus*) from Alaska, Canada and Greenland. Journal of Environmental Monitoring 13:2260-2267.

Routti, H., R. J. Letcher, E. W. Born, M. Branigan, R. Dietz, T. J. Evans, M. A. McKinney, E. Peacock, and C. Sonne. 2012. Influence of carbon and lipid sources on variation of mercury and other trace elements in polar bears (*Ursus maritimus*). Environmental Toxicology and Chemistry 31:2739-2747.

Russell, R. H. 1975. The food habits of polar bears of James Bay and southwest Hudson Bay in summer and autumn. Arctic 28:117-129.

Rydberg, J., J. Klaminder, P. Rosen, and R. Bindler. 2010. Climate driven release of carbon and mercury from permafrost mires increases mercury loading to sub-arctic lakes. Science of the Total Environment 408:4778-4783.

Sahanatien, V., and A. E. Derocher. 2012. Monitoring sea ice habitat fragmentation for polar bear conservation. Animal Conservation 15:397-406.

SARC. 2012. Species status report for polar bear (Ursus maritimus) in the Northwest Territories. Species at Risk Committee, Yellowknife, Northwest Territories, Canada.

Schliebe, S., B. Benter, E. V. Regehr, L. Quakenbush, J. Omelak, M. Nelson, and K. Nesvacil. 2016. Co-management of the Alaskan harvest of the Alaska–Chukotka polar bear subpopulation: How to implement a harvest quota. Wildlife Technical Bulletin ADF&G/DWC/WTB-2016-15, Division of Wildlife Conservation, Alaska Department of Fish and Game, Juneau, Alaska.

Schliebe, S., T. Evans, K. Johnson, M. Roy, S. Miller, C. Hamilton, R. Meehan, and S. Jahrsdoerfer. 2006. Range-wide status review of the polar bear (*Ursus maritimus*). Page 262 pp. *in* U. S. F. a. W. Service, editor., Anchorage, Alaska.

Schliebe, S., K. D. Rode, J. S. Gleason, J. Wilder, K. Proffitt, T. J. Evans, and S. Miller. 2008. Effects of sea ice extent and food availability on spatial and temporal distribution of polar bears during the fall open-water period in the Southern Beaufort Sea. Polar Biology 31:999-1010.

Schuster, P. F., R. G. Striegl, G. R. Aiken, D. P. Krabbenhoft, J. F. Dewild, K. Butler, B. Kamark, and M. Dornblaser. 2011. Mercury export from the Yukon River basin and potential response to a changing climate. Environmental Science & Technology 45:9262-9267.

Shadbolt, T., G. York, and E. W. T. Cooper. 2012. Icon on Ice: International Trade and Management of Polar Bears. Vancouver, B.C.

Smith, M. A., Q. T. Smith, J. Morse, A. Baldivieso, and D. Tosa. 2010a. Arctic marine synthesis: Atlas of the Chukchi and Beaufort seas. Audubon Alaska, Anchorage, Alaska.

Smith, P. A., K. H. Elliott, A. J. Gaston, and H. G. Gilchrist. 2010b. Has early ice clearance increased predation on breeding birds by polar bears? Polar Biology 33:1149-1153.

Smith, T. G. 1980. Polar bear predation of ringed and bearded seals in the land-fast sea ice habitat. Canadian Journal of Zoology 58:2201-2209.

Smith, T. G. 1985. Polar bears, *Ursus maritimus*, as predators of belugas, *Delphinapterus leucas*. Canadian Field-Naturalist 99:71-75.

Smith, T. G., M. O. Hammill, and G. Taugbøl. 1991. A review of the developmental, behavioural and physiological adaptations of the ringed seal, *Phoca hispida*, to life in the arctic winter. Arctic 44:124-131.

Smith, T. G., and L. A. Harwood. 2001. Observations of neonate ringed seals, *Phoca hispida*, after early break-up of the sea ice in Prince Albert Sound, Northwest Territories, Canada, spring 1998. Polar Biology 24:215-219.

Smith, T. G., and C. Lydersen. 1991. Availability of suitable land-fast ice and predation as factors limiting ringed seal populations, Phoca hispida, in Svalbard. Polar Research 10:585-594.

Sonne, C. 2010. Health effects from long-range transported contaminants in Arctic top predators: An integrated review based on studies of polar bears and relevant model species. Environment International 36:461-491.

Sonne, C., M. Dyck, F. F. Riget, J. E. B. Jensen, L. Hyldstrup, R. J. Letcher, K. Gustavson, M. T. P. Gilbert, and R. Dietz. 2015. Penile density and globally used chemicals in Canadian and Greenland polar bears. Environmental Research 137:287-291.

Sørstrøm, S. E., P. J. Brandvik, I. Buist, P. Daling, D. Dickins, L.-G. Faksness, S. Potter, J. Fritt-Rasmussen, and I. Singsaas. 2010. Oil in ice - JIP. Joint industry program on oil spill contingency for Arctic and ice-covered waters, summary report. Report No. 32, Project No. 800537, SINTEF Materials and Chemistry, Marine Environmental Technology.

Stenhouse, G. B., L. J. Lee, and K. G. Poole. 1988. Some characteristics of polar bears killed during conflicts with humans in the Northwest Territories, 1976-86. Arctic 41:275-278.

Stirling, I. 1988. Polar Bears. University of Michigan Press, Ann Arbor, Michigan.

Stirling, I. 2002. Polar bears and seals in the eastern Beaufort Sea and Amundsen Gulf: A synthesis of population trends and ecological relationships over three decades. Arctic 55:59-76.

Stirling, I., and D. Andriashek. 1992. Terrestrial maternity denning of polar bears in the eastern Beaufort Sea area. Arctic 45:363-366.

Stirling, I., D. Andriashek, and W. Calvert. 1993. Habitat preferences of polar bears in the western Canadian Arctic in late winter and spring. Polar Record 29:13-24.

Stirling, I., and W. R. Archibald. 1977. Aspects of predation of seals by polar bears. Journal of the Fisheries Research Board of Canada 34:1126-1129.

Stirling, I., and A. E. Derocher. 1993. Possible impacts of climatic warming on polar bears. Arctic 46:240-245.

Stirling, I., and A. E. Derocher. 2012. Effects of climate warming on polar bears: a review of the evidence. Global Change Biology 18:2694-2706.

Stirling, I., and N. J. Lunn. 1997. Environmental fluctuations in arctic marine ecosystems as reflected by variability in reproduction of polar bears and ringed seals. Pages 167-181 *in* S. J. Woodin and M. Marquiss, editors. Ecology of Arctic Environments, Special Publication of the British Ecological Society, Number 13. Blackwell Science Ltd., Oxford, England.

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

Stirling, I., and N. A. Øritsland. 1995. Relationships between estimates of ringed seal (*Phoca hispida*) and polar bear (*Ursus maritimus*) populations in the Canadian Arctic. Canadian Journal of Fisheries and Aquatic Sciences 52:2594-2612.

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

Stirling, I., and J. E. Ross. 2011. Observations of cannibalism by polar bears (*Ursus maritimus*) on summer and autumn sea ice at Svalbard, Norway. Arctic 64:478-482.

Stirling, I., and T. G. Smith. 2004. Implications of warm temperatures, and an unusual rain event for the survival of ringed seals on the coast of southeastern Baffin Island. Arctic 57:59-67.

Stishov, M. S. 1991. Distribution and numbers of polar bear maternity dens on Wrangel and Herald Islands during 1985–1989. Pages 91-113 *in* A. M. Amirkhanov, editor. Population and Communities of Mammals on Wrangel Island. CNIL Glavokhoty RSFSR, Moscow, Russia.

Stone, I. R., and A. E. Derocher. 2007. An incident of polar bear infanticide and cannibalism on Phippsøya, Svalbard. Polar Record 43:171-173.

Stroeve, J., M. M. Holland, W. Meier, T. Scambos, and M. Serreze. 2007. Arctic sea ice decline: Faster than forecast. Geophysical Research Letters 34:5.

Stroeve, J. C., V. Kattsov, A. Barrett, M. Serreze, T. Pavlova, M. Holland, and W. N. Meier. 2012. Trends in Arctic sea ice extent from CMIP5, CMIP3 and observations. Geophysical Research Letters 39:n/a-n/a.

Stroeve, J. C., T. Markus, L. Boisvert, J. Miller, and A. Barrett. 2014. Changes in Arctic melt season and implications for sea ice loss. Geophysical Research Letters 41:1216-1225.

Taylor, M., T. Larsen, and R. E. Schweinsburg. 1985. Observations of intraspecific aggression and cannibalism in polar bears (*Ursus maritimus*). Arctic 38:303-309.

Taylor, M. K., D. P. Demaster, F. L. Bunnell, and R. E. Schweinsburg. 1987. Modeling the sustainable harvest of female polar bears. Journal of Wildlife Management 51:811-820.

Thiemann, G. W., A. E. Derocher, S. G. Cherry, N. J. Lunn, E. Peacock, and V. Sahanatien. 2013. Effects of chemical immobilization on the movement rates of free-ranging polar bears. Journal of Mammalogy 94:386-397.

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

Thorup, S. 2014. Oil and gas in Greenland – still on ice? . Notes From The Field – An English Law Perspective On The Oil & Gas Market. Andrews Kurth Kenyon LLP, https://www.andrewskurth.com/insights-1165.html.

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

USDOI. 2015. BSEE, BOEM issue proposed regulations to ensure safe and responsible exploratory drilling offshore Alaska. U.S. Department of the Interior, https://www.doi.gov/news/pressreleases/bsee-boem-issue-proposed-regulations-to-ensure-safe-and-responsible-exploratory-drilling-offshore-alaska.

USFWS. 2010a. Polar bear (*Ursus maritimus*): Chukchi/Bering Seas stock. Final polar bear stock assessment report. U.S. Fish and Wildlife Service, Marine Mammals Management, Anchorage, Alaska. https://www.fws.gov/alaska/fisheries/mmm/stock/final_cbs_polar_bear_sar.pdf.

USFWS. 2010b. Polar bear (*Ursus maritimus*): Southern Beaufort Sea stock. Final polar bear stock assessment report. U.S. Fish and Wildlife Service, Marine Mammals Management, Anchorage, Alaska. https://www.fws.gov/alaska/fisheries/mmm/stock/final_sbs_polar_bear_sar.pdf.

USFWS. 2015. Oil spill response plan for polar bears in Alaska. U.S. Fish and Wildlife Service, Marine Mammals Management, Anchorage, Alaska, USA.

USFWS. 2016. Polar bear (*Ursus maritimus*) conservation management plan, final. U.S. Fish and Wildlife Service, Region 7, Anchorage, Alaska.

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

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

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

Vorkamp, K., R. Bossi, F. F. Riget, H. Skov, C. Sonne, and R. Dietz. 2015. Novel brominated flame retardants and dechlorane plus in Greenland air and biota. Environmental Pollution 196:284-291.

Ware, J. V., K. D. Rode, J. F. Bromaghin, D. C. Douglas, R. R. Wilson, E. V. Regehr, S. C. Amstrup, G. M. Durner, A. M. Pagano, J. Olson, C. T. Robbins, and H. T. Jansen. In press. Habitat degradation affects the summer activity of polar bears. Oecologia.

Watts, P. D., and S. E. Hansen. 1987. Cyclic starvation as a reproductive strategy in the polar bear. Symposium of the Zoological Society of London 57:305-318.

Weber, D. S., P. J. V. De Groot, E. Peacock, M. D. Schrenzel, D. A. Perez, S. Thomas, J. M. Shelton, C. K. Else, L. L. Darby, L. Acosta, C. Harris, J. Youngblood, P. Boag, and R. Desalle. 2013. Low MHC variation in the polar bear: Implications in the face of Arctic warming? Animal Conservation 16:671-683.

Whiteman, J. P., H. J. Harlow, G. M. Durner, R. Anderson-Sprecher, S. E. Albeke, E. V. Regehr, S. C. Amstrup, and M. Ben-David. 2015. Summer declines in activity and body temperature offer polar bears limited energy savings. Science 349:295-298.

Wiig, Ø., S. Amstrup, T. Atwood, K. Laidre, N. Lunn, M. Obbard, E. Regehr, and G. Thiemann. 2015. Ursus maritimus. The IUCN Red List of Threatened Species 2015: e.T22823A14871490. http://dx.doi.org/10.2305/IUCN.UK.2015-4.RLTS.T22823A14871490.en. Accessed 06 January 2016.

Wiig, Ø., A. E. Derocher, and S. E. Belikov. 1999. Ringed seal (*Phoca hispida*) breeding in the drifting pack ice of the Barents Sea. Marine Mammal Science 15:595-598.

Wildlife Management Advisory Council (WMAC) (Northwest Territories). Letter to: Honorable J. Michael Miltenberger (Government of Northwest Territories), Honourable John Edzerza (Government of Yukon), Honourable Peter Kent (Member of Parliament for Thornhill (Ontario)). 2011 July 25. 13 leaves. Re: Recommendations for Northern Beaufort Sea Polar Bear Population Boundary Change and Total Allowable Harvest. Located at; The Joint Secretariat - lnuvialuit Renewable Resource Committees, Inuvik, Northwest Territories, Canada.

Wilson, N. 2016. NEB extends Imperial's MacKenzie River Valley 1.2 Bcf gas pipeline approval. Alberta Oil. Venture Publishing, Inc., www.albertaoilmagazine.com/2016/01/neb-extends-imperials-mackenzie-gas-plan/.

Wilson, R. R., J. S. Horne, K. D. Rode, E. V. Regehr, and G. M. Durner. 2014. Identifying polar bear resource selection patterns to inform offshore development in a dynamic and changing Arctic. Ecosphere 5:1-24.

Wilson, R. R., E. V. Regehr, K. D. Rode, and M. St Martin. 2016. Invariant polar bear habitat selection during a period of sea ice loss. Proceedings of the Royal Society B: Biological Sciences 283:20160380.

York, G., V. Sahanatien, G. Polet, and F. Koopmans. 2014. WWF species action plan: polar bear, 2014-2020. WWF International, Gland, Switzerland.