U.S. Fish and Wildlife Service

Polar Bear

Conservation Management Plan

Disclaimer:

This Conservation Management Plan (Plan) delineates reasonable actions we, the U.S. Fish and Wildlife (USFWS), believe will contribute to the conservation and recovery of polar bears (*Ursus maritimus*). Funds necessary to achieve the objectives identified in this Plan are subject to budgetary and other constraints, as well as the need to address other agency priorities. This Plan does not necessarily represent the views, official positions, or approval of any individuals or agencies involved in its formulation, other than USFWS. The approved Plan will be subject to modification as dictated by new findings, changes in species status, and the completion of conservation management actions.

This Plan represents the views and interpretations of the USFWS regarding the conservation and recovery of the polar bear only. USFWS's approach set forth in this polar bear Conservation Management Plan does not necessarily preclude other approaches in developing Endangered Species Act recovery plans or Marine Mammal Protection Act conservation plans.

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https://www.fws.gov/alaska/fisheries/mmm/polarbear/pbmain.htm

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Polar Bear Conservation Management Plan

Prepared by the Polar Bear Recovery Team:

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Executive Summary

Today, polar bears roam the northern reaches of the planet, but as their sea-ice habitat continues to shrink due to Arctic warming, their future in the U.S. and ultimately their continuation as a species are at risk. Their eventual reprieve turns on our collective willingness to address the factors contributing to climate change and, in the interim, on our ability to improve the chances that polar bears survive in sufficient numbers and places so that they are in a position to recover once the necessary global actions are taken.

Polar bears are an ice-dependent species that rely on sea ice as a platform to hunt ice seals and to raise their young. The current global polar bear population is estimated to be 22,000 to 31,000. Polar bears range across 5 Arctic nations; for management purposes, their population is divided into 19 subpopulations. These subpopulations have been further grouped into four ecoregions based on the spatial and temporal dynamics of sea ice in the subpopulations' range. The near- and mid-term impacts of sea-ice loss on polar bears will vary among subpopulations and ecoregions but over the long term, those impacts are anticipated to be significant for polar bear numbers range wide if global greenhouse gas emission levels are not significantly reduced.

PLAN PHILOSOPHY

The Polar Bear Conservation Management Plan (Plan) was developed as a practical guide to implementation of polar bear conservation in the United States. From a legal perspective, the purpose of the Plan is to articulate the conditions whereby polar bears would no longer need the protections of the Endangered Species Act (ESA) and to lay out a collective strategy that moves us towards achieving those conditions. A parallel path is laid out for improving the status of polar bears under the Marine Mammal Protection Act (MMPA).

Many governmental and non-governmental agencies, institutions, and organizations are currently involved in polar bear conservation. These entities are integral to the conservation of the species. Going forward, conservation of polar bears will require the collective will and collaboration of nations and Native communities, of government agencies and private organizations, of scientists and subsistence hunters. This Plan reflects the diverse input of several of those stakeholders. It also emphasizes local engagement, from the oil and gas industry activities on the North Slope of Alaska that keep employees safe and minimize defense-of-life kills, to the Alaska Native peoples who have lived with and depended on polar bears for thousands of years and will be integral to conservation of the species going forward.

Although the Plan satisfies the statutory requirements of the ESA and the MMPA, it is more broadly focused than a typical recovery or conservation plan. At its core, the Plan contains a set of fundamental goals reflecting shared values of diverse stakeholders. The goals focus on conservation of polar bears while recognizing values associated with subsistence take, human safety, and economic activity.

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These fundamental goals are described in quantitative terms associated with ESA and MMPA requirements, and are stepped down to measurable demographic and threats-based criteria. The Plan identifies a suite of high priority conservation and recovery actions to achieve those criteria. Strategic monitoring will focus both on implementation (the extent to which the plan is followed and recovery actions are taken) and effectiveness (the extent to which recovery actions are successful and progress is made).

This Plan is meant to be a dynamic, living document and is expected to be revised periodically as new knowledge becomes available. Recognizing the uncertainties inherent in polar bear management, monitoring and research are integral to implementation. As new information is gathered to track and evaluate progress, it should feed back into the Plan, allowing revision of the conservation and recovery criteria, as well as refinement of the conservation strategy.

THE PRIMARY THREAT TO POLAR BEARS

As identified in the final rule listing the polar bear as a threatened species under the ESA, the decline of sea ice habitat due to changing climate is the primary threat to polar bears (73 FR 28211). The single most important achievement for polar bear conservation is decisive action to address Arctic warming (Amstrup et al. 2010, Atwood et al. 2016), which is driven primarily by increasing atmospheric concentrations of greenhouse gases. Short of action that effectively addresses the primary cause of diminishing sea ice, it is unlikely that polar bears will be recovered. Addressing the increased atmospheric levels of greenhouse gases that are resulting in Arctic warming will require global action. While this Plan calls for action to promptly reduce greenhouse gas emissions, the focus is on wildlife management actions within the United States that will contribute to the survival of polar bears in the interim so that they are in a position to recover once Arctic warming has been abated.

CONSERVATION STRATEGY

Along with the threat posed by sea-ice loss and the inadequacy of existing regulatory mechanisms to address climate change, other current or potential sources of polar bear mortality will likely become more significant going forward. Potential management concerns in the U.S. include human-bear conflicts and defense-of-life removals, subsistence harvest, loss of denning habitat, and contamination from spills. This plan outlines actions the U.S. Fish and Wildlife Service (USFWS) and its partners ("we") can take to preclude these from threatening the persistence or recovery of polar bears while the global community works to address and limit atmospheric levels of greenhouse gases.

MANAGEMENT GOALS AND CRITERIA

Polar bears are important to humans for many reasons. In seeking an enduring, collaborative strategy for management, this Plan recognizes the array of values held by diverse communities engaged in polar bear conservation. The Plan proposes six Fundamental Goals. The first three involve securing the long-term persistence of polar bears on different geographic scales: (1) range-wide (the global scale of the ESA listing); (2) ecoregions (an intermediate scale that reflects a goal of maintaining intraspecific diversity); and (3) the State of Alaska (encompassing the 2 polar bear subpopulations partially within the United States). Fundamental Goal 4 recognizes the nutritional and cultural needs of native peoples with connections to polar bear populations, including the opportunity for harvest of polar bears for subsistence purposes as that term is understood in the context of U.S. laws. Fundamental Goal 5 calls for continued management of human-bear interactions to ensure human safety and to conserve polar bears. Finally, Fundamental Goal 6 seeks to achieve polar bear conservation while minimizing restrictions to other activities within the U.S. range of the polar bear, including economic development.

Two criteria are identified as guidance for our management actions under the MMPA. The first calls for maintenance of the "health and stability of the marine ecosystem" and for polar bears to retain their role as a "significant functioning element of the ecosystem," as reflected in maintenance of at least 70% of the historical carrying capacity for polar bears. The second is a take-based criterion requiring that the rate of direct human-caused removals maintains a subpopulation above its maximum net productivity level (*mnpl*) relative to carrying capacity.

The ESA recovery criteria for delisting are expressed at a fundamental level for two geographic scales. At the scale of the listed species, the fundamental criterion is that probability of persistence worldwide be at least 95% over 100 years. This Plan identifies 4 recovery units, corresponding to four polar bear ecoregions. At this intermediate scale, the fundamental criterion is that the probability of persistence in each of the 4 recovery units be at least 90% over 100 years.

The ESA demographic criteria focus on four measures of population status: survival rate, recruitment rate, carrying capacity, and the rate of human-caused removals. Recovery is achieved when all of the following conditions are met in each recovery unit: (i) the mean adult female survival rate is at least 93-95% (currently and as projected over 100 years); (ii) the ratio of yearlings to adult females is at least 0.1-0.3 (currently and as projected over 100 years); (iii) 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%; and (iv) the rate of human-caused removals maintains the population in each recovery unit above its maximum net productivity level relative to carrying capacity.

The Plan then identifies ESA threats-based criteria representing the levels at which sea-ice loss and human-caused removals would not be considered a threat under the ESA. Sea-ice loss, the primary threat identified in the 2008 listing determination, will cease to be a threat to polar bear recovery when the average duration of the ice-free period in each recovery unit (i) is expected not to exceed 4 months over the next 100 years based on model projections, or (ii) is expected to stabilize at longer than 4 months and there is evidence that polar bears can meet the demographic criteria (above) under that longer ice-free period. Human-caused removals were not identified as a threat in the 2008 listing rule. However, the rule recognized the potential that they could become a threat to polar bear recovery, in particular as populations are affected by sea-ice loss. This would be the case if those human-caused removals reduce the probability of persistence below 90% over 100 years in any of the 4 recovery units. Potential future management concerns posed by disease, oil and gas activities, contamination from spills, and increased Arctic shipping are acknowledged but, because these factors have not been identified as threats at present, no recovery criteria are associated with them.

To achieve recovery under the ESA, the criteria at all three levels—fundamental, demographic, and threats-based—must be met.

CONSERVATION/RECOVERY ACTIONS

The Plan identifies a strategic suite of high priority conservation and recovery actions. The first and foremost action for the purpose of recovery is to stop Arctic warming and the loss of sea ice by limiting atmospheric levels of greenhouse gases. The principal mechanism for doing that is to substantially reduce global greenhouse gas emissions. Other actions, which can be implemented by USFWS and its partners, are aimed at the near- and mid-term goal of providing polar bears in the U.S. the best possible chance of persisting when climate change has been addressed and further Arctic warming has stopped. These actions include managing human-bear conflicts, collaboratively managing subsistence harvest, protecting denning habitat, and minimizing the risk of contamination from spills. While the focus of this plan is primarily on actions in the U.S., priority actions also include collaborating with Canada and Russia on management of the 2 subpopulations for which the U.S. shares oversight.

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Along with these actions, the Plan calls for monitoring and research specifically targeting the information needed to assess the Plan's criteria and guide the Plan's actions. Strategic monitoring will enable us to determine whether our actions, and this Plan, are effective in the near- and mid-term at conserving polar bears or whether they need to be modified.

Finally, to facilitate implementation of these actions, the Plan envisions continuation of the Recovery Team in the form of a collaborative Implementation Team. The Implementation Team will meet on a regular basis to share information, revisit priorities, and leverage resources.

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I. BACKGROUND

Polar bears occur in 19 subpopulations 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 (Fig. 1). The United States contains portions of two subpopulations: the Chukchi Sea and the Southern Beaufort Sea. These 2 subpopulations have also been identified as "stocks" under the MMPA.

Polar bear subpopulations have been further classified as occurring in one of four ecoregions (Fig. 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 of time 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 Polar Basin Divergent Ecoregion, which includes the two United States subpopulations, is characterized by the formation of annual sea ice that is swept away from the shore as sea ice melts during the summer. The Polar Basin Convergent Ecoregion is characterized by annual sea ice that converges towards shoreline, allowing bears access to nearshore ice year-round. Although information is limited, the global genetic structure of polar bears appears to reflect the four ecoregions (Paetkau et al. 1999, Peacock et al. 2015).

The most recent circumpolar population estimate by the IUCN Red List Assessment was 26,000 (95% Confidence Interval of 22,000 to 31,000) polar bears (Wiig et al. 2015).

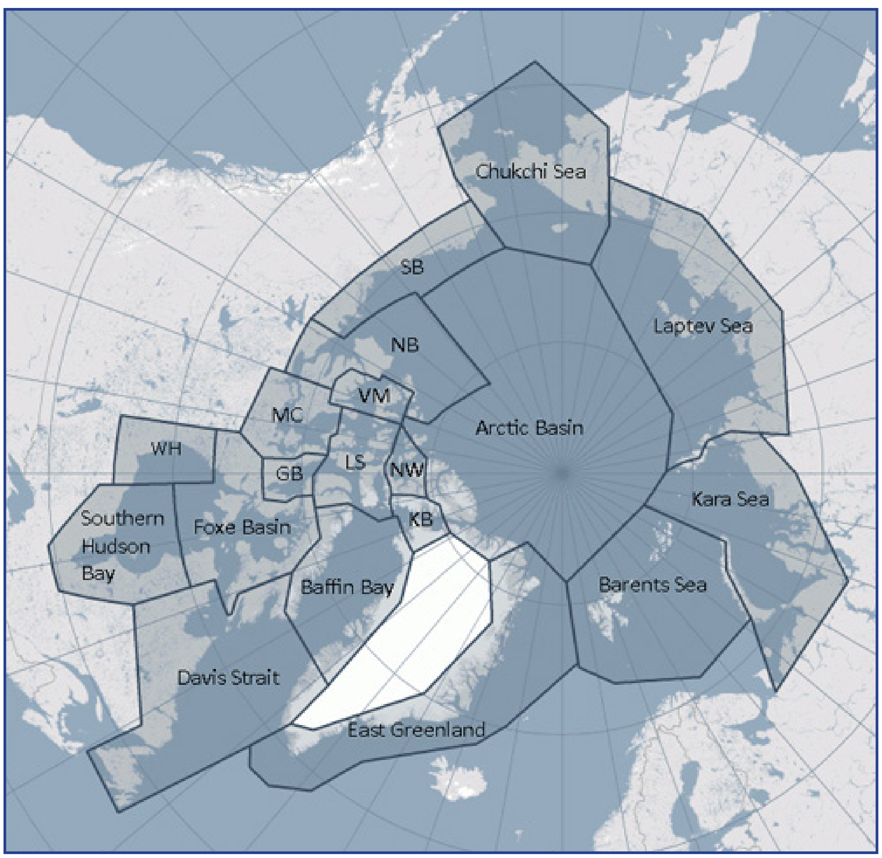

Figure 1. Map of the polar bear subpopulations (source: Polar Bear Specialist Group). The subpopulations include: Southern Beaufort Sea (SB), Chukchi Sea, Laptev Sea, Kara Sea, Barents Sea, East Greenland, Northern Beaufort (NB), Kane Basin (KB), Norwegian Bay (NW), Lancaster Sound (LS), Gulf of Boothia (GB), M'Clintock Channel (MC), Viscount Melville Sound (VM), Baffin Bay, Davis Strait, Foxe Basin, Western Hudson Bay (WH), Southern Hudson Bay and the Arctic Basin (AB).

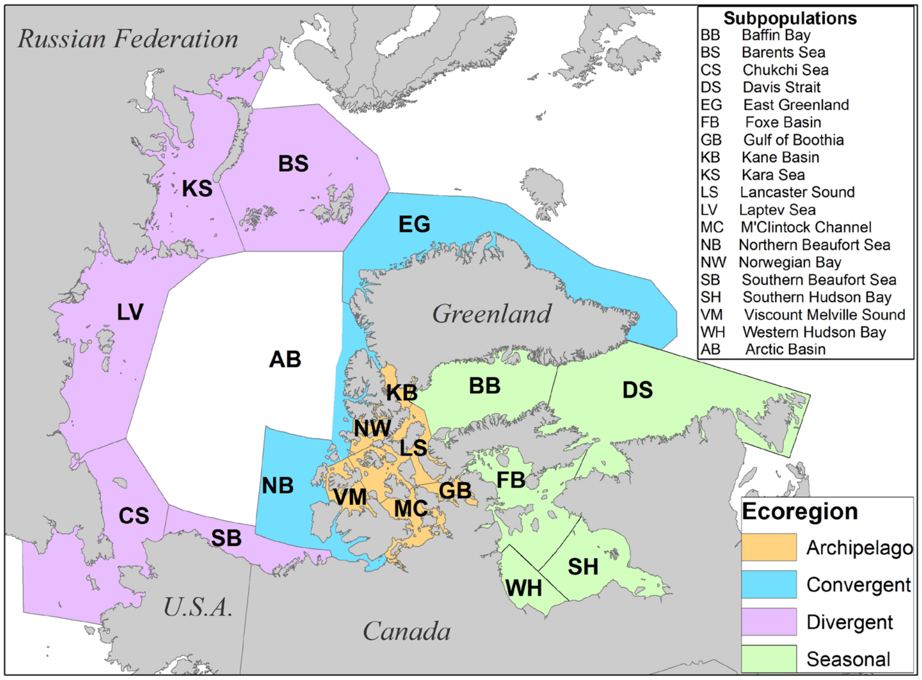

Figure 2. Ice ecoregions (Amstrup et al. 2008). These ecoregions are equated with ESA recovery units in this Plan.

Polar bears are relatively long-lived, and are characterized by late sexual maturity, small litter sizes, and extended maternal investment in raising young. These are all factors that contribute to a low reproductive rate; as a result, high adult survival rates, particularly of females, are required to maintain population levels. Survival rates exceeding 93 percent for adult females are essential to sustain polar bear subpopulations (Regehr et al. 2015).

Sea ice is the primary habitat for polar bears. Polar bears depend on sea ice as a platform on which to: hunt and feed on seals; seek mates and breed; travel to terrestrial maternity denning areas; den; and make long-distance movements. Polar bear movements are closely tied to the seasonal dynamics of sea-ice extent as it retreats northward during summer melt and advances southward during autumn freeze.

A more detailed biological background can be found in Appendix A.

The United States Fish and Wildlife Service (USFWS) listed the polar bear (*Ursus maritimus*) as a threatened species under the Endangered Species Act of 1973 as amended (ESA) on May 15, 2008 (73 FR 28211); as a result, it automatically became a "depleted" species under the Marine Mammal Protection Act of 1972 as amended (MMPA).

The USFWS has four purposes for this Plan. The first is to meet the recovery planning requirement of the ESA. Section 4(f) directs the USFWS to develop plans for listed species which identify "objective, measurable" recovery criteria and site-specific recovery actions with estimated time and cost to completion (16 USC §1533(f)(1)(B)). The second purpose is to develop a conservation plan under the MMPA, patterned after ESA recovery plans but with a goal of conserving and restoring a species to its optimum sustainable population (16 USC § 1383 (b)). The third purpose is to create a national plan related to management of polar bears in the U.S. to be appended to the Circumpolar Action Plan for Polar Bear Conservation developed by the signatories to the *1973 Agreement on the Conservation of Polar Bears*. Those signatories are the five countries with polar bear populations (Canada, Denmark on behalf of Greenland, Norway, the Russian Federation, and the United States), known collectively as the "Range States." Consistent with the 1973 Agreement (Articles VII and IX), the Range States prepared a Circumpolar Action Plan, which will be supplemented by a national plan from each country to describe the specific conservation actions it will take, in accord with its domestic laws. The final purpose of this Plan is to provide a unifying framework for conservation of polar bears by partners within the United States.

The Primary Threat to Polar Bears

Sea ice is rapidly thinning and retreating throughout the Arctic (Stroeve et al. 2012). 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 and possibly centuries given the current trends in global greenhouse gas emissions (IPCC 2014), the long persistence time of certain greenhouse gases 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 until increases in atmospheric greenhouse gases are stopped.

The threats to polar bears identified in the ESA listing determination were the loss of sea-ice habitat due to climate change and the inadequacy of existing mechanisms curtailing that threat (73 FR 28277). It cannot be overstated that the single most important action for the recovery of polar bears is to significantly reduce the present levels of global greenhouse gas (GHG) emissions, which are the primary cause of warming in the Arctic. Recently, Atwood et al. (2016) corroborated the climate threat by determining through Bayesian network modeling that the most influential driver of adverse polar bear outcomes in the future will likely be declines in sea-ice conditions, and secondarily declines in the marine prey base. Mortality from *in situ* anthropogenic factors like hunting and defense of life will likely exert considerably less influence on future polar bear population outcomes, while stressors such as trans-Arctic shipping, oil and gas exploration, development, and production, and point-source pollution appear to impose little risk to the long-term persistence of polar bears.

The levels that global greenhouse gas emissions reach in the coming decades will have a tremendous influence on the abundance and distribution of polar bears in the future. Polar bears will likely be extirpated from much of their present-day range if emissions continue to rise at current rates throughout the 21st century (Amstrup et al. 2008); however, if the rise in global mean temperature can be kept below 2 degrees C, which could only be accomplished by prompt and very aggressive reductions in worldwide GHG emissions, the probability of greatly reduced polar bear populations could be substantially lowered (Atwood et al. 2016). The best prognosis for polar bears entails aggressive GHG mitigation combined with optimal polar bear management practices, which together could maintain viable polar bear populations in most regions of the Arctic (Fig. 3, Amstrup et al. 2010). To that end, this Plan provides a framework for USFWS and its partners to accomplish the latter goal, while governments, industries, and citizens throughout the world aspire to accomplish the former.

There are positive signs. Parties to the United Nations Framework Convention on Climate Change (UNFCCC) agreed at their Paris meeting in December 2015 to the goal of "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C" (Article 2.1(a), United Nations 2015). Although the self-determined pledges by each nation toward reducing their emissions over the next 10–15 years are non-binding and currently insufficient to keep warming under 2°C, the Parties have agreed to work together to increase those pledges before 2020. If the Paris Agreement's central aim to keep global warming well below 2°C can be achieved, it is far more likely that polar bears Arctic-wide can be fully recovered because the threat of sea-ice loss will be significantly curtailed in all recovery units.

Figure 3 illustrates the markedly different levels of impact on polar bear habitat during summer that result when hypothetical best-case (Fig. 3a)

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and worst-case (Fig. 3c) scenarios of future GHG emissions are compared. The figure shows coastal areas where polar bears could come ashore during summer and spend no more than 4 months before the sea ice returned, a period of food deprivation that polar bears are well-adapted to accommodate assuming they have adequate advance access to prey (Molnár et al. 2010, 2014; Robbins et al. 2012). If present rates of GHG emissions were to continue unabated to century's end (a worst-case scenario, Fig. 3c), limited areas in the Canadian Archipelago and northern Greenland might be suitable for polar bears to occupy during summer, or possibly not, because half of the climate models project ice-free conditions lasting ≥5 months (a point when modeled effects of food deprivation become more severe; Molnár et al. 2010, 2014) Arctic-wide. The possibility for such extreme summer sea ice melt under the worst-case GHG emissions scenario raises concerns for polar bear persistence, especially since prey abundances could also be negatively impacted by changes to the Arctic Ocean's food web (Arrigo et al. 2008; Hoegh-Guldberg and Bruno 2010; Schofield et al. 2010; Tremblay et al. 2015). In stark contrast, Fig. 3a shows end-of-century outcomes for a best-case scenario in which GHG emissions are promptly and very aggressively reduced to levels that keep average global warming below 2°C (relative to the preindustrial era). The aims of the Paris Agreement, adopted by 195 countries in 2015 (United Nations 2015), calls for such aggressive GHG mitigation. At century's end under an aggressively mitigated GHG emissions scenario (Fig. 3a), all models agree that most coastal areas in the Canadian Archipelago and northern Greenland could be used by polar bears during summer without undue risk of becoming stranded onshore for more than 4 months, and perhaps similarly for areas in Russia, which would improve the chances of polar bears persisting in all 4 ecoregions. Achieving the levels of mitigation put forth by the Paris Agreement is arguably tentative, however, in that it requires timely and unprecedented global commitments as well as unproven technological advances (Tollefson 2015; Smith et al. 2016). If GHG emissions are promptly mitigated and stabilized (Fig. 3b), all or most climate models project the Canadian Archipelago and northern Greenland could be used by polar bears during summer (like Fig. 3a), while only half the models or fewer project suitable coastal areas throughout the rest of the Arctic.

The future for polar bears is yet to be determined, and while many sources of uncertainty preclude our ability to precisely forecast their future status (Douglas and Atwood 2017), the sooner global warming and sea ice loss are stopped, the better the long-term prognosis for the species. To this end, we endorse efforts everywhere, big and small, to mitigate greenhouse gas emissions in an ecologically sound manner, and emphasize the direct and immediate relationship between success in these efforts and the future status of the polar bear.

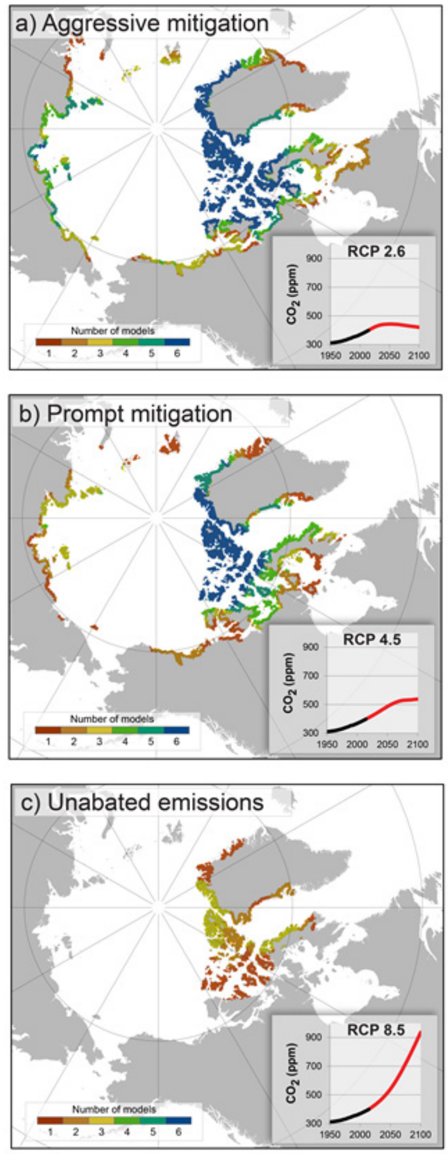

Figure 3. Coastal areas where polar bears could come ashore for no more than 4 months during each summer of the last decade of the 21st century (2091–2100), as projected by 6 global climate models forced with 3 greenhouse gas emission scenarios. With increasing CO_2 emissions (Representative Concentration Pathway [RCP] 2.6, 4.5, and 8.5 respectively), coastal areas where the offshore summer ice-free period is projected to be 4 months or less in duration occur in fewer areas, and are corroborated by fewer models. Colors along the coastlines denote the level of agreement among the 6 models analyzed; greater uncertainty exists when fewer models agree. Inset shows the observed rise in atmospheric CO_2 from 1950–2014 (black line) and the scenario-specific change from 2015–2100 (red line). Figure from Douglas and Atwood (2017).

II. CONSERVATION STRATEGY

Although the need to reduce emissions contributing to climate change has been recognized in national plans (President's Climate Action Plan, White House 2013b) and action by the USFWS and other agencies (EPA proposed carbon pollution standards for existing stationary sources, 79 FR 34830 et seq.), more needs to be done in the United States and around the globe to slow the warming trends that are harming Arctic ecosystems and polar bears, which depend on those ecosystems and play an integral role in their functioning.

Recognizing that USFWS lacks the authority to regulate greenhouse gas emissions, we must rely on the United States and other nations to address the emissions that are the primary contributor to ongoing climate change, whether such reductions are via laws, regulations, market-based incentives, or a combination of approaches. Under this Plan, our specific contribution toward curbing global emissions will be a science-based communication effort highlighting the urgent need for significant reductions in emissions to help achieve a global atmospheric level of greenhouse gases that will support conditions for recovery of polar bears from projected declines.

While global efforts are made to curb atmospheric levels of greenhouse gases, there are actions the USFWS and its partners can take in the U.S. that will improve the ability of polar bears to survive in the wild in sufficient numbers and distribution so that they are in a position to recover once the threat of further Arctic warming has been removed. Overutilization was not identified as a threat to the species throughout all or a significant portion of its range. However, the listing rule noted that continued efforts were necessary to ensure that harvest or other forms of removal did not exceed sustainable levels, particularly for subpopulations experiencing nutritional stress or declining numbers as a consequence of habitat change (73 FR 28280). Even for populations affected to a lesser degree by environmental changes and habitat impacts, the rule noted that effective implementation of existing regulatory mechanisms was necessary to address issues related to overutilization (73 FR 28280). Looking ahead, additional challenges to polar bear conservation that may rise to the level of a threat include disease, shipping, oil and gas activities, and oil spills.

Specifically, our conservation strategy calls for the following actions:

- Limit global atmospheric levels of greenhouse gases to levels appropriate for supporting polar bear recovery and conservation, primarily by reducing greenhouse gas emissions
- Support international conservation efforts through the Range States relationships
- Manage human-bear conflicts
- Collaboratively manage subsistence harvest
- Protect denning habitat
- Minimize risks of contamination from spills
- Conduct strategic monitoring and research

The focus of this Plan is on those actions the USFWS and its partners can take, primarily in the U.S. These include actions with stakeholders and partners to mitigate various forms of disturbance and mortality, which although they are not currently threats to polar bear subpopulations, may become threats in the future. Conservation actions, many of which are already underway, will be proactive, informed by strategic monitoring, and carried out with ongoing support from an Implementation Team.

We will track the effectiveness of these actions in the near- and mid-term by monitoring demographic and threats-based criteria in the Polar Basin Divergent ecoregion—a region where polar bears are highly vulnerable to Arctic warming (Atwood et al. 2016) and the home to both of the United States' subpopulations.

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III. MANAGEMENT GOALS AND CRITERIA

A. Fundamental Goals

The fundamental goals express the intentions of this Plan and will be used to guide management, research, monitoring, and communication. They include the goals of the MMPA and the ESA, as they relate to polar bear conservation and recovery, with a particular focus on the U.S. The fundamental goals also reflect the input and aspirations of stakeholders closely connected with polar bears and their habitat, including the State of Alaska, the North Slope Borough, Alaska Native peoples, conservation groups, and the oil and gas industry. In most cases, the fundamental goals represent range-wide aspirations, but the specific applications under this Plan pertain primarily to the polar bear subpopulations linked to Alaska.

The fundamental goals apply to three spatial scales: the entire polar bear range, significant regional population segments (currently equated with ecoregions), and subpopulations in the United States. They also reflect different temporal scales ranging from long-term (~100 years, to reflect generational goals), to mid-term (~50 years, to reflect steps to put polar bears in the best position to recover once the primary threat is addressed), to near-term.

Anticipating that polar bear populations are likely to decline as sea ice recedes (73 FR 28212), some of the goals reflect long-term desired outcomes, rather than predictions of the likely future. In addition, it may not be possible to achieve all of these goals simultaneously and to their fullest degree. One of the challenges in implementing this Plan will be finding the right trade-off among these fundamental goals, appropriately recognizing the statutory guidance, as well as other social values.

Fundamental Goals

The fundamental goals of the Polar Bear Conservation Management Plan arise from the statutory obligations under the Marine Mammal Protection Act and the Endangered Species Act, the goals of the Circumpolar Action Plan, as well as the values of polar bear conservation partners in Alaska.

1. Secure the long-term persistence of wild polar bears as a species and as a significant functioning element in the ecosystem of which they are a part.
2. Secure the long-term persistence of polar bears at scales that represent the genetic, behavioral, life-history, and ecological diversity of the species.
3. Secure the long-term persistence of the two polar bear subpopulations in the United States (the Southern Beaufort Sea and Chukchi Sea subpopulations).
4. Recognize the nutritional and cultural needs of native peoples with connections to polar bear populations, including the opportunity for continued harvest of polar bears.
5. Continue to manage human-bear interactions to ensure human safety and to conserve polar bears.
6. Achieve polar bear conservation while minimizing restrictions to other activities within the range of the polar bear, including economic development.

Fundamental Goal 1: Secure the long-term persistence of wild polar bears as a species and as a significant functioning element in the ecosystem of which they are a part.

The central purpose of this Plan, both in itself, and as the United States' contribution to the Range States' Circumpolar Action Plan, is to ensure that polar bears remain in the wild on this planet, and remain a significant functioning element of the Arctic ecosystem, long into the future. This central purpose is readily shared by all stakeholders.

Species qualify for protection under the ESA if they are in danger of extinction throughout all or a significant portion of their range (endangered) or are likely to become so in the foreseeable future (threatened). The aim of recovery efforts, therefore, is to ensure survival and reduce the risk of extinction to the point that the species no longer requires or qualifies for protection under the ESA, rather than to restore the species to historical levels.

The MMPA has specific provisions that apply to "depleted" species, a status that applies to polar bears as a species because of its ESA listing (16 USC §1362(1)). Congress found in the MMPA that species and population stocks "should not be permitted to diminish beyond the point at which they cease to be a significant functioning element in the ecosystem of which they are a part, and consistent with this major objective, they should not be permitted to diminish below their optimum sustainable population" (16 USC §1361(2)).

In 2008 the USFWS found that the polar bear is likely to become an endangered species within the foreseeable future throughout all of its range and listed the species as threatened under the ESA (73 FR 28212). Thus, the focus of Fundamental Goal 1 is on polar bears as a species. The long-term persistence aspect of this goal is especially related to requirements of the ESA, and the role of the species as a significant functioning element in the ecosystem is especially related to requirements of the MMPA.

Fundamental Goal 2: Secure the long-term persistence of polar bears at scales that represent the genetic, behavioral, life-history, and ecological diversity of the species.

Beyond the goal of keeping polar bears extant in the wild, and recognizing that Arctic warming will not affect polar bear subpopulations equally, it is also important to maintain a broad geographic distribution to conserve genetic, behavioral, ecological, and life-history diversity. Applicable recovery planning guidance developed jointly by National Marine Fisheries Service (NMFS) and USFWS under the ESA (NMFS and USFWS 2010) suggests recovery units may be considered "to conserve genetic robustness, demographic robustness, important life history stages, or some other feature necessary for long-term sustainability of the entire listed entity." In addition, although they apply explicitly to listing decisions under the ESA, the "significant portion of the range" and "distinct population segment" policies provide guidance regarding the importance of intraspecific diversity. Under the MMPA, the finding by Congress that marine mammals should be maintained as significant functioning elements of their ecosystem supports the view that polar bears should be conserved in more than a small portion of their historic range. Intermediate-scale groupings of polar bears capture important intraspecies genetic and life-history diversity; as explained below, the polar bear ecoregions (Amstrup et al. 2008) provide a reasonable proxy of this diversity.

Beyond its fundamental importance, this goal also serves as an effective means to secure the long-term persistence of polar bears range-wide (Fundamental Goal 1) and of polar bears in the United States (Fundamental Goal 3). Conserving the broad spatial distribution and ecological diversity of polar bears over the near- and mid-term—while longer-term solutions to climate change emerge—will provide the greatest opportunity and flexibility for future actions to achieve the ESA and MMPA standards and goals for polar bears.

Fundamental Goal 3: Secure the long-term persistence of the two polar bear subpopulations in the United States (the Southern Beaufort Sea and Chukchi Sea subpopulations).

Conservation of polar bears in Alaska is important for ecological, cultural, spiritual, economic, and aesthetic values. To achieve desirable outcomes associated with these values, securing persistent populations of polar bears in the United States over the long term is an important goal. Admittedly, current predictions pointing to range reductions and population declines highlight the aspirational nature of this goal. In the short- and mid-term, forestalling potential extirpation of polar bears from the United States will serve as a means to achieve Fundamental Goals 1 and 2.

This Plan seeks conservation and recovery of the species range-wide, even if the primary focus of the Plan's conservation and recovery actions is on the two United States subpopulations. The individual management plans produced by the other Range States to underpin the Range States' Circumpolar Action Plan will address additional actions for the remaining subpopulations in a manner consistent with each nation's own statutory, cultural, and economic objectives as well as the *1973 Agreement on the Conservation of Polar Bears*. We acknowledge and support the conservation actions of the other Range States to the extent they contribute to recovery of the species.

Fundamental Goal 4: Recognize the nutritional and cultural needs of native peoples with connections to polar bear populations, including the opportunity for continued subsistence harvest of polar bears.

Local native communities throughout the Arctic have a long tradition of living with polar bears. Those communities have engaged in polar bear harvest consistent with long-standing traditions that provide for the nutritional and cultural needs of communities and have been integral to the success of polar bear conservation activities. Article III of the *1973 Agreement on the Conservation of Polar Bears* allows harvest of polar bears in the exercise of traditional rights of local people. Congress recognized the cultural importance of subsistence harvest to Alaska Native peoples in both the MMPA and the ESA. The MMPA specifically allows non-wasteful harvest of marine mammals, including those that are depleted, by coastal-dwelling Alaska Native peoples (take of polar bears from the Chukchi Sea subpopulation is governed under Title V, 16 USC §1423). The ESA similarly exempts Alaska Native subsistence harvest from the prohibition on take of threatened or endangered species. Commercial trade is not authorized, however. This does not preclude creation and sale of authentic Alaska Native handicrafts and clothing as authorized by these two statutes. Both the MMPA and ESA acknowledge the conservation context of the subsistence exception by authorizing the Secretary to regulate such harvest if necessary (16 USC §1371(b), 16 USC §1539(e)).

This fundamental goal is intended to provide future generations of Alaska Natives the opportunity to meet nutritional and cultural needs through the harvest of polar bears. Achievement of this goal will require the continued responsible management of harvest by Alaska Native peoples, other indigenous peoples, the United States, and other Range States.

Fundamental Goal 5: Continue to manage human-polar bear interactions to ensure human safety and to conserve polar bears.

The likelihood of interactions between humans and polar bears increases: as polar bears spend more time on shore due to a number of factors including receding sea ice; as their primary prey declines and they seek alternative food; as the human population near the Arctic coast increases; and as industrial activity in the Arctic increases. Ensuring the safety of people living and working in the coastal areas frequented by polar bears is a paramount concern. A secondary but important consideration for polar bear conservation is the outcome of human-bear interactions on polar bears. Frequent interactions with people pose a threat to polar bears, both directly, if bears have to be killed, and indirectly, through habituation to humans, food conditioning, and other possible risks.

Fundamental Goal 6: Achieve polar bear conservation while minimizing restrictions to other activities within the range of the polar bear, including economic development.

Local, regional, state, national, and global communities benefit from human activities in the Arctic, including tourism, recreation, oil and gas development, mining, shipping, and scientific research. In some cases, these activities may be compatible with polar bear conservation; in others, there may be conflicts. Finding strategies here in the United States that allow both would benefit multiple stakeholders. This goal reflects objectives in the administration's "National Strategy for the Arctic Region" (White House 2013a), which calls on United States federal agencies to use integrated Arctic management to balance economic development, environmental protection, and cultural values.

In the following three sections (organized by the MMPA, ESA, and other motivations, respectively), the Fundamental Goals are expressed as quantitative measures; for the goals related to the MMPA and ESA, criteria associated with conservation and recovery are provided. Where appropriate, these fundamental criteria are further described with stepped-down demographic and threats-based criteria (Table 1).

Table 1. Three-tier framework for MMPA conservation criteria and ESA recovery criteria; and performance metrics for the remaining Fundamental Goals. The criteria are arranged in three tiers: fundamental (directly related to the fundamental goals); demographic (stepped-down to the level of population demographic rates); and threats-based (stepped-down further to the level of threats). For the fundamental goals (FG) not directly linked to MMPA or ESA, performance metrics are described, without additional tiers or performance thresholds.

MMPA Conservation	ESA Recovery	Other Fundamental Goals
Fundamental Criteria & Performance Metrics		
Conservation Criterion 1: The health and stability of the marine ecosystem, as evidenced by its capacity to support polar bears, are maintained, and each subpopulation of polar bears is maintained as a significant functioning element of that ecosystem. (FG3) AND **Conservation Criterion 2**: Each subpopulation is managed so that its population size is above the maximum net productivity level relative to carrying capacity. (FG3)	**Recovery Criterion 1**: The worldwide probability of persistence is at least 95% over 100 years. (FG1) AND **Recovery Criterion 2**: The probability of persistence in each recovery unit (ecoregion) is at least 90% over 100 years. (FG2)	**FG4:** Cumulative take (all human-caused removals) level over the next 50 years for each subpopulation that includes parts of Alaska. **FG5**: Number of human-bear conflicts in Alaska that result in injury or death to humans or bears. **FG6**: Economic impacts of polar bear management actions, including direct and indirect expenses, and lost or foregone opportunities.
Demographic Criteria		
MMPA Demographic Criterion 1: The intrinsic growth rate of each subpopulation is above, and is expected to remain above, a minimum level that indicates the health of the marine ecosystem is not impaired; and the carrying capacity in each subpopulation is above, and is expected to remain above, 70% of mean historical carrying capacity, indicating that the stability of the marine ecosystem is not impaired. AND **MMPA Demographic Criterion 2:** Total human-caused removals in each subpopulation do not exceed a rate *h* (relative to the subpopulation size) that maintains the subpopulation above its maximum net productivity level relative to carrying capacity.	**ESA 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. AND **ESA 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. AND **ESA 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%. AND	

Continued

Table 1. Continued.

MMPA Conservation	ESA Recovery	Other Fundamental Goals
	ESA 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		
	Sea ice: In each recovery unit, either (a) the average 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 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. AND **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.	

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B. Conservation Criteria under the Marine Mammal Protection Act

Conservation plans are developed for depleted species or stocks under the MMPA. "Each plan shall have the purpose of conserving and restoring the species or stock to its optimum sustainable population. The Secretary shall model such plans on recovery plans required under section 4(f) of the Endangered Species Act of 1973" (16 USC §1383b(b)(2)). Species or stocks of marine mammals are designated as "depleted" in one of 3 ways: because they fall below the optimum sustainable population (OSP) level, as determined by the federal government or by a state to whom authority has been transferred; or because they are listed as endangered or threatened under the ESA. In this case, to no longer be considered depleted, polar bears would have to be delisted under the ESA. (The ESA recovery criteria are covered later; this section considers only the MMPA criteria.) This Plan describes MMPA conservation criteria at two levels: fundamental and demographic (Table 1). These criteria are nested: the demographic criteria are derived from the fundamental criteria using the best scientific information available at the time of assessment.

MMPA fundamental criteria

Fundamental Goals 1, 2, and 3 are tied to the conservation standards of the MMPA. Here, those Goals are translated into specific criteria. At the fundamental level, the goals for conservation of polar bears under the MMPA are achieved when both of the following criteria are met:

> **MMPA Conservation Criterion 1: The health and stability of the marine ecosystem, as evidenced by its capacity to support polar bears, are maintained, and each subpopulation of polar bears is maintained as a significant functioning element of that ecosystem.**
>
> **MMPA Conservation Criterion 2: Each subpopulation is managed so that its population size is above the maximum net productivity level relative to carrying capacity.**

The MMPA criteria apply both to the worldwide population and to the individual subpopulations. The depleted entity is the worldwide population of polar bears, because the depleted status under the MMPA was due to the listing of the species under the ESA. Thus the criteria apply to the species as a whole. To meet the criteria worldwide, it is sufficient to meet them in each stock. The two Alaskan polar bear subpopulations (Southern Beaufort Sea, Chukchi Sea) have been identified as "stocks" under the MMPA (74 FR 69139). This Plan further assumes that all 19 of the polar bear subpopulations qualify as stocks under the MMPA. The management focus of this Plan is the United States' contribution to polar bear conservation, so the conservation actions described below focus primarily on the two subpopulations found in United States territory.

Basis for the MMPA fundamental criteria

In the MMPA, Congress found that stocks should not be permitted to diminish below their OSP level. The MMPA defines OSP as "the number of animals which will result in the maximum productivity of the population or the species, keeping in mind the carrying capacity of the habitat and the health of the ecosystem of which they form a constituent element" (16 USC §1362(9)). One of the challenges in interpreting OSP for polar bears is the expectation that both the carrying capacity and the intrinsic growth rate of subpopulations may change over time due to anthropogenic forces, namely climate change. We have addressed that expectation by adopting two MMPA criteria in this Plan: one focused on maintaining the carrying capacity of the habitat and the health of the ecosystem; and one focused on managing lethal removals to maintain each subpopulation above its maximum net productivity level. These constituent elements in the definition of OSP are not separable; to meet OSP, both elements need to be met.

We considered two possible ways to keep "in mind the carrying capacity of the habitat and the health of the ecosystem" when defining OSP: one approach is to adopt a single standard that combines the concepts of maximum net productivity level and carrying capacity into one criterion; the other approach is to adopt two standards that specify criteria for the two elements separately. Under the first approach, Maximum Net Productivity Level (MNPL) would be defined relative to a historical, undisturbed carrying capacity and health of the ecosystem; thus maintenance of carrying capacity and management of removals are achieved under a single criterion. Under the second approach, maximum net productivity level (*mnpl*) would be defined relative to the current carrying capacity, and a separate (but not separable) criterion would be established for maintenance of carrying capacity and health of the ecosystem. We use the abbreviations MNPL and *mnpl* to refer to the one- and two-standard approaches to interpreting OSP, respectively. Both of these may be reasonable interpretations of the intent of Congress, with the choice of interpretation being made to best achieve conservation in the context of a particular species. We believe the unique setting of polar bear conservation calls for use of the second approach. First, the primary threat to polar bears is loss of sea-ice habitat brought about by climate change and a corresponding loss of carrying capacity and ecosystem health. Thus, a criterion that deals specifically with carrying capacity and ecosystem health allows us to focus on the primary threat. Second, polar bears are legally hunted in the United States for subsistence purposes, and are occasionally legally killed in defense of human life. The management of such take is also important for the conservation of polar bears, so a criterion that specifically addresses such take is valuable. The one-standard approach does not separate the effects of habitat change from the effects of removals, and does not provide a standard that can be used to directly manage take, so it does not serve to advance the conservation of polar bears. In this Plan, because of the unique circumstances of polar bears, we follow the two-standard approach to interpreting OSP.

Health and stability of the marine ecosystem. The first criterion addresses the degree to which it is acceptable for the marine ecosystem to change as a result of anthropogenic causes (as reflected in changes in the carrying capacity or the health of the ecosystem). It is clear that significant declines in these attributes are not acceptable under the MMPA. In the "findings and declaration of policy" section of the MMPA, Congress indicates that "the primary objective of [marine mammal] management should be to maintain the health and stability of the marine ecosystem" (16 USC §1361(6)). Another purpose of the law is to ensure that stocks do not "diminish beyond the point at which they cease to be a significant functioning element in the ecosystem of which they are a part" (16 USC §1361(2)). Further, Congress directed that the "carrying capacity of the habitat and the health of the ecosystem" be kept in mind when determining OSP (16 USC §1362(9)). In the extreme, if polar bears are extirpated from large parts of their range because of loss of sea ice, then they surely will have ceased to be a significant functioning element of the ecosystem; indeed, the "health and stability of the marine ecosystem" will have been changed. The health and stability of the marine ecosystem likely can, however, be maintained, and polar bears likely can remain a significant functioning element of the ecosystem without remaining at historical numbers, provided efforts are made "to protect essential habitats… from the adverse effects of man's actions" (16 USC §1361(2)). We propose to evaluate the health of the marine ecosystem using the intrinsic growth rate for polar bears, and the stability of the marine ecosystem using the carrying capacity for polar bears. If the health of the ecosystem declines, the survival and reproductive rates of polar bears, and hence their intrinsic rate of population growth, will decline. If the ability of the ecosystem to support polar bears declines, the carrying capacity will decline.

Congress did not provide any further explanation of the term "significant functioning element in the ecosystem," there is not any legislative history associated with this term, and the case law is limited. Further, we are not aware of any regulatory action or conservation plans by either the USFWS or NMFS that have defined or incorporated this term. Nor is there guidance on interpreting "health and stability of the marine ecosystem." Nevertheless, we believe these purposes of the MMPA are particularly relevant for polar bear conservation because of the nature of the long-term threats, and thus, we are applying these terms in this plan.

Polar bears play a unique function in the Arctic ecosystem as a top predator. In considering the ecological function of other top predators (grizzly bears and wolves) in their ecosystems, Pyare and Berger (2003) argue that the ecological function of these large carnivores is as important a measure of status as their demographic prospects, because "Research continues to demonstrate that these terrestrial carnivores, perhaps more so than most other threatened or endangered species, have far-reaching consequences for their ecosystems." Similar arguments can be made for the highly influential role that sea otters (*Enhydra lutris*) have in maintaining the marine ecosystems they occupy (Estes and Duggins 1995; USFWS 1994, 2013).

The effects of the marine ecosystem on polar bear populations and the effects of polar bear populations on the marine ecosystem are both important considerations in evaluating the health and stability of the ecosystem, and whether polar bears are a significant functioning element of the ecosystem. This broad understanding of MMPA Conservation Criterion 1 is important in any future evaluation of the criteria in this Plan. In the next section, we focus on intrinsic growth rate and carrying capacity of the polar bear population as indicators of the health and stability of the marine ecosystem, respectively. They may not be good indicators, but they are nevertheless indicators, not direct measures of health and stability, and the broader perspective of ecosystem function should not be lost, especially at lower trophic levels.

The primary threat to polar bears, and the threat most at odds with the intent of the MMPA, is the expected long-term loss, through climate change, of the ecosystem of which polar bears are a part. This first MMPA criterion, perhaps the highest and most ambitious standard in this Plan, would likely require substantial reduction in worldwide greenhouse gas emissions as well as substantial reduction in the loss of sea ice Arctic-wide.

Maximum net productivity level. The second MMPA criterion addresses the extent to which it is acceptable for lethal removals to reduce the size of a polar bear subpopulation relative to its potential size in the absence of such removals. This criterion integrates the biological concepts of carrying capacity, maximum net productivity level, intrinsic growth rate, sex- and age-composition of the population, sex- and age-composition of lethal removals (including subsistence harvest), and sustainable take. At any point in time, the population size at which a population is most productive is conditional on the extent to which limiting resources are utilized. The availability of limiting resources, which determine the carrying capacity, can vary naturally or through anthropogenic forces, and the maximum net productivity level (*mnpl*) will vary in proportion. Likewise, the intrinsic growth rate can vary over time, as a function of the health of the ecosystem, and the intrinsic growth rate also affects the maximum net productivity. Both of these considerations, the possibly changing carrying capacity and the possibly changing intrinsic rate of growth, need to be kept in mind when evaluating the number of removals that will maintain a population above its maximum net productivity level. In long-lived mammal populations in which removals are unbiased with regard to age or sex, maximum net productivity occurs at some population size greater than 50% of carrying capacity; for polar bears, demographic analysis suggests that this level occurs at approximately 70% of carrying capacity (Regehr et al. 2015).

MMPA demographic criteria

Health and stability of the marine ecosystem. As suggested above, the health and stability of the Arctic marine ecosystem, respectively, are reflected in the intrinsic rate of growth and the carrying capacity of polar bear populations. The intent of the first MMPA criterion is to ensure that polar bears remain a functioning element of the ecosystems associated with each subpopulation and that the intrinsic growth rate and carrying capacity do not decline to the point that this function is lost. Although this does not require maintaining the historical levels of intrinsic growth rate and carrying capacity, it will require substantial and successful efforts to limit the anticipated losses from climate change, so that polar bears and their ecosystem remain healthy and stable.

> **MMPA Demographic Criterion 1: The intrinsic growth rate of each subpopulation is above, and is expected to remain above, a minimum level that indicates the health of the marine ecosystem is not impaired; and the carrying capacity in each subpopulation is above, and is expected to remain above, 70% of mean historical carrying capacity, indicating that the stability of the marine ecosystem is not impaired.**

The MMPA provides clear technical guidance on how to determine the tolerable reduction in population size as a result of human-caused removals (see "Maximum net productivity level," below), but it does not provide similar guidance for reduction as a result of habitat loss or other threats besides human-caused removals. Nevertheless, with regard to a loss of carrying capacity, we reason that the reduction of carrying capacity to 70% of its historical level would produce an impact to a polar bear population of similar magnitude to human-caused removals at the level that achieves *mnpl*.

There is not a parallel way to determine a threshold for the intrinsic growth rate, because reductions in growth rate affect populations in a different manner than reductions in carrying capacity or population size. Thus, at this time, we cannot make the policy interpretation needed to establish the first half of MMPA Demographic Criterion 1.

The intrinsic growth rate and carrying capacity may change independently. For instance, the carrying capacity for a subpopulation might decline substantially, but the intrinsic growth rate of the subpopulation might remain satisfactory. For MMPA Demographic Criterion 1 to be met, both conditions need to be met.

For polar bears, we propose using the reference period 1953–1972 for determinations of "historical" carrying capacity. At the time of the enactment of the MMPA, Arctic marine ecosystems were believed to be intact, so the period preceding 1972 serves as a time when the "health and stability of the marine ecosystem" in the Arctic were at historical levels. The period of measurement record for Arctic sea-ice extent begins in 1953; the September sea-ice extent over the period 1953–1972 showed variation around a stable mean (Fig. 4). Thus, to the extent that scientists and managers seek to determine the historical carrying capacity for a given subpopulation, we propose that the period 1953–1972 is a relevant reference.

The estimation of carrying capacity, whether current or historical, is difficult, because it can rarely be observed directly. Rather it needs to be inferred from magnitude and trends in population size and habitat metrics, taking into account the levels of human-caused removals. There are a variety of methods that could be used for this estimation task, and development of these for polar bear subpopulations is needed. The possible methods include: (1) establishing a relationship between current carrying capacity and some relevant habitat metric for which we have measurements in the reference period, and back-extrapolating; (2) estimating carrying capacity over a time series of abundance or other life-history measures, using hierarchical population modeling techniques, and inferring the historical carrying capacity; or (3) assuming carrying capacity has remained stable until recently, inferring the recent carrying capacity from estimates of population size and human-caused removal rates, and using that as an estimate of historical carrying capacity. The first

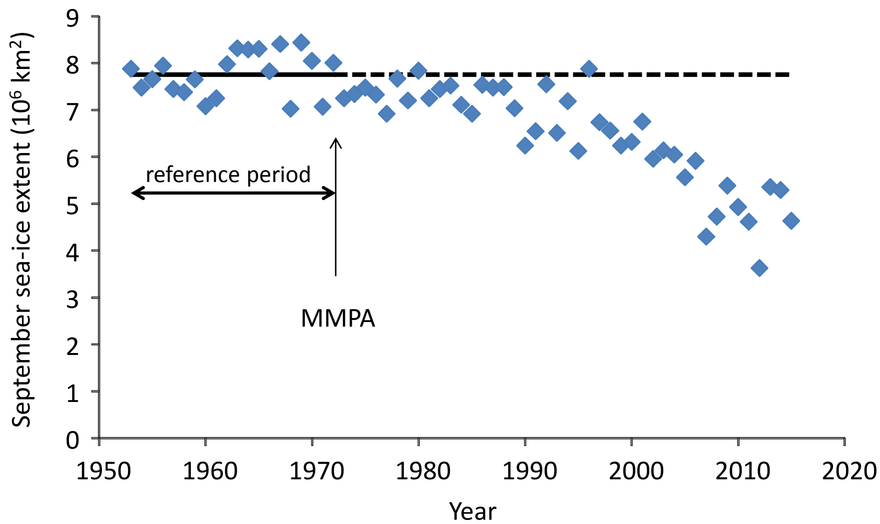

Figure 4. Arctic sea-ice extent in September, 1953–2015, in millions of square kilometers. The solid and dashed lines show the mean extent for the period 1953–1972. We propose that this reference period is suitable for evaluating "historical" conditions of polar bears in the context of the MMPA.

two methods will be quite difficult, the third method is more manageable but the assumptions may be more difficult to justify for some subpopulations.

As noted above, we are treating polar bear carrying capacity as an indicator of the stability of the marine ecosystem. For practical purposes, assessment of individual subpopulations could be undertaken with other indicators (e.g., sea ice).

Regarding polar bears as a functioning element of the ecosystem, complex methods to assess the functional diversity of ecosystems have been proposed (e.g., Petchey and Gaston 2002), but the application of such methods to a changing Arctic involving polar bears would likely be difficult and insensitive to meaningful near-term ecological changes. Thus, at this time, we do not have enough information to propose more detailed measures, and associated thresholds, to directly assess the functional role of polar bears in their ecosystem. Development of such measures is an important task under this Plan. Thoughtful development of approaches based on the particular roles polar bears play in the ecosystem could help with assessment as this Plan is updated in the future.

Maximum net productivity level. At the fundamental level, MMPA Conservation Criterion 2 requires that each polar bear subpopulation size is above its *mnpl*; at this time, we estimate this occurs at approximately 70% of the maximum number of polar bears the environment can support on average (Regehr et al. 2015). Estimating the subpopulation size at carrying capacity, and by extension the *mnpl*, is challenging because environmental factors limiting population growth vary with time and are difficult to measure. Nonetheless, it is possible to manage wildlife populations in a way that satisfies the fundamental criterion if removal levels are based on an estimate of current population size and a harvest rate *h* that is designed to maintain a population above its *mnpl* with some acceptable level of probability. Thus, the MMPA demographic criteria for maintaining a subpopulation above *mnpl* can be stated using this more proximate metric:

> **MMPA Demographic Criterion 2: Total human-caused removals in each subpopulation do not exceed a rate *h* (relative to the subpopulation size) that maintains the subpopulation above its maximum net productivity level relative to carrying capacity.**

The removal rate that achieves MMPA Demographic Criterion 2, *h*, depends on the underlying demographic rates for the subpopulation, the sex and age composition of the subpopulation, as well as the sex and age composition of removals. A valuable reference point is the removal rate, h_{mnpl}, that achieves *mnpl* at equilibrium when removals are in direct proportion to the sex and age composition of the subpopulation (i.e., when removals do not select for certain sex or age classes of animals). The value of h_{mnpl} is derived based on population dynamics theory, general life history parameters for the species, and subpopulation-specific demographic information (Runge et al. 2009). For polar bears, h_{mnpl} is likely 79–84% of the intrinsic population growth rate (Regehr et al. 2015). The theoretical maximum population growth rate for the species is approximately 6–14% (Taylor et al. 2009, Regehr et al. 2010) but may be less if habitat loss or other factors affect subpopulations negatively through density-independent effects.

These interpretations of *mnpl* represent the views of USFWS for the purpose of conserving polar bears. This approach does not necessarily preclude other approaches to determining *mnpl* or MNPL in other conservation plans.

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C. Recovery Criteria under the Endangered Species Act

The ESA requires a recovery plan to incorporate, to the maximum extent practicable, “objective, measurable criteria which, when met, would result in a determination, in accordance with the provisions of this section, that the species be removed from the list [of endangered and threatened wildlife]…” (16 USC §1533(f)(1)(B)(ii)). Following a three-tier framework, this Plan describes recovery criteria at three levels (Table 1): fundamental, demographic, and threats-based. These criteria are meant to be compatible: the demographic and threats-based criteria are derived from the fundamental criteria, using the best available scientific information available at the time of assessment. To achieve recovery, the criteria at all three levels need to be met.

ESA fundamental criteria

The aspects of Fundamental Goals 1 and 2 that refer to securing long-term persistence are tied to recovery under the ESA. Here, those Goals are translated into quantitative measures with threshold criteria associated with recovery. At the fundamental level, both of the following criteria need to be met to achieve recovery of polar bears:

> **Recovery Criterion 1: the worldwide probability of persistence is at least 95% over 100 years.**
>
> **Recovery Criterion 2: the probability of persistence in each recovery unit (ecoregion) is at least 90% over 100 years.**

Basis for the ESA recovery criteria

The conservation of species is a key purpose of the ESA, and the Act defines conservation in terms of bringing species to the point that the Act’s provisions are no longer necessary. The ESA does not specify a numerical standard for determining when a species is threatened or endangered, nor is there a universal approach for making such determinations. Although the ESA does not use terms such as “probability” or “persistence,” the definitions of endangered (“in danger of extinction throughout all or a significant portion of its range,” 16 USC §1532(6)) and threatened suggest that the risk of extinction is a primary concern. Thus, many scholars of the ESA have identified the fundamental goal of recovery as reducing the probability of extinction to an acceptable level, stated equivalently as keeping the probability of persistence above some threshold (e.g., Doremus 1997, Gregory et al. 2013, Ralls et al. 2002, Regan et al. 2013, Seney et al. 2013). In listing decisions and recovery plans where probability of persistence has been used, the threshold between “threatened” and “listing is not warranted” has been characterized by a number of values, roughly ranging between 90% and 99% probability of persistence over a century (e.g., USFWS 1995, 2002; see also DeMaster et al. 2004, Regan et al. 2013). In this Plan, we adopt a desired probability of persistence of 95% over a century for the listed entity; although an even higher probability is the aspiration of all the management partners, the question is the degree of persistence at which the species no longer needs the protections of the ESA. If the probability of persistence is greater than 95% over the next 100 years, then the risk of extinction is low enough and distant enough that it is not likely to become in danger of extinction in the foreseeable future.

This Plan uses probability of persistence to express the fundamental recovery criteria for polar bears. Given the nature of the primary threat to polar bears–loss of sea ice due to changes in climate–as well as the speed at which the climate would respond to changes in atmospheric levels of greenhouse gases, 100 years is a time period over which we could see movement towards recovery or towards extinction depending on worldwide efforts to curtail emissions. The first criterion focuses on the listed entity (the worldwide population of polar bears) and indicates this particular measure of recovery will be achieved when the probability of persistence over 100 years is at least 95%.

Beyond this Plan’s first criterion for survival of the listed entity, the second criterion further specifies that a significant portion of the diversity of the species, as represented by the ecoregions, must also be conserved, in order to promote recovery through representation and redundancy. The risk tolerance for extinction for each of the individual ecoregions (10%) is higher than for the species as a whole (5%) because the ecoregions are only components of the listed entity. It’s worth noting that if the probabilities of persistence in the four recovery units are independent and each 90%, the probability of persistence of the listed entity is 99.99%. Although the assumption of independence is unlikely, this calculation suggests that Recovery Criterion 2 may be considerably more protective than Recovery Criterion 1.

The purposes of an intermediate scale (i.e., recovery unit) in Recovery Criterion 2 include (1) to preserve diversity among polar bears—diversity that is at the heart of ESA protection and important to species viability; (2) to acknowledge that polar bears in different regions may experience different threats and conditions and exhibit different responses to those, which may warrant different conservation approaches now or in the future; and (3) to provide redundancy, and hence increase the survival of the species, by conserving polar bears in more than one region. In order to remove the danger of extinction “within the foreseeable future throughout all or a significant portion of the range" (16 USC §1532(20)), a high probability of persistence in each of the recovery units is needed.

Ecoregions. The best available science suggests that the "ecoregions" proposed by Amstrup et al. (2008) capture broad patterns in genetic and life-history variation for the species. Furthermore, ecoregions were based on observed and forecasted changes in sea-ice habitat and thus capture anticipated variation in the primary long-term threat. We recognize that further research, building on an existing body of work (Spalding et al. 2007, Thiemann et al. 2008), is needed on details of the genetic, behavioral, ecological, and threats-based factors that distinguish spatial groupings of polar bears.

Recovery units. In ESA recovery planning, a "recovery unit" is "a special unit of the listed entity that is geographically or otherwise identifiable and is essential to the recovery of the entire listed entity, i.e., recovery units are individually necessary to conserve genetic robustness, demographic robustness, important life history stages, or some other feature necessary for long-term sustainability of the entire listed entity." Furthermore, "establishment of recovery units can be a useful recovery tool, especially for species occurring across wide ranges with multiple populations or varying ecological pressures in different parts of their range." (NMFS and USFWS 2010, section 5.1.7.1). Because recovery units are "essential to the recovery of the entire listed entity," the criteria must be met in all recovery units in order for recovery to be achieved and for delisting to be recommended.

Ecoregions as recovery units. Polar bears occur in 19 subpopulations throughout the circumpolar Arctic; one of the largest ranges for an extant large carnivore. Within this range the species exhibits variation in genetics, behavior, and life-history strategies. Within the timeframe considered by this Plan, polar bears are expected to experience different pressures resulting in potentially high probabilities of extirpation (e.g., in some parts of the Polar Basin Divergent Ecoregion) to moderate probabilities of persistence (e.g., in the Archipelago Ecoregion) (Amstrup et al. 2008, 2010). National and local management regimes, including collaborative management across jurisdictions, also vary across the species' range.

This Plan uses the 4 ecoregions as recovery units because this approach provides a reasonable representation of important variation for both polar bears and the threats they face. This approach helps augment the persistence of polar bears as a whole by conserving them in multiple regions and allowing conservation actions to be tailored to the most pressing issues in each region. Consequently, persistence of polar bears in all 4 ecoregions is necessary to the recovery of the listed entity.

Any intermediate spatial-scale grouping of polar bears, if meant to apply over a long time scale, will reflect a number of assumptions and imperfections, due to scientific uncertainty and the dynamic nature of climate change and its effects on ecosystems. Using the 4 ecoregions defined by Amstrup et al. (2008) as recovery units represents current knowledge of the ecological diversity of polar bears and their future response to climate change. But because the current information is imperfect, it may be important to conserve an even finer-scale representation of current polar bear diversity in the near term, while seeking to improve our scientific understanding of the distribution of important polar bear ecological diversity. As understanding of polar bears, climate change effects, and other relevant information increases, the delineation of the recovery units should be reviewed and, if appropriate, modified, to reflect the best available science.

Definition of "persistence." In the two ESA recovery criteria (above), we define "persistence" as maintaining the population size in a recovery unit (or worldwide) at greater than 15% of the population size of the unit at the time of listing or greater than 100 individuals, whichever is larger. If, at any point during a 100-yr forecast, the projected population drops below this threshold, it is considered not to have persisted. This threshold is not a desired population target. Rather, by focusing on the probability of persisting above the threshold, the criteria represent the risk tolerance at which we could reasonably conclude that polar bears are no longer threatened. To achieve recovery, the population size needs to be sufficiently larger than the threshold and the threats sufficiently reduced to ensure that the risk of dropping below the threshold is small (i.e., less than 10% over 100 years). (The distinction between "conservation and survival", in the manner those terms are used in Section 4(f) of the ESA [16 USC §1533(f)], is useful here. The persistence threshold represents the point at which the population is no longer surviving. Recovery, that is, "conservation", is a higher bar than merely surviving.) For large mammals, the effects of demographic stochasticity become prominent at population sizes less than 100 (Morris and Doak 2002, Wieglus 2001). For polar bears, mating success may decline when subpopulation density falls below a fraction of present-day values (i.e., there might be an Allee effect), but this point depends on the sex- and age-structure of the population, as well as the population-specific demographic parameters (Molnár et al. 2008, 2014). As the geographic scope expands from subpopulation to recovery unit to species, the Allee effect threshold may occur at lower fractions of the original population size, and will depend on the geographic distribution and connectivity of bears within the unit. The

Table 2. Estimates of population size (with 95% confidence limits) and persistence floor for each ecoregion. The estimates and confidence limits for the ecoregions were calculated by the same methods Wiig et al. (2015) used for the global population.

	Archipelago	Convergent	Divergent	Seasonal	Total
Population size	4945	3004	9751	8785	26485
(2015) estimate	(3900–6000)	(800–5200)	(5800–13700)	(7800–9700)	(22000–31000)
15% threshold	742	451	1463	1318	3973

15% threshold is a placeholder based on available information at a subpopulation level (Molnár et al. 2008), and should be re-evaluated on a case-by-case basis and as new information arises. The 2015 update to the IUCN Red List Assessment for polar bears (Wiig et al. 2015) summarizes the best available information about the population size in each ecoregion; although the underlying data span a number of years, we view this as the best estimate of the population sizes around the time of listing (Table 2). The 15% threshold exceeds 100 animals in all four ecoregions, thus, the 15% threshold is the operational criterion for persistence (recognizing that this is the threshold for survival, not recovery).

ESA demographic criteria

The demographic recovery criteria are derived from the fundamental recovery criteria, but are stated in more proximate measures of population status. The spatial scale of the demographic criteria is the recovery unit. Although the listed entity is polar bears throughout their range, Recovery Criterion 2 identifies the ecoregions as recovery units. To meet the ESA recovery criteria, the fundamental and demographic recovery criteria need to be met for each recovery unit. Thus, the recovery criteria can be focused at the recovery unit level. Recognizing that the United States only has management jurisdiction in parts of one recovery unit (the Polar Basin Divergent Ecoregion), that unit is the main focus of our recovery efforts, but assessment of the recovery of the listed entity needs to consider all of the recovery units.

The demographic criteria focus on three measures of population status: survival rate, reproductive rate, and carrying capacity. Recovery at the recovery-unit (ecoregion) scale would be achieved when all four of the following criteria are met:

ESA 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.

ESA 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.

ESA 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%.

ESA 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.

Although Fundamental Recovery Criterion 2 (90% probability of persistence at the recovery unit level) is the standard for assessment, these demographic criteria use population metrics to represent an equivalent condition, given the current state of knowledge. These are, of course, a simplification of all the population dynamics that give rise to a high probability of persistence, but these are based on the most influential drivers of persistence. Based on life-history theory, adult female survival exerts the largest influence on population growth rate, which is, in turn, a strong driver of resilience and persistence. The ratio of yearlings to adult females incorporates a number of aspects of the recruitment process: breeding probability, litter size, and cub-of-the-year survival. Populations need recruitment to persist, and for some long-lived species, recruitment rates vary more than adult survival rates and drive most of the observed variation in population growth rate. Finally, the probability of persistence is related to population size and hence carrying capacity, because the risk associated with annual variation and chance events is magnified at smaller population sizes.

The first three demographic recovery criteria are not independent. The specific threshold required for any one depends on the thresholds required for the other two (Fig. 5). For example, if the carrying

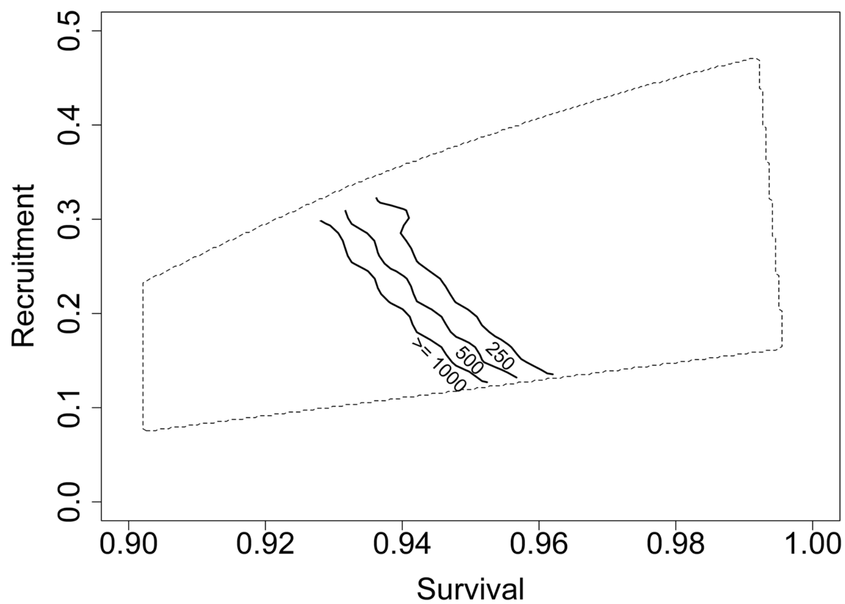

Figure 5. Values of three ESA demographic criteria that provide a 90% probability of persistence (Regehr et al. 2015). The combination of survival (x-axis), recruitment (y-axis), and carrying capacity (contours) needs to be above and to the right of the corresponding contour to provide the required probability of persistence. There are trade-offs among these criteria, such that if any of these measures are quite high, the standard for the others can be lower. For example, if the recruitment rate (yearling to adult female ratio) was expected to remain above 0.3 and the carrying capacity was expected to remain above 1000, the adult female survival rate would only need to be 0.93 to achieve recovery. In this graph, the rate of total human-caused removals is assumed to be at the maximum rate allowable under MMPA Demographic Criterion 2.

capacity were only expected to remain above 500 and the recruitment rate (ratio of yearlings to adult females) were expected to remain above 0.2, the adult female survival rate would need to remain above 0.95 (assuming the rate of human-caused removals is less than h). Because many possible combinations of these three parameters can produce the same probability of persistence, the criteria are described as ranges, but to achieve recovery, the combination of demographic criteria needs to meet the standards for ESA Fundamental Criterion 2 (90% probability of persistence for the recovery unit).

The third demographic criterion (carrying capacity, distribution, and connectivity needed to meet ESA Fundamental Criterion 2) provides the buffer that is needed to protect the population in a recovery unit from dropping below the level at which small-population dynamics take over. A specific threshold for carrying capacity cannot be determined at this time because, as noted earlier, there is uncertainty about how to scale potential Allee effects from the subpopulation level up to the ecoregion level. Given that future reductions in population size due to habitat loss will likely be accompanied by contraction of the geographic range within each ecoregion, it is likely that Allee effects and other negative small-population effects would not manifest until population size is considerably lower than 15% of the population size at the time of listing. At the ecoregion level, the population size at which Allee effects appear may also depend on the distribution and connectivity of subpopulations within the ecoregion. If the subpopulations in an ecoregion were well connected, a carrying capacity of 500–1000 animals, in combinations with the other demographic criteria, may be enough to assure the desired level of persistence (Fig. 5, Regehr et al. 2015), but in other situations, a higher carrying capacity might be needed. Thus, we cannot determine the specific thresholds for carrying capacity, distribution, and connectivity at this time, because we lack an understanding of how those factors will interact to provide the buffer necessary to assure a high probability of persistence. But we do know that the buffer provided by the third demographic criterion is needed; the other demographic criteria alone cannot assure recovery.

The fourth demographic criterion specifies an upper bound on the rate of direct human-caused removals, and the other demographic criteria have been calculated assuming that rate. (Direct human-caused removals are those that occur as a direct result of human action, such as subsistence hunting, defense-of-life, and incidental take. Indirect removals, such as those that occur as a result of habitat degradation, are captured either in the survival rate or the carrying capacity. This distinction is largely in deference to the ability to monitor direct, but not indirect, removals.) If the rate of human-caused removals is less than this upper bound, the demands for the other demographic criteria can be reduced, provided the persistence criterion is met. It is also possible to meet ESA Fundamental Criterion 2 (90% probability of persistence over 100 years) without meeting ESA Demographic Criterion 4 (human-caused removal rate less than *h*), but this would require even higher survival and reproductive rates than specified by the second and third demographic criteria (see discussion, below, of ESA Threats-based Criterion 2). Thus, while the fourth demographic criterion is not strictly necessary for recovery, we have included it as a recovery criterion because it reiterates MMPA Demographic Criterion 2, the combination of non-anthropogenic mortality and anthropogenic mortality is critical, and the other demographic criteria can only be set in the context of the anthropogenic mortality.

There are three particular challenges in developing and evaluating these demographic criteria: climate change effects, density-dependence, and harvest. First, sea-ice loss related to climate change is a long-term threat that will present changing conditions for ice-dependent Arctic species like the polar bear. All of these demographic criteria are likely met currently for the Polar Basin Divergent Ecoregion, as well as for others; the concern is that they will not continue to be met as climate-driven sea-ice loss increases, which is why polar bears were listed. Thus, the evaluation of the demographic criteria needs to assess whether they will continue to be met over the next 100 years. Second, survival and recruitment (the first two demographic criteria) may be density-dependent, that is, they naturally decrease as the population size approaches carrying capacity. Thus, a threshold value for those rates is meaningless unless it is associated with a particular population density. Here, we have chosen to establish these criteria in reference to the *mnpl*, which is the population size, relative to the carrying capacity at a point in time, that produces the highest net annual production, assuming removals are unbiased with regard to age and sex. This is a particularly practical reference point because for polar bear populations that are managed to be near *mnpl*, the observed survival and recruitment rates can be compared directly to the criteria. Third, for any populations that are subject to direct human-caused removals, the survival rate will be the product of both the survival rate in the absence of anthropogenic take and the survival rate associated with those removals, taking into account the sex and age composition of the population and of the removals. The survival rate in Demographic Criterion 1 refers to the survival rate in the absence of removals, and hence encompasses non-anthropogenic mortality; the total take rate in Demographic Criterion 4 refers to anthropogenic mortality.

The demographic criteria listed above are stated in terms of average values of the true underlying rates, not annual rates. Annual variation around these mean values is expected; the criteria require that the mean values of those stochastic processes be above the indicated thresholds. Using average values assumes that potential future change in how much the rates vary from year-to-year will not, in itself, have a meaningful effect on persistence. Also the demographic criteria were derived assuming a perfect ability to estimate them; the empirical precision needed has not yet been developed. If the demographic rates are measured or forecast with considerable error, then it is possible to think that the criteria have been achieved when the true values do not, in fact, meet the criteria or, vice versa, to think that the criteria have not been achieved when, in fact, they have. The risk due to sampling error has not been directly incorporated into the interpretation of these criteria, but that consideration should be evaluated carefully whenever a population status assessment is made, and could be incorporated into a future revision of this Plan.

The estimation of annual and mean rates for three of the four demographic parameters (survival, recruitment, and take rates) can be conducted with monitoring programs that are already in place in several polar bear subpopulations, including the Southern Beaufort Sea. These programs currently involve the marking and recapturing of individual bears over time. Note, however, that the existing monitoring programs are focused at the subpopulation level but the ESA demographic criteria are focused at the recovery unit level; research will be needed to understand how to make inference at the recovery unit level from data at the subpopulation level (Regehr et al. 2015). The estimation of the fourth demographic parameter, carrying capacity, is notoriously challenging, because the link between habitat variables and population responses is often poorly understood. Modern statistical methods (known as "hierarchical models") provide a way to estimate "latent" parameters like carrying capacity, by integrating survival, recruitment, harvest, habitat, and population size data into a single statistical framework (Royle and Dorazio 2008). If such a statistical model is developed for polar bears, it can then be linked to forecasts of the habitat variables (Durner et al. 2009) to provide the current and projected estimates of carrying capacity needed for Demographic Criterion 3.

As noted above, these demographic criteria should be subject to periodic revision as new information becomes available to inform their derivation.

Because of this, use of the demographic criteria is not a substitute for development of a full population viability analysis for evaluation of the fundamental recovery criteria. Such development will allow both refinement of the demographic criteria as well as direct evaluation of the fundamental criteria.

ESA threats-based criteria

The ESA threats-based recovery criteria are derived from the fundamental and demographic recovery criteria described above, but are stated with regards to the threats to the species, so that they correspond to the listing factors described in the ESA (16 USC§1533(a)) and facilitate achievement of the demographic criteria. The listing rule for polar bears identified one threat, loss of sea ice, under Factor (A) "threatened destruction…of its habitat." The rule also acknowledged, under Factor (D) "inadequacy of existing regulatory mechanisms," that "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" (73 FR 28288). In what follows, we discuss threats-based recovery criteria in 3 categories: those threats that were identified in the listing rule and are currently an impediment to recovery (sea-ice loss); those potential threats that are not currently an impediment to recovery, but could become impediments before the threats in the first category are addressed; and those potential threats that could become an issue in the future, but are of more distant concern at this time. We develop threats-based recovery criteria for the first two categories, but not the third, noting that future revisions of this Plan will need to revisit the proximity and severity of threats and potential threats in all categories.

As with the demographic recovery criteria, the scale of the threats-based criteria is the recovery unit. To meet the ESA recovery criteria, the demographic and threats-based recovery criteria need to be met for each recovery unit.

Sea ice and terrestrial habitat. The primary threat to polar bears is loss of its sea-ice habitat, driven by Arctic warming. In some subpopulations, the physiological and demographic effects of longer ice-free periods are already evident (Regehr et al. 2007, 2010; Rode et al. 2014; Bromaghin et al. 2015) and polar bears already have exhibited behavioral responses to longer ice-free periods, spending more time on land during the summer (Fischbach et al. 2007; Schliebe et al. 2008; Rode et al. 2015; Atwood et al. 2016). Given the predicted increase in ice-free periods, these behavioral changes are anticipated to increase and are expected to lead to an increase in population-level demographic effects in the future. In the long term, recovery of polar bears will require measures to address the loss of sea ice (climate change mitigation); in the mid-term, recovery may also require attention to conservation of the terrestrial habitats polar bears use during the ice-free months. While there could be some trade-off among these efforts, such that greater terrestrial conservation might allow for achieving recovery of polar bears with lesser climate mitigation than otherwise would be needed, the most critical aspect is that polar bears are able to maintain adequate access to prey resources. Both aspects of this threat (sea ice and terrestrial habitat) are discussed below: a specific criterion is offered for sea ice; development of a criterion for terrestrial habitat will require more research.

In three of the four recovery units (Polar Basin Divergent, Polar Basin Convergent, Archipelago, Fig. 2), the annual ice-free period has historically been short and polar bears have had potential access to seals nearly uninterrupted year-round. But for one of the recovery units (Seasonal Ice, Fig. 2), polar bears have historically coped with an ice-free summer during which they had reduced access to prey. There is empirical evidence that the potential for fasting mortality may increase after 120 days (Lunn and Stirling 1985; Molnár et al. 2010, 2014; Robbins et al. 2012; Cherry et al. 2013), thus, we assume that polar bears, given sufficient access to prey during other times of year, are capable of persisting with an average ice-free period of 4 months or less. It is possible that polar bears can persist with a longer ice-free period than 4 months, or could do so if they made adaptations (e.g., altered seasonal migration, alternative food sources). To achieve recovery in a recovery unit, we would either need to have evidence that the ice-free period was going to remain 4 months or less, or evidence that the ice-free period was going to stabilize at something longer than 4 months and that polar bears were able to persist at that longer ice-free period.

> **ESA 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.**

In making this assessment, the focus is on the area of seasonal or permanent sea ice supporting prey resources that underlie the carrying capacity of a recovery unit. An ice-free month is defined as a month during which less than 50% of the relevant area of sea is covered by sea ice with more than

50% ice concentration (based on monthly average sea-ice concentration, or for more than 15 days if based on daily sea-ice data). In addition to aligning with the timeframe of the fundamental recovery criteria, a 100-year period is used to allow long-term feedbacks in the climate system to stabilize and to average over short-term (decadal-scale) oscillations associated with natural climate variability (Kay et al. 2011, Lovejoy 2014). The assessment of the stability of the ice-free period in part (b) above should accommodate the expectation that uncertainties in 100-year forcing scenarios and differences among model ensembles may produce some forecasts with subtle increases in the length of the ice-free period (i.e., of no more than 1 month over 100 years), which we accept as indistinguishable from "stable."

These criteria may change in future revisions of the Plan as more is learned about polar bears, their habitat requirements, the availability of alternate prey, and how polar bears and their prey populations respond to diminishing sea ice. The sea-ice criteria use model projections of sea ice extent as a proxy for the amount of time polar bears will be forced ashore or away from sea ice over shelf waters during summer in the future. How an ice-free month is defined underpins the proxy's efficacy, and the definition should be revised as more is learned about what sea-ice conditions best predict when polar bears arrive and depart from land, and how those relationships differ in different recovery units.

Assessments of future sea-ice conditions should be made using projections from an ensemble of state-of-the-art, fully coupled, general circulation models (GCMs) (Harris et al. 2014). Each model in the ensemble should possess reasonable ability to simulate past observations of seasonal sea-ice dynamics (Wang and Overland 2009, Massonnet et al. 2012). For projecting future sea-ice conditions, the GCMs should be forced with one or more scenarios that depict plausible levels of forcing for a baseline future in which no presumptions are made about greenhouse gas mitigation practices that have not yet been adopted into law or that do not already show empirical evidence of adoption. What constitutes the baseline will hopefully change over time as nations enact changes to stabilize global warming, and future assessments should reflect these changes. If more than one baseline forcing scenario is deemed plausible, the sea-ice criteria should be evaluated using projections from an unbiased representation of the competing scenarios. Each model should be represented by an equivalent number of realizations (model runs), preferably more than one.

Using projections of future sea ice from climate models assumes that the primary limiting feature of the environment for polar bears is the sea-ice platform itself, and that if the platform is stabilized then polar bears will have adequate access to prey (primarily ice seals). It is conceivable that changes to the environment could alter the seal populations and distributions so that even if the ice platform were stabilized, polar bears would not have access to suitable prey. Future status assessments should consider prey abundance and prey availability and reevaluate the assumption that sea ice is the sole limiting factor for polar bear access to prey.

Although polar bears in several of the recovery units have historically spent the majority of their life on the sea ice, land has been and is increasingly becoming important for denning and as a summer refuge (Kochnev 2002, Ovsyanikov 2012, Fischbach et al. 2007, Rode et al. 2015, Atwood et al. 2016). Given that the extent of summer sea ice is projected to decline through the 21st century (Overland and Wang 2013, Barnhart et al. 2016), terrestrial habitat is likely to become an increasingly important refuge for polar bears. The ability of bears to maintain access to terrestrial denning areas without compromising foraging opportunities pre- and post-denning may be an important factor determining whether reproduction and cub survival is affected by sea-ice loss (Derocher et al. 2004). This distributional change may also have ramifications for the status of the polar bear recovery units if use of terrestrial habitat has fitness or genetic implications.

While ice habitat is critical to the ability of polar bears to access their prey, protection of denning and summering habitats is and may become increasingly important in supporting the long-term persistence of polar bears, including in the Polar Basin Divergent Ecoregion. Increased use of land is likely to heighten the risk of human-bear interactions and conflicts, particularly if anthropogenic activity in the Arctic increases as projected (e.g., Vongraven et al. 2012), the human population in the Arctic grows, and management of attractants to polar bears is not improved. Moreover, an expanding anthropogenic footprint has the potential to influence the spatial distribution, connectivity, and quality of lands that might serve as terrestrial refugia for polar bears. Currently, access to usable terrestrial habitats is probably not compromised for polar bears, but there is insufficient data at this time to formalize the criteria required to protect terrestrial habitat. Further monitoring is needed of any potential threats to polar bear terrestrial habitat use and availability, and the effects those threats may have on population vital rates.

The 2008 rule listing the polar bear as a threatened species under the ESA acknowledged that there were no known regulatory mechanisms in place at the national or international level that directly and effectively addressed the primary threat to polar bears—the rangewide loss of sea-ice habitat (73 FR 28288). Although Parties to the UNFCCC met regularly to negotiate efforts to curb global greenhouse gas emissions and temper the threats posed by continued global warming, their efforts lacked broad international consensus and commitment. Meanwhile, global CO_2 emissions have increased 60% over the past 25 years (Jackson et al. 2016), leading some to conclude that a warming climate of 2 degrees C or more above the pre-industrial level is unavoidable (Sanford et al. 2014). The agreement by those Parties to the goal of "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C" (Article 2.1(a), United Nations 2015) represents an important step towards establishing a credible regulatory mechanism designed to address the primary threat to polar bears.

To keep net global warming well below 2°C, global greenhouse emissions must be promptly and aggressively reduced. Under a scenario of aggressive GHG mitigation, Amstrup et al. (2010) forecasted that polar bears in most regions of the Arctic could have healthy populations if accompanied by full implementation of well-designed wildlife management. Atwood et al. (2016) forecasted a dominant likelihood of greatly reduced polar bear populations in two recovery units (the Polar Basin Divergent and Seasonal Ice Ecoregions) based on contemporary climate models forced with an aggressively mitigated emissions scenario (RCP 2.6). Nevertheless, end-of-century model projections of sea ice under the RCP 2.6 scenario show a likelihood that polar bear populations could summer onshore for 4 or fewer months in parts of all recovery units (Fig. 3), thus achieving Threats-based Criterion 1 (sea ice), albeit with the possibility of greatly reduced population sizes in some areas. And, since most climate models do not project that the Arctic Ocean will become entirely ice-free under the RCP 2.6 emissions scenario (Hezel et al. 2014), some polar bears might adopt an alternative strategy (if viable) of remaining on the sea ice as it retreats during summer, then exercising an option to migrate anywhere with abundant prey and sea ice during winter.

Human-caused removals. There are multiple types of direct, lethal removals of polar bears, including legal harvest that meets management or conservation goals, legal harvest that results in overutilization or other negative outcomes for management or conservation, illegal harvest (poaching), authorized incidental take, human-bear conflicts that result in the death of polar bears, and polar bears killed as a direct result of other human activity. In many of the polar bear subpopulations where data are available, mortality due to harvest exceeds mortality to manage human-bear conflict, which exceeds human-caused mortality from other sources (Shadbolt et al. 2012).

The subsistence harvest of polar bears, as represented by Fundamental Goal 4, was not identified as a threat to polar bears in the listing rule, and should not become a threat to recovery so long as harvest occurs at a rate that has only a small or negligible effect on the persistence of populations (Atwood et al. 2016, Regehr et al. 2015). Guidelines for such a rate for total human-caused removals, including subsistence harvest, are established under the MMPA-based demographic criteria associated with Fundamental Goal 3 and related to Fundamental Goal 4. In brief, these criteria seek to: (1) identify a human-caused removal rate that maintains populations above the *mnpl*; (2) protect the opportunities for subsistence harvest by minimizing other lethal take; and (3) establish co-management of polar bears by Alaska Native and Federal partners.

The ESA-based criterion for the total level of direct, lethal removals for polar bears by humans, as described here, does not replace the MMPA-based criteria for human-caused removals. Rather, the ESA-based criterion represents a less protective take threshold at which removals would compromise polar bear persistence in relation to Fundamental Goals 1 and 2 (the MMPA-based criterion additionally requires that take be low enough to allow the population to stabilize above *mnpl*). A quantitative Population Viability Analysis, similar to that used for estimating demographic criteria, represents an appropriate tool for evaluating the effects of total human-caused removals following the tiered framework proposed below.

The 2008 listing rule found that currently, human-caused removals "[do] not threaten the polar bear throughout all or a significant portion of its range" but that "Continued efforts are necessary to ensure that harvest or other forms of removal do not exceed sustainable levels" (73 FR 28280). Provided the following criterion is met, human-caused removals will not be considered a "threat" to recovery.

> **ESA 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.**

As written, this criterion is largely a recapitulation of ESA Fundamental Criterion 2 (90% probability of persistence in each recovery unit), with a focus on the effect of human-caused removals on the probability of persistence. In the event that an appropriate quantitative model is not available to assess this criterion, it could be evaluated using a tiered approach:

1. Criterion met: Total human-caused removals are below the removal rate that maintains the population above *mnpl* (*h*), as defined under ESA Demographic Criterion 4. Removals at this rate are likely to have no effect, or a negligible effect, on persistence. In this case, a population viability analysis would not be needed to know this criterion was met. As noted earlier, this is also the most likely path to recovery, given the other motivations in this plan to maintain removals at or below this level.
2. Criterion possibly met: Total human-caused removals exceed *h* but are below the upper limit described under "Criterion not met." Removals within this range could result in different outcomes, including: removals resulting in equilibrium population size below *mnpl* but with a negligible effect on persistence; removals leading to a small equilibrium population size, and therefore either having some negative effect on persistence over the period of interest or shortening the median time to extirpation; or removals that have a high probability of resulting in population sizes far below *mnpl* and a significant negative effect on persistence. The annual removal rate and its effects must be balanced against other Fundamental Goals and threats to achieve the desired overall level of persistence as stated in ESA Fundamental Recovery Criterion 2. This is the range in which ESA Demographic Criterion 4 is not met but recovery is still possible, provided the other demographic rates exceed their minimal standards enough to meet the persistence criterion. If the human-caused removals in a recovery unit were in this range, a population viability analysis would be needed to assess this potential threat.
3. Criterion not met: Total human-caused removals result in a 10% or greater decrease in the probability of persistence over 100 years, compared to a scenario with no removals. At this upper limit, removals would violate ESA Fundamental Criterion 2 even in the absence of all other threats.

Additional factors of potential future concern. A number of other factors, including disease, shipping, oil and gas development, and oil spills, were evaluated in the 2008 listing rule for polar bears but not found to be threats; thus, they do not require threats-based recovery criteria. Further, because the potential for these factors to become threats in the future is distant or low enough (Atwood et al. 2016), they do not warrant development of specific criteria to indicate when they might become a threat.

At present, exposure to disease and parasites is not a threat to the persistence of polar bears. However, data on the exposure of polar bears to disease agents and parasites are quite limited (i.e., restricted almost entirely to the Southern Beaufort Sea subpopulation), and there is no information on putative links between disease status and population vital rates. The lack of information is a concern given that climate change is expected to have both direct and indirect effects on disease dynamics in the Arctic due to changes in host-pathogen associations, altered transmission dynamics, and host and pathogen resistance (Burek et al. 2008). Concern is exacerbated by the fact that polar bears have a naïve immune system (Weber et al. 2013), which may make them particularly vulnerable to new pathogens, and greater time on land during ice-free summers may increase exposure to new pathogens. Thus although the best available science currently indicates that disease and parasites are not a threat to polar bears (Atwood et al. 2016), periodic monitoring of polar bear health (to include exposure to disease agents, pollutants, and contaminants) is warranted.

With regard to the other factors, the continued decline of summer sea ice will allow greater human access to the Arctic Ocean, increasing the prospect of oil and gas exploration and development (Gautier et al. 2009) and the opening of new shipping routes (Smith and Stephenson 2013). There are a number of hypothesized ways this increased activity could affect polar bears, but perhaps the greatest risk is through exposure to oil spills, because even minimal ingestion of oil by polar bears can be lethal (St. Aubin 1990). Other activities, like coastal patrol, research, and commercial fishing, could also increase with the decline of summer sea ice. But, changing ice conditions have only recently allowed increased human activities in the Arctic Ocean and limited information exists to predict how polar bear populations would respond to increased human activity (Peacock et al. 2011, Vongraven et al. 2012). The current partnerships in the United States between industry and natural resource management agencies have led to successful mitigation efforts that have limited disturbance to denning bears and reduced the number of bears killed in defense of life, and are likely to continue to do so in the near future. While monitoring of these potential avenues of stress to polar bears is warranted, these factors do not require threats-based criteria at this time. In future updates to this Plan, however, these factors should be reevaluated.

D. Other Measures of Achievement

Fundamental Goals 4, 5, and 6 are not derived directly from statute, but instead are included because they are expressions of other societal values that could be affected by polar bear management. Performance requirements do not need to be prescribed for these goals (as they do for ESA recovery criteria and MMPA conservation criteria). It is important, however, to measure achievement of these goals, particularly to provide an adaptive feedback loop for improving future conservation actions. The following three measurement scales provide quantitative expressions of these Fundamental Goals.

Fundamental Goal 4, measurement scale: Cumulative take (all human-caused removals) level over the next 50 years for each subpopulation that includes parts of Alaska. The cumulative take level over the next 50 years represents the opportunity for subsistence harvest by multiple generations of Alaska Natives combined with other forms of human-removal. We strive to ensure sustainable continued harvest opportunities, although providing the opportunity does not require that the take actually occurs at the full level specified under MMPA Demographic Criterion 2. Note that harvest management under the guidelines of this Plan may include ongoing harvest—even for populations that are declining due to environmental effects—as long as the harvest is responsibly managed (in accordance with the MMPA Demographic Criterion 2) and does not in itself become a driver of declining ability to secure long-term persistence.

Fundamental Goal 5, measurement scale: Number of human/bear conflicts in Alaska that result in injury or death to humans or bears. With decreasing sea ice, we anticipate an increase in the number of bears onshore and an increase in human activities in the Arctic. This combination will likely result in an increase in human-bear encounters. To ensure that the measurement scale actually reflects the effectiveness of conservation efforts in improving human safety, monitoring of additional variables associated with human-bear encounters will be needed to provide context.

Fundamental Goal 6, measurement scale: Economic impacts of polar bear management actions, where "economic impacts" means additional cost (direct expense, indirect expense, lost or foregone opportunity, additional time) associated with a specific action. This goal acknowledges that while our primary goal is polar bear conservation, we recognize the need for compatible economic activity in the United States Arctic. The measurement scale provides a means to consider whether and how potential conservation strategies and actions may affect economic development, both locally and globally. This allows a more explicit consideration of the trade-offs between economic development and conservation actions, to seek solutions in which economic development does not undermine the ability to achieve recovery and conservation of polar bears, and in which conservation does not unnecessarily limit economic development.

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E. The Population Dynamics of Conservation, Recovery, and Harvest

If we are successful in achieving the criteria described in this Plan, what will conservation and recovery of polar bears look like? The conservation criteria under the MMPA and the recovery criteria under the ESA are not stated in terms of desired population sizes, because conservation and recovery could be achieved at different population levels. Instead, the criteria are stated in terms of demographic processes (e.g., persistence, survival, reproduction, carrying capacity, anthropogenic mortality) that link back to the fundamental goals for polar bears, several of which were framed in terms of probability of persistence. The concepts behind the demographic processes may be unfamiliar to some readers, so it is fair to ask, what would conservation and recovery look like? Why do all of these criteria add up to fulfillment of the obligations under MMPA and ESA? And how is it that harvest can be compatible with conservation and recovery?

A picture of conservation

As described above, the proposed MMPA criteria seek two things: to maintain the health and stability of the marine ecosystem, as reflected in the intrinsic growth rate and carrying capacity for polar bears, above a certain level; and to maintain each polar bear subpopulation above its maximum net productivity level. The first MMPA criterion indicates that there is a limit to the loss of carrying capacity that can occur before the stability of the marine ecosystem is lost and polar bears would cease to be a significant functioning element of the ecosystem (Fig. 6, scenario 1). The threshold described in this Plan indicates that a substantial portion (70%) of the historical carrying capacity must be maintained (where "historical" carrying capacity refers to the carrying capacity in the decades preceding enactment of the MMPA). If a declining carrying capacity

Key Terms

Carrying capacity. The size at which a population would stabilize if there were no direct anthropogenic removals. The carrying capacity can change over time, if the underlying habitat changes.

Stable ecosystem threshold. The threshold for carrying capacity identified in MMPA Conservation Criterion 1 below which the stability of the marine ecosystem is unacceptably altered.

Intrinsic growth rate. The population growth rate in the absence of anthropogenic removals and at low density. This is the potential growth rate, not the observed growth rate, and is an important measure of the resilience of a population.

Maximum net productivity level. The population size at which the net growth in the population (births minus non-anthropogenic deaths) is greatest. Under the interpretation used in this Plan, *mnpl* changes in proportion to carrying capacity.

Quasi-extinction floor. The threshold for evaluating "extinction" under the ESA in this Plan. Rather than use outright extinction as the condition to be avoided, we are using a more conservative definition that avoids the conditions that might give rise to an unavoidable downward spiral. If a population crosses below this threshold, it has ceased to persist, for purposes of assessment under the ESA.

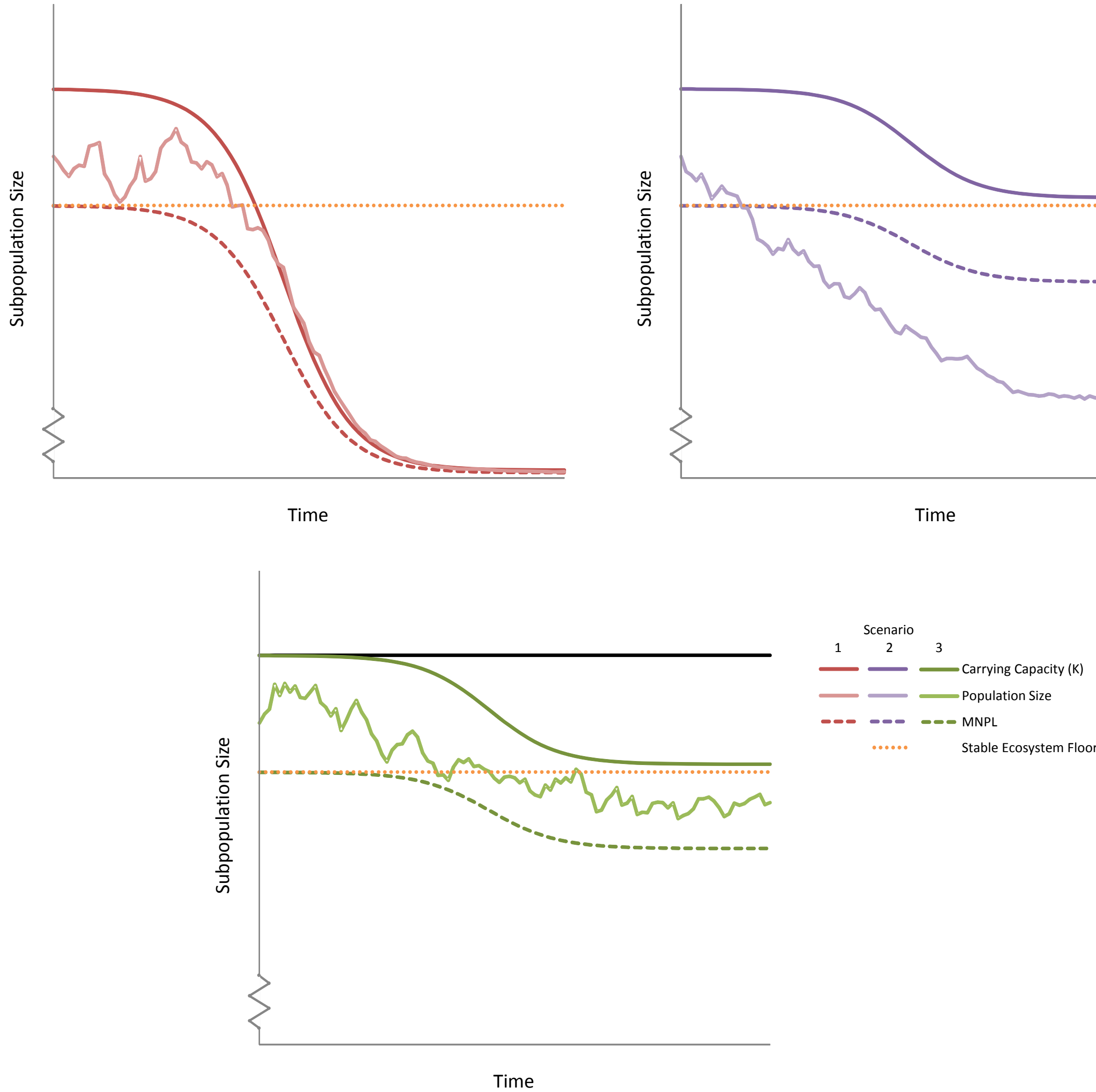

Figure 6. Achieving the MMPA conservation criteria requires keeping carrying capacity above the stable ecosystem threshold, and keeping the population between *mnpl* and carrying capacity. Scenario 1 (red) shows the trend over time of a subpopulation with well-managed take, but in an ecosystem that loses nearly all capacity to support polar bears; this is the expectation for polar bears in most subpopulations if the threat of climate change is not abated. Scenario 2 (purple) shows the trend over time of a subpopulation with unsustainable levels of take, which cause the population size to decline below *mnpl* and may decrease population viability. Scenario 3 (green) shows the trend over time of a subpopulation with well-managed take and an ecosystem that stabilizes before it reaches the point at which the health and stability are lost, even though a portion of the original carrying capacity is lost. The black line in scenario 3 provides a reference to the carrying capacity in the absence of an anthropogenic effect on polar bear habitat. This figure is a simplification for the purpose of illustration; assessment of the criteria will also need to take into account annual variation, precision of estimates, and other considerations.

stabilizes and is expected to remain stabilized above the threshold associated with a stable ecosystem, then the first criterion is met (Fig. 6, scenario 3). This criterion does not require that the historical carrying capacity (Fig. 6, scenario 3, black line) be maintained, but rather that the decrease in carrying capacity is limited and ultimately stabilized; the historical carrying capacity is nevertheless a valuable reference point for understanding the extent of decrease in carrying capacity and associated ecosystem stability. Note that the first criterion concerns the carrying capacity, not the population size (which may be below the carrying capacity because of human-caused removals); if the population size drops below the threshold, but the carrying capacity does not, the criterion is still met, although some thoughtful consideration of the level of take might be prompted. In the absence of global efforts to abate the causes and effects of climate change, scenario 1 is the expectation for polar bears in most subpopulations; substantial worldwide effort would be needed to turn scenario 1 into scenario 3. Achievement of this goal is the most important and ambitious aim of this Plan.

The second MMPA criterion addresses the level of human-caused removals of polar bears. The maximum net productivity level (*mnpl*) is the population size at which the net productivity (birth and survival of juveniles to adulthood, minus deaths of adults) is greatest; for polar bears, this is estimated to occur at about 70% of the carrying capacity (Regehr et al. 2015). We have interpreted the *mnpl* as proportional to the carrying capacity at any point in time (Fig. 6)—as carrying capacity declines, so does the population size at which productivity is highest. If human-caused removals exceed the allowable rate, the population will decrease below *mnpl* (Fig. 6, scenario 2). If all human-caused removals, including subsistence take, are well-managed, then the population size should remain between *mnpl* and carrying capacity (Fig. 6, scenarios 1 and 3). To do this requires adjusting the total take as the population size declines, as the intrinsic growth rate declines, or both.

Thus, scenario 3 (green) in Figure 6 shows a picture of successful achievement of both MMPA conservation criteria developed in this Plan. This picture, however, is not the current expectation for most of the subpopulations worldwide. The second MMPA criterion (maintenance of *mnpl*) is not a primary concern, because the United States will continue to work with its partners to maintain the Southern Beaufort and Chukchi Sea populations above *mnpl*, and because processes exist, or are being initiated by the individual Range States, to manage human-caused removals in many of the other subpopulations. On the other hand, in all four of the ecoregions, significant loss of carrying capacity is expected as the extent, thickness, and duration of sea ice decline (Atwood et al. 2016). Although the specific analyses have not been completed against the first MMPA criterion (ecosystem health and stability), the best scientific information available suggests that in at least three of four ecoregions, this criterion is not expected to be met within 50–100 years (e.g., scenario 1 in Fig. 6). Thus, to achieve the conservation purposes of the MMPA for polar bears, global actions need to be taken to reduce the long-term loss of sea ice to tolerable levels, while responsibly managing all forms of human-caused removal, including subsistence harvest.

A picture of recovery

The ESA criteria described above fundamentally seek a high degree of assurance that viable populations of polar bears (as defined for the purposes of this Plan) will persist in all four ecoregions for a long period of time. To achieve such assurance, three important qualities of the populations are needed: resilience, buffering, and limited removals. Resilience arises when the intrinsic population growth is high, so that the population can quickly rebound from any short-term decline; such resilience comes from having high survival and reproductive rates (ESA Demographic Criteria 1 and 2). A high carrying capacity buffers the population from the risk that natural variation will cause it to decline to unacceptable low levels (ESA Demographic Criterion 3). Finally, human-caused removals (for any purpose, including defense-of-life and subsistence) remove some of the resilience (by reducing the survival rate), so they must be limited (ESA Demographic Criterion 4). To assure long-term persistence, these criteria not only need to be met at the time of assessment, but also at all points in time going forward 100 years from that point.

Currently, polar bears do not meet these criteria in at least three ecoregions (Seasonal Ice, Polar Basin Divergent, and Polar Basin Convergent). Based on forecasts of atmospheric gases, Arctic air and sea temperatures, and sea-ice extent, polar bear populations are expected to decline to small fractions of their historical population sizes (Atwood et al. 2016). The red line in Figure 7 shows a hypothetical scenario that roughly matches the expectation for one or two of the ecoregions (including the Polar Basin Divergent ecoregion)—as sea ice is lost, the population will decline precipitously, crossing below the threshold at which the dynamics of small populations take over. These dynamics include demographic stochasticity, Allee effects, and inbreeding, which may create an "extinction vortex" that leads to nearly inescapable extinction. The population level at which these small population dynamics take over is called the quasi-extinction floor and represents failure—the effective loss of bears in an ecoregion. To achieve recovery, the forecast trend needs to be changed, so that the population is expected to remain safely buffered above the quasi-extinction floor. In most species that have recovered under the ESA (e.g., wolves, bald eagles, peregrine falcons), the trajectory looked like the blue line in Figure 7: the species showed a substantial decline; the species was listed under the ESA, often as the population approached a perilous point; recovery actions were implemented and the population trend turned around; then delisting occurred when the long-term prognosis was secure. But note that recovery under the ESA did not necessarily return these species to historical levels, only to levels that assured the species no longer needed the protection of the ESA. Polar bears were listed at a much earlier stage because the primary threat, loss of sea ice, could be foreseen in advance. With this advanced notice, we have the potential opportunity to achieve recovery without ever approaching perilously low numbers

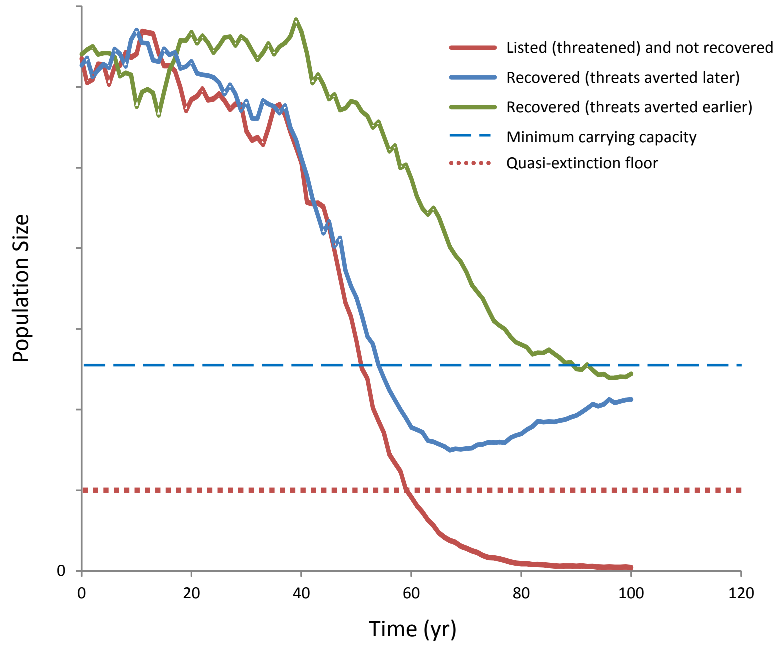

Figure 7. Achieving ESA recovery criteria requires keeping the population level high enough that there is a low chance of ever crossing below the quasi-extinction floor. Three hypothetical scenarios show population response to a substantial loss of habitat. Recovery occurs when the threats are adequately ameliorated and available information indicates with a high degree of confidence that the population will not drop below the quasi-extinction floor. This requires resilience in the population (high potential growth rate) as well as a buffer (carrying capacity far enough above the floor), but does not require the population to return to historical levels. The green and blue lines depict hypothetical species trajectories where adequate management of threats occurs, stopping the decline and resulting in stability, either without (green) or with (blue) the need for some restoration, whereas the red line depicts a situation where threats are not ameliorated and the species' status deteriorates until extinction occurs.

(green line, Fig. 7). Although we would, of course, prefer never to see a decline in polar bear numbers, if we can turn the red line in Figure 7 (the current status, with projected declines) into the green line, we will have achieved a huge conservation success, and polar bears would no longer need the protection of the ESA.

The ESA criteria in this Plan add up to recovery. Achievement of the demographic criteria would indicate that the populations in each ecoregion were resilient, and would remain so for a long period of time. The carrying capacity criterion, coupled with considerations of distribution and connectivity, would ensure enough redundancy within each ecoregion to buffer against the effects of environmental variability and catastrophic events. The achievement of these criteria in all four recovery units would confer representation, ensuring that the genetic, behavioral, life-history, and ecological diversity of polar bears is conserved. Achievement of the threats-based criteria would indicate that the threats that led to listing had been addressed. Finally, achievement of the fundamental criteria indicates that the likelihood of becoming endangered had been reduced to the point that polar bears no longer needed the protections of the ESA. While it may seem counterintuitive that all of this might be achieved while still losing a substantial portion of the present population, this is a consequence of having been able to list polar bears early enough to address a long-term threat. Reflection on past successful recovery efforts shows that rather than a return to historical levels, the ESA strives to reduce threats to the point that the species is not in danger of extinction, nor likely to become so in the foreseeable future, throughout all or a significant portion of its range. For many species, recovery can be achieved at less than historical population levels.

The compatibility of harvest with conservation and recovery

It is not unusual to authorize incidental take of a species protected under either the MMPA or the ESA, and the standards for such authorization are well described and well implemented. It is, however, much less common to purposefully seek to harvest species that need the protections of the ESA or the MMPA, but it does occur in a small number of special cases. Subsistence harvest of polar bears for a variety of cultural and nutritional purposes

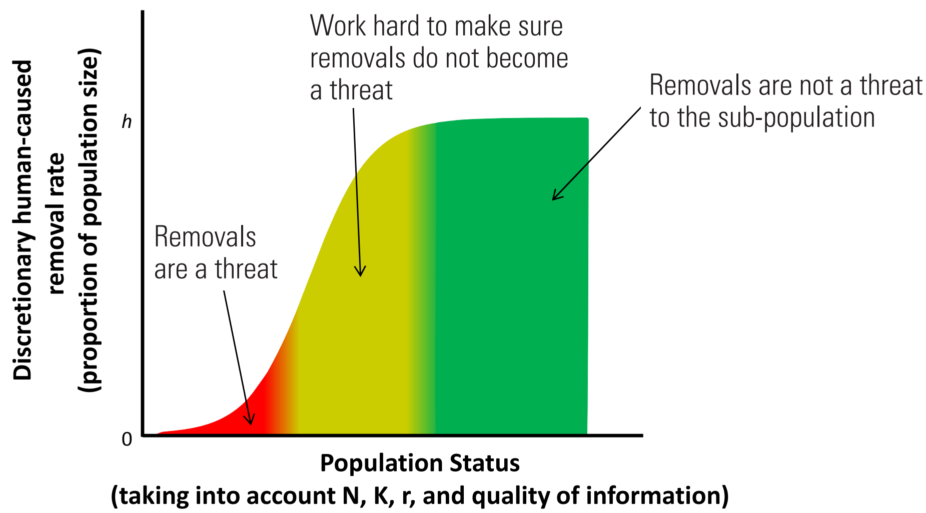

Figure 8. Three-level framework for management of polar bear take. In the green zone, the maximum number of annual removals is proportional to the population size, with the proportion (the rate) sensitive to any changes in the intrinsic rate of growth of the population. In the yellow zone, additional efforts are warranted, including consideration of increased monitoring effort, reduction of defense-of-life or other removals, and reduction in subsistence harvest. In the red zone, emergency measures to reduce or minimize all human-caused removals are recommended. In all three zones, the colored region represents the range of removal rates that meet the conservation guidelines of this Plan; the local choice of where to fall within those bounds can take into account the specific context of the subpopulation.

is a central tradition for Alaska Native people, as well as other native Arctic peoples. The ESA and MMPA both recognize the importance of subsistence harvest for Alaska Native people. In fact, both laws allow certain subsistence harvest by Alaska Native people even when a species is “threatened” or “depleted.” In this Plan, we recognize continued subsistence harvest as a fundamental goal associated with polar bear conservation and recovery. We also provide conditions for harvest to ensure: under the ESA, that harvest does not appreciably reduce the likelihood of survival or recovery; and under the MMPA, that harvest does not affect our ability to achieve the conservation goals of the Act.

The guidelines for harvest management described in Section IV.b of this Plan outline a three-level framework for implementation at the subpopulation level (Fig. 8). The central idea of this framework is that harvest opportunity can be maintained if its management is sensitive to any changes in population size, intrinsic growth rate, or carrying capacity. The three zones arise out of an effort to balance the Fundamental Goals of this Plan. In the green zone, the opportunity for subsistence harvest (Fundamental Goal 4) dominates the management of take, because the conservation goals (Fundamental Goals 1–3) are not facing near-term risk. In the red zone, the conservation goals (Fundamental Goals 1–3) dominate the management of take because threats to the species have become severe, and thus, harvest opportunity needs to be curtailed. In the yellow zone, we seek a balance of the two sets of goals, with continuation of some degree of harvest opportunity while watching the conservation status carefully.

The concepts underlying this framework for management of human-caused removals are founded in harvest theory (Wade 1998, Runge et al. 2009) and a careful consideration of polar bear population dynamics. Appendix C provides the scientific basis for managing harvest opportunity in a manner compatible with the conservation and recovery of a species that is expected to decline in the near- and mid-term.

F. Uncertainty, Assumptions, and the Need for Adaptive Feedback and Management

The links between the tiers of criteria in this framework are based on our current understanding of polar bear demography and threats, which is incomplete. Thus, in deriving demographic criteria, assumptions and uncertainty about the demographic processes (such as regarding Allee effects), the means and variances of the survival and reproductive rates, the mechanism and magnitude of density-dependence, and the role of density-independent drivers of change give rise to uncertainty about the demographic criteria. Likewise, the derivation of threats-based criteria is affected by various types of uncertainty, such as: uncertainty regarding the nature, mechanism, and magnitude of the various threats; uncertainty about the behavioral responses of polar bears to changing conditions in the marine ecosystem, such as prey base, denning conditions, and other effects of climate change; uncertainty in the trajectory of sea ice as driven by climate change; and uncertainty in climate forecasts themselves. We recognize there are other gaps in knowledge that add to scientific uncertainty. Even if there is strong policy certainty about the fundamental criteria, the demographic and threats-based criteria might be less certain, because of the scientific uncertainty inherent in their derivation. We also acknowledge policy uncertainty in the establishment of the fundamental criteria themselves.

The standards established in this Plan, however, meet the statutory requirements of the MMPA and ESA and will result in conservation and recovery, even in the face of the uncertainties described above. To achieve the statutory requirements in the face of uncertainty, we needed to err on the side of conservation and recovery of polar bears, possibly at the cost of other fundamental goals. If and when uncertainties are resolved, it is more likely than not that the conservation and recovery criteria can become less demanding, allowing even better achievement of the other goals.

For these reasons, this Plan should be viewed as dynamic, not static, and the criteria should be revised over time as new data are acquired and critical scientific and policy uncertainties are reduced or resolved. The fundamental criteria could be revised if policy insights arise. Depending on the nature of any changes that may be made in the fundamental criteria, the demographic criteria may change. Further, even if the fundamental criteria do not change, the demographic criteria may be fine-tuned as new scientific information increases our understanding of polar bear population dynamics. The threats-based criteria will likely be subject to revision as new data help us understand the nature of the current and emerging threats and the responses of polar bear populations to them. Any changes to the demographic and threats-based criteria will remain founded in the fundamental criteria.

It is the intent of this Plan to use an adaptive management approach to revise and update the fundamental goals, conservation criteria, and recovery criteria, as well as various assumptions underlying our analyses, as new scientific and policy information becomes available that demonstrates such revisions are appropriate. By using such an adaptive feedback approach, we will be able to identify triggers for such revisions to conservation and recovery criteria and, therefore, maintain transparency and support for any modifications.

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IV. CONSERVATION MANAGEMENT STRATEGY

A. Collaborative Implementation

Implementation of the Conservation Management Plan will rely on the participation of Alaska Native, Local, State, Federal, Range States, and private partners with a vested interest in polar bears in the Alaskan Arctic. This strategy primarily focuses on the actions within the purview of the partners who developed this Plan; however, in the long term the recovery and conservation of polar bears will depend on actions taken by a much larger group of nations, agencies, companies, entities, and individuals to address the primary threat, as well as potential future threats. With the exception of management of atmospheric greenhouse gases, which requires global engagement, this Plan addresses the actions that can be taken under the jurisdiction of partners in the Alaskan Arctic with an interest in polar bears. Thus, in the text to follow, "we" refers to those agencies and entities who will be primarily involved in its implementation. This Plan focuses mostly on actions needed to conserve and recover the polar bear subpopulations linked to the United States. It was generally not practicable to develop conservation and recovery actions for the subpopulations outside of the United States. Given the autonomy and unique statutory and cultural considerations of individual Range States, developing actions beyond what is included in this Plan would not promote the conservation and survival of the species. However, this Plan will be part of the Circumpolar Action Plan for polar bears that was developed by the five Range States with the goal of achieving polar bear conservation rangewide. In addition, there are actions outside the context of this Plan that the United States government may undertake bilaterally or multilaterally to advance polar bear conservation internationally.

A Recovery Implementation Team will be created to coordinate implementation, monitoring, and research activities to maximize efficiency and effectiveness with available resources. The Implementation Team will evaluate progress toward the criteria identified in Section III of this Plan and will make recommendations regarding appropriate adaptive management. It will serve as a venue for the exchange of data, ideas, and information among agencies, Native communities, entities, and interested parties. In turn, it will make summaries available to the public.

The Implementation Team will be composed of representatives from Alaska Native, State, Federal, International, and private agencies and entities with a vested interest in and authority to manage for polar bear conservation. The majority of the focus of the Implementation Team will be on the Polar Basin Divergent Ecoregion, specifically the two United States subpopulations. Recognizing that recovery of polar bears requires effort in each ecoregion, however, the USFWS will remain active in implementing the *1973 Agreement on the Conservation of Polar Bears* and the 2000 *Agreement with the Government of the Russian Federation on the Conservation and Management of the Alaska-Chukotka Polar Bear Population*. Similarly, the USFWS will remain an advisor to the *Inuvialuit-Inupiat Polar Bear Management Agreement* for management of polar bears in the Southern Beaufort Sea subpopulation and will welcome opportunities to engage with Canada under the 2008 *Memorandum of Understanding for the Conservation and Management of Shared Polar Bear Populations*.

The Implementation Team will consist of an Executive Committee that will provide overall guidance on Plan implementation and be broadly responsible for leading the Team by sharing and promoting the exchange of data and information on: Alaska polar bear populations and their habitat; threats; and ongoing management, monitoring, and research activities. The Executive Committee will produce reports at least every two years highlighting ongoing activities and tracking progress toward the fundamental, demographic, and threats-based criteria. The Executive Committee is not a decision-making body, although it may provide recommendations to member agencies and entities on topics such as priorities, funding, and cooperative projects. The Executive Committee does not supersede the authority of the USFWS or other member agencies.

The Executive Committee will establish Working Groups as needed to address key issues and focus areas (Fig. 9). Initially, Working Groups will be created to address the following: (1) Science—including both monitoring and research; (2) Human-Polar Bear Interactions; and (3) Communications. The goal is to have the Science Working Group focused on the specific monitoring actions to track the fundamental, demographic, and threats-based criteria contained in this Plan. The Science Group will also serve as a forum for exchange of information on ongoing and planned research activities and also to identify priority areas for research initiatives into the future. When considering research opportunities, the Science Working Group will focus on applied research, with a strong emphasis on knowledge that will help to achieve the fundamental goals in this Plan. Both the monitoring and research aspects of the Science Work Group should appropriately integrate empirical knowledge and Traditional

Ecological Knowledge (Voorhees et al. 2014) and should support the use of new technologies and less-invasive methods.

The Working Groups and the Executive Committee are not entities charged with action. They are focused on coordinating and making recommendations. It is ultimately up to the individual agencies, entities, and organizations themselves to take actions consistent with their mandates, priorities, and available resources. For example, a Communication Working Group may identify a need for information to be provided to local communities on deterrence methods for polar bears. Once this need was identified, the responsible agencies or entities would inform the Executive Committee whether this was an action they could implement.

The Communication Working Group will be asked to work with the Executive Committee to establish a website to facilitate information exchange within the Executive Committee as well as with the general public. In the first five years of its existence, the Polar Bear Conservation Management Plan Implementation Team will meet at least twice a year. The intention is that one meeting will be an annual assessment focused on documenting activities conducted and new information made available over the prior calendar year and looking forward to planned activities for the upcoming calendar year. The information on actions and progress in the United States can then be provided as input to monitor the Circumpolar Action Plan. A check-in meeting will be held at approximately the six month point to assess whether activities have proceeded as planned and to make adjustments, as necessary and appropriate. The meetings may occur in person or by teleconference, as needed. After the first five years, the Implementation Team should reconsider the schedule on which it meets. Terms of reference, appointment letters, and roles and responsibilities for the Executive Committee and associated Working Groups will be developed so that they can be issued along with the final Conservation Management Plan. The structure and functions outlined here may be adjusted as implementation proceeds; changes will be made to accommodate unanticipated challenges and needs.

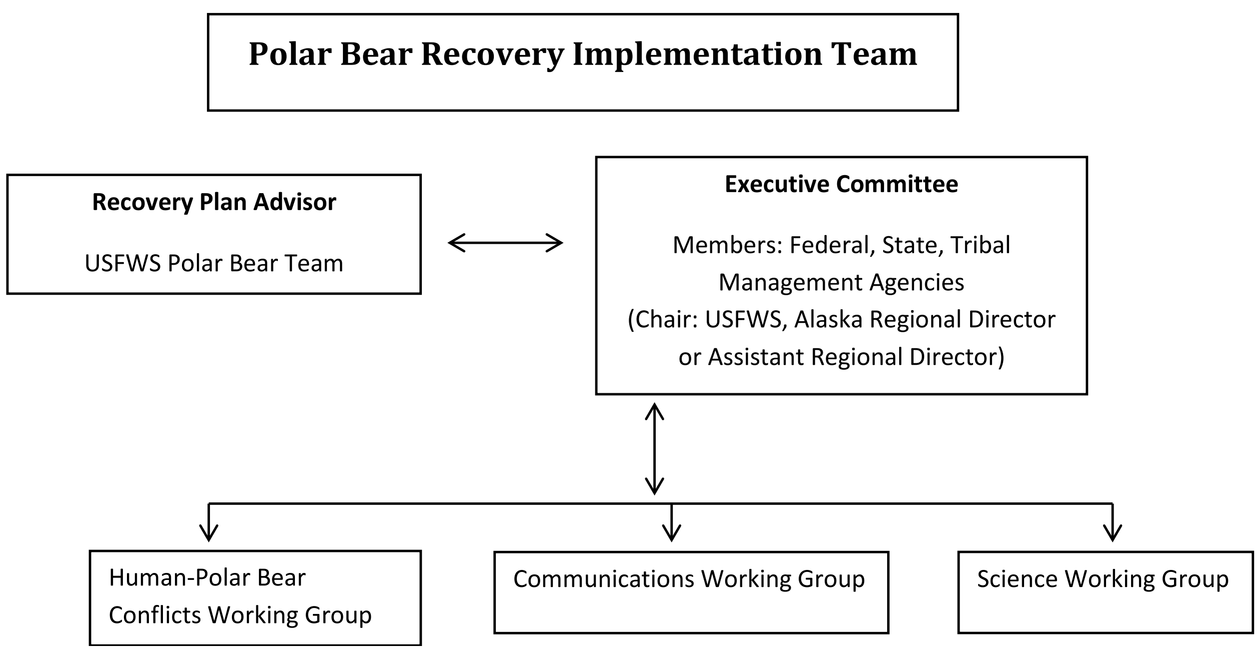

Figure 9. Structure of the Polar Bear Recovery Implementation Team.

B. Conservation and Recovery Actions

The following high-priority actions (each explained in detail below) are necessary to achieve the fundamental goals of this Plan:

- Limit global atmospheric levels of greenhouse gases to levels appropriate for supporting polar bear recovery and conservation, primarily by reducing greenhouse gas emissions
- Support international conservation efforts through the Range States relationships
- Manage human-bear conflicts
- Collaboratively manage subsistence harvest
- Protect denning habitat
- Minimize risks of contamination from spills
- Conduct strategic monitoring and research

Aside from actions to promote swift and substantial reductions in greenhouse gas emissions at the global and other large scales, the actions above are primarily, but not exclusively, focused on the United States portion of the Polar Basin Divergent Ecoregion with a management focus on the two subpopulations shared by the United States. Many of the actions emphasize the importance of local engagement and implementation and are already underway. The role of this Plan and the Implementation Team is to continue and expand those actions, using adaptive management to make them more effective where possible.

Time and cost. The cost estimates in this document are the projected annual costs, including salaries, for 2017–2022 as required to meet the proposed conservation needs for the United States portion of the Polar Basin Divergent Ecoregion during this initial five-year period. We anticipate that continuation of all of the high priority recovery actions will be necessary until sea-ice loss is no longer driving the population towards extinction or until our adaptive management efforts lead us to identify new priorities. Therefore, estimated costs to full recovery are shown by projecting forward in five-year increments each of the costs included, with appropriate adjustments for inflation, until either of those conditions occurs. These cost estimates are significantly higher than current funding for polar bear management and research in the United States as some needs are currently not adequately addressed. All cost estimates are approximate and subject to revision. The actions described here will be undertaken if and when funding is available.

Contingent on funding, these actions, if not already underway, will be initiated in the next five years and should continue until the effects of climate change no longer pose a threat to polar bear conservation, and recovery criteria have been met.

Management Actions that were considered but not identified as high priority recovery actions are included in Appendix B.

Limit global atmospheric levels of greenhouse gases to levels appropriate for supporting polar bear recovery and conservation, primarily by reducing greenhouse gas emissions

As previously stressed, *the single most important action for conservation and recovery of polar bears* is a prompt and aggressive global reduction in the emission of greenhouse gases contributing to Arctic warming (Amstrup et al. 2010). More action is needed in the United States and elsewhere to move from the current baseline trajectory to an aggressive effort to curtail emissions globally. Recently, steps have been taken towards achieving this goal. In December 2015, world leaders secured a global agreement to combat climate change, but additional commitments are still needed to keep global warming below 2 degrees C. In the U.S., domestic efforts are underway to inspire that change by informing key audiences about the likely impacts of changes in global climate (see for example, U.S. Department of State, 2015, initial GHG reduction pledge http://www4.unfccc.int/submissions/INDC/Published%20Documents/United%20States%20of%20America/1/U.S.%20Cover%20Note%20INDC%20and%20Accompanying%20Information.pdf; U.S. Global Climate Change Research Project http://www.globalchange.gov; and Environmental Protection Agency http://www.epa.gov/climatechange).

One specific contribution to this effort will be research to better understand linkages between atmospheric concentrations of GHG, sea ice, and polar bear resource selection and demographics. A second contribution will be to develop and deliver 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. The strategy will also communicate the effects of climate change on coastal Arctic peoples who derive cultural and nutritional benefit from polar bears. The ultimate goal of our communication effort is to prompt the needed actions to maintain and, as needed, restore, sea-ice habitat by implementing sufficient regulatory, market-driven, and voluntary actions at global and national scales to address the anthropogenic causes of Arctic warming and abate the threat to polar bears posed by sea-ice loss.

Conservation and recovery actions
Appropriate entities, both in the U.S. and internationally, will implement regulatory, market-driven, and voluntary actions to address the anthropogenic causes of Arctic warming and abate the threat to polar bears posed by sea-ice loss by keeping global warming below 2 degrees C. (Cost undeterminable)
(i). USFWS and partners will develop and deliver an effective communications strategy to inform United States and global audiences of the urgent need to reduce greenhouse gas emissions and the benefits to polar bears and to coastal Arctic peoples of doing so. ($685,000)
(ii). USFWS and partners will continue their efforts to reduce their own GHG emissions consistent with Executive Orders and other organizational directives. ($7,000,000)
Total cost: minimum of approximately $7,685,000 per year

Support international conservation efforts through the Range States relationships

Work closely with other Range States to implement conservation actions outlined in Circumpolar Action Plan for the global population. Polar bear range reaches five Arctic nations. These Range States have long recognized the need to coordinate polar bear conservation efforts (*1973 Agreement on the Conservation of Polar Bears*). In their capacity as parties to that Agreement, the Range States adopted a Circumpolar Action Plan in 2015. The purpose of the Circumpolar Plan is to broadly address range-wide conservation challenges such as the threat to polar bears posed by global greenhouse gas emissions, and potential threats like human-bear conflicts and illegal trade, which must be effectively managed for the species to survive until climate change is addressed. As a Range State, we anticipate contributing to the implementation of international priorities that coincide with our own priorities and are in alignment with our statutory responsibilities. We also plan to share strategies and best management practices with our Range State partners. In turn, advances in knowledge and management practice made by Range State partners will actively inform implementation of this Plan in the United States. The Recovery Team recognizes that there may be benefit in supplementing this Plan and the Circumpolar Action Plan with additional national or international actions for the benefit of Arctic ecosystems and polar bears.

Pursue targeted conservation efforts with Canada and Russia by sharing resources and expertise. Along with implementation of measures in the Circumpolar Action Plan focused on polar bear conservation range-wide, we anticipate undertaking specific conservation efforts with Russia and Canada, international neighbors with whom we share management of the Chukchi Sea and Southern Beaufort Sea polar bear subpopulations, respectively. Specifically, we will work with Russia to better monitor and manage human-caused removals in that country. Based on recent information, polar bear take in Russia may be declining (Kochnev 2014) but in past accounts, mortality was thought to be large (Aars et al. 2006). We will also work with Russia to protect denning habitat in Chukotka and on Wrangel Island, where almost all denning for the Chukchi Sea population occurs (Garner et al. 1990). Likewise, in addition to working with Canada on issues related to the Southern Beaufort Sea subpopulation, we will provide support to Canada's efforts to manage polar bears in the Canadian Archipelago, which we anticipate will provide key terrestrial polar bear refugia as sea ice declines (Derocher et al. 2004; Amstrup et al. 2008, 2010; Peacock et al. 2015).

Conservation and recovery actions
1. 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.
2. Work with Russia to (a) protect denning habitat in Chukotka and Wrangel Island through development of den detection models and avoidance strategies; and (b) better monitor human-caused removal of polar bears in Russia and jointly improve efforts to minimize human-bear conflicts.
3. Provide support for polar bear management efforts in the Canadian Archipelago.
Total cost: approximately $729,000 per year

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Manage human-polar bear conflicts

With reduced ice extent, increasing numbers of polar bears with poorer body condition than observed historically are making their way to shore earlier in the spring and staying later in the fall (Obbard et al. 2006). Once on land, polar bears are unable to reach their preferred food, ice seals, so they primarily fast (Ramsay and Hobson 1991) or scavenge (Miller et al. 2004). Simultaneously, reductions in summer sea ice will allow expanded development opportunities and growing human activity in polar bear habitat (Vongraven et al. 2012). These factors increase the likelihood of human-bear conflicts with negative consequences for both humans and bears.

Minimizing lethal take of polar bears from human-bear conflicts, including take from industrial, research, or other activities, contributes to polar bear conservation over the long term (Fundamental Goal 3) and in the near term, protects opportunities for continued subsistence harvest (Fundamental Goal 4). From a demographic perspective, wildlife populations are affected by the total level of direct human-caused removals. For polar bears, there are several types of removals that have different causes and different value to humans. Consistent with provisions in the ESA and MMPA, this Plan recognizes the importance of providing opportunities for subsistence harvest as an inherently important component. Lethal take of polar bears incidental to human-bear conflicts, industrial operations, or research activities should be minimized because they have negative implications for the conservation of subpopulations in the United States including potentially reducing opportunities for subsistence harvest.

Provisions to minimize these other sources of take will continue to be implemented within the existing regulatory frameworks (e.g., the USFWS Incidental Take Program under the MMPA, for industrial activities) or review processes (e.g., the USGS, USFWS, and ADF&G Institutional Animal Care and Use Committees, for research activities). Examples of these ongoing efforts include partnerships with the oil and gas industry over the past 30 years of operations on the North Slope, and polar bear patrols led by the North Slope Borough. To build on these efforts, we will develop an overarching strategy and best management practices to prevent, monitor, and manage human-polar bear conflicts in the United States. Those practices will include rapid response plans for situations where a large number of hungry bears are stranded on shore.

We will work with local communities and with industry to develop human-polar bear interaction and safety plans that include attractant management (to minimize bears being attracted to human communities for food), bear awareness training, safety procedures for bear encounters, proper bear hazing techniques, and reporting requirements. And we will work with communities to implement the components of those plans such as best practices for garbage management at households and community landfills, bear-proof food-storage options, and location of whale bone piles to reduce food attractants that draw polar bears into human communities.

We will continue to support local capacity for polar bear patrols and other management efforts directed towards residents and visitors. Specifically, we will expand the scope and improve the effectiveness of community polar bear patrols through consistent funding, standardized methods, and better reporting of data on interactions through our work with the Range States Conflict Working Group and the Polar Bear Human Interactions Management System (PBHIMS database).

Conservation and recovery actions
1. Develop and communicate a strategy to prevent, monitor, and manage human-polar bear conflicts for the subpopulations in the United States with input from local residents, conservation partners, and invited experts.
2. Develop and communicate response plans for the subpopulations in the United States to address the prospect of increasing numbers of hungry bears on shore with input from local residents, conservation partners, and invited experts.
3. Develop and implement human-polar bear interaction and safety plans for United States communities with polar bears, to include attractant management, bear awareness training, safety procedures for bear encounters, proper hazing techniques, and reporting requirements.
4. Reduce attractants in United States communities with polar bears, through development and distribution of best practices for garbage management and food storage.
5. Improve the scope and effectiveness of United States community polar bear patrols, through increased funding, standardized methods, and better reporting of data on interactions.
Total cost: approximately $1,282,000 per year.

Collaboratively manage subsistence harvest

The co-management of polar bears by Alaska Native and Federal partners is supported under domestic laws and the *1973 Agreement on the Conservation of Polar Bears*, recognizing the importance of co-management for maintaining the ability of Alaska Native people to meet nutritional and cultural needs, mitigating human-polar bear conflicts, monitoring subsistence harvest, and ensuring subsistence harvest rates that are consistent with the management and conservation goals described in Section III of this Plan.

In this Plan, we adopt a framework for identifying limits on total human-caused removals. The goals of this framework include: to ensure that removals do not have a negative effect on population persistence, thus increasing the likelihood that recovery is possible once climate change has been addressed; and to provide long-term opportunities for subsistence use of polar bears by Alaska Natives. A co-management system between Alaska Native, Federal, and other partners provides the foundation for this framework and its success. This includes the ability to monitor take and collect biological samples from harvested polar bears (e.g., through the USFWS Marking, Tagging, and Reporting Program and the North Slope Borough) and the ability to adjust harvest rates towards adherence with the principles in Section III of this Plan (e.g., through the U.S.-Russia Bilateral Agreement and the Inupiat-Inuvialuit Agreement). Because both United States polar bear subpopulations are shared with other countries, continued cooperation with international partners is necessary for responsible management and conservation.

The framework for management of human-caused removals, including subsistence harvest, is founded on three principles. First, human-caused removals are managed at the subpopulation level by the appropriate co-management partners, taking into account factors specific to that subpopulation (e.g., traditional practices, management objectives, and local conditions). Second, annual removal levels are state-dependent with respect to population size (and by extension, carrying capacity) and intrinsic growth rate. Thus, the framework is intended to account for multiple ecological mechanisms through which ecological change (e.g., loss or gain of sea-ice habitat, decrease or increase in prey availability) and other factors could affect polar bears. Third, a three-level system identifies thresholds at which increasing efforts are taken to minimize the effects of human-caused removals (Fig. 8).

Under the three-level system, graduated management and conservation actions are tied to pre-established thresholds. Above the upper threshold, the subpopulation shows a resilient intrinsic rate of growth and the carrying capacity provides a large buffer against the risk of extirpation (Fig. 8, green zone). In this first zone, ESA and MMPA criteria regarding take are met, and total human-caused removals are managed using a state-dependent strategy. It may be possible to meet conservation goals for subpopulations in this zone with a relatively low investment in monitoring, for example, with longer intervals between monitoring efforts.

A subpopulation would fall into the second zone (i.e., between the upper and lower thresholds) if the carrying capacity, population size, or intrinsic growth rate fell below thresholds indicating that one or more conservation criteria were not being met (Fig. 8, yellow zone). In this zone, additional actions are warranted, and the best combination of actions will depend on local considerations and the causes of decline. Potential actions include: greater investment in monitoring of human-caused removals, population size, carrying capacity, or intrinsic growth rate; decreased interval between monitoring efforts; increased efforts to reduce conflicts that require defense-of-life and other removals besides subsistence harvest; and reduction in the rate of total removals, including subsistence harvest. Thus, should a U.S. polar bear subpopulation drop below either of the MMPA demographic criteria (*mnpl* or minimum carrying capacity), additional restrictions on all human-caused removals, including harvest, may be warranted. It should also be considered that natural feedback mechanisms may decrease removal rates for a subpopulation in this zone, such as decreased interactions between humans and polar bears, decreased access to traditional subsistence hunting areas, and voluntary changes in the behavior of individual hunters or villages.

A subpopulation would fall into the third zone (i.e., below the lower threshold) if the carrying capacity, population size, intrinsic growth rate, or other measures indicated that the risk of extirpation was heightened (Fig. 8, red zone). In this zone, emergency measures should be considered to reduce or minimize all human-caused removals, with a goal of affording the subpopulation an increased probability of persistence. Preliminary analyses suggest that a subpopulation size below 350 animals may warrant concern in this regard (Science and TEK Work Group, unpublished data), although multiple interacting factors can affect when a declining subpopulation enters this third zone. Furthermore, historically smaller subpopulations (e.g., those with smaller geographic ranges) may meet the MMPA demographic criteria, and thus remain in the first zone for management purposes, at population sizes below this threshold. Thus, this threshold should only serve as preliminary guidance and should be further evaluated on a subpopulation-specific basis. If a subpopulation is managed according to this framework for human-caused removals, we believe that removals will not be a threat to persistence. Thus, a subpopulation should fall into the third zone if the primary threat has not been adequately addressed; reduction of human-caused removals at this point can only serve to provide a small amount of additional time to address the primary threat.

Consistent, thorough, and coordinated monitoring is needed to support this framework for managing human-caused removals. The better the monitoring, the less risk-averse the local authorities need to be in setting annual limits for removals; that is, good monitoring supports all of the Fundamental Goals. Of particular importance is the reporting of polar bear mortality itself, including reporting of subsistence harvest, natural mortality, defense-of-life-and-property removals, and industrial take. Documentation of these mortalities, and where possible, collection of samples for demographic and health assessment, provides valuable information for evaluating achievement of the criteria in this plan, as well as for identifying priority actions. Such monitoring is best undertaken using local personnel, skills, and resources. The development of appropriate protocols for reporting take may need to take into account the local context. Local communities may need resources from external partners to support this reporting effort.

The details of the three-level system will, and should be, specific to each subpopulation. The particular criteria and thresholds that indicate transitions between zones, and the actions to be undertaken in each zone, will need to be developed. This Plan offers guidance, in the form of the framework described above, and the Implementation Team can offer technical support. It is the vision of this Plan that the specifics of management of subsistence harvest and other human-caused removals be developed at the subpopulation level by the participating co-management partners.

Conservation and recovery actions
1. Collaborate with co-management partners 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.
2. Develop detailed guidance, with proposed analytical methods, for designing a take-management framework at the subpopulation level.
3. Maintain, improve, and support reporting protocols for all forms of human-caused mortality and for harvest biomonitoring efforts, both within the United States and with international partners.
4. Improve communications with Alaska Native organizations and communities to ensure that hunters and residents of rural Alaska are more meaningful partners in polar bear co-management activities.
Total cost: approximately $1,242,000 per year.

Protect denning habitat

The availability of and access to terrestrial denning habitat is an important component of polar bear reproduction. Collaborative processes are currently in place to minimize effects on denning bears (e.g., the Incidental Take Program under the MMPA, for industrial activities). Going forward, we will continue those efforts with industry and others, and will work to improve our ability to detect dens and identify desirable denning habitat.

As sea ice declines and the availability of stable sea ice suitable for denning decreases, terrestrial denning habitat will become even more important (Fischbach et al. 2007). We will work with partners to minimize development and disturbance on barrier islands, which provide or could provide crucial habitat for denning, migrating, and resting and we will work collectively to minimize and mitigate impacts when development occurs there.

Conservation and recovery actions
1. Continue den detection, mapping, behavioral, and habitat work in polar bear habitat in the United States.
2. Minimize development and disturbance on barrier islands (where denning habitat is most limited). Where development occurs in polar bear habitat within the United States, work collaboratively to mitigate loss of denning habitat.
Total cost: approximately $197,000 per year.

Minimize risk of contamination from spills

Ship traffic and offshore oil and gas activities have increased due to summer sea ice declines (Gautier et al. 2009, Smith and Stephenson 2013), increasing the risk to polar bears and their prey of exposure to oil spills. Spills have the potential to harm polar bears in numerous ways, including through impaired thermoregulation (Hurst and Øritsland 1982, Hurst et al. 1991), ingestion (Derocher and Stirling 1991, Øritsland et al. 1981, St. Aubin 1990), and consumption of contaminated prey (Stirling 1990). Depending on the size, location and timing, a spill could affect a large number of animals (Amstrup et al. 2006).

Current regulatory processes (e.g., NEPA analyses, ESA section 7 consultations, MMPA incidental take regulations) and industry-led plans and practices have contributed to the absence of any major mishaps affecting polar bears in 30 years of oil and gas operations on the North Slope. Continued vigilance is imperative, particularly with the opening of new shipping lanes, the prospect of offshore oil exploration and development, and the increased risk of contaminant release from community tank farms and landfills along the coast. We will 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.

Conservation and recovery actions
1. Update existing oil spill modeling and scenarios; anticipate potential overlap with seasonal polar bear movements, aggregations, and important habitats within the United States.
2. Review and comment on proposed projects and activities in polar bear habitat within the United States (e.g., oil and gas exploration, new shipping routes and regulations, and community tank farms) to mitigate potential adverse outcomes.
3. Develop and distribute standard operating procedures and mitigation plans for deterrence, rescue, and handling of oiled polar bears.
Total cost: approximately $501,000 per year.

Conduct strategic monitoring and research

This section focuses on strategic monitoring to evaluate the effectiveness of this Plan. Areas of research are identified and more details are provided in Appendix B. The monitoring actions identified at this time are those possible with available knowledge and tools, for example animal tracking using collars or tags. Investment in additional research is essential to improve our knowledge and identify additional more effective and efficient (and less invasive) methods for monitoring population status and the effectiveness of our actions. This work requires active engagement of current and new partners in research activities including Universities, other Federal, State, and local agencies, along with industry and non-governmental entities.

The fundamental goals, demographic criteria, and threats-based criteria described above clearly state the needs for conservation and recovery, and represent the best interpretation of available policy guidance and scientific evidence. To address the remaining uncertainties in the policy interpretations and scientific evidence, an adaptive management plan for updating and revising the conservation and recovery criteria should be designed early in the recovery implementation process. Some of the components of such a plan are described in detail below; others are identified elsewhere in the document. One of the first tasks of the Implementation Team will be to prioritize these information needs.

Conservation and recovery actions
1. Develop an adaptive management plan for updating and revising the conservation and recovery criteria.
2. Develop specific analytical methods for evaluating the ESA and MMPA Demographic Criteria.
Total cost: (included in operational costs of Implementation Team).

1. Strategic monitoring to determine if Plan goals are being met

As stated previously, the ultimate measure of success of this Plan will be evaluated with the fundamental criteria and performance metrics (Table 1). As a practical matter, the specified demographic and threats-based criteria are intended to guide conservation planning and status assessments. These criteria are more easily measured proxies for our fundamental goals, and can be used to track progress toward those goals. In addition to monitoring these criteria, which describe the condition of polar bears and their environment, it is also important to track implementation of the management activities identified in the previous conservation and recovery action section of this Plan. Furthermore, it is important to evaluate whether the management activities had the intended effect. Monitoring must focus both on implementation (the extent to which the plan is followed and recovery actions are taken) and effectiveness (to what extent recovery actions are successful and progress is made). Collectively, monitoring the demographic and threats-based criteria, tracking implementation of management activities, evaluating the effect of management activities, and continuing to refine the demographic and threats-based criteria as new information is obtained, provide the adaptive management framework necessary to meet the goals of this Plan.

This section outlines methods to monitor demographic and threats-based criteria. The ultimate goals of monitoring are to understand the state of the system, continue to learn about its dynamics, detect changes including those due to management activities, and use this information to trigger new or additional management actions as necessary to meet the goals of the Plan. Recovery is an iterative process. Through careful monitoring, the data generated and lessons learned through implementing individual recovery actions feed back into refining the recovery plan and strategy.

One of the key questions regarding monitoring is the appropriate scale. The ESA demographic and threats-based criteria apply to each recovery unit and the MMPA demographic criteria apply to each subpopulation. Because of the logistical challenges associated with monitoring outside the United States, the focus of the monitoring actions in this Plan is on the two subpopulations of polar bears resident in the United States within the Polar Basin Divergent Ecoregion. The fundamental goals will ultimately be evaluated at the species level, which will require international coordination.

This section provides the metrics that will be used to monitor the Conservation Management Plan. It is likely that the Implementation Team may identify the need for a more detailed monitoring plan that will specify the power of different monitoring approaches, including use of Traditional Ecological Knowledge, to detect change, what kinds of changes are important (increases or decreases), and over what time period. Traditional Ecological Knowledge, for example, could be used to describe changes that may be occurring prior to being detected by science, and to provide insight to aspects of the ecosystem possibly overlooked by science. Once appropriate objectives are specified, scientists can then design monitoring that will meet the stated needs. The Implementation Team may also identify different or additional metrics to track progress toward the fundamental goals.

a. MMPA demographic criteria

Health and stability of the marine ecosystem. The intrinsic growth rate of each subpopulation is above, and is expected to remain above, a minimum level that indicates the health of the marine ecosystem is not impaired; and the carrying capacity in each subpopulation is above, and is expected to remain above, 70% of mean historical carrying capacity, indicating that the stability of the marine ecosystem is not impaired.

Maximum net productivity level. Total human-caused removals in each subpopulation do not exceed a rate *h* (relative to the subpopulation size) that maintains the subpopulation above its maximum net productivity level relative to carrying capacity.

Significant functioning element in the ecosystem. As stated previously, at this time we do not have enough information to propose measures to directly assess the functional role of polar bears in their ecosystem. Instead, we offer some potential approaches that could serve as proxies by focusing on particular roles that polar bears play. Further thought should be given to these approaches during implementation of this Plan and adjustments to monitoring should be made as appropriate.

- Energy flow among trophic levels linked to polar bears
- Behavior of prey species
- Distribution and demographics of prey species
- Persistence and distribution of scavengers that rely on polar bear kills (e.g., foxes)
- Availability of polar bears for subsistence harvest
- Polar bear behavioral diversity necessary to maintain resilience to environmental stressors
- Polar bear densities (e.g., bears per km^2) on sea ice or land habitats at certain times of year
- Carrying capacity and intrinsic growth rate at the subpopulation and ecoregion level, as estimated through hierarchical modeling of demographic and habitat data
- Habitat measures (like ice-free months) that could serve as a proxy for health and stability of the ecosystem

Monitoring Activity	Data Obtained / Output
Monitor the number of subsistence hunting removals in the SB subpopulation	**Number of direct, lethal removals in the SB subpopulation**
Monitor the number of defense-of-life removals in the SB subpopulation from villages, industry, and any other causes	
Monitor the number of subsistence hunting removals in the CS subpopulation	**Number of direct, lethal removals in the CS subpopulation**
Monitor the number of defense-of-life removals in the CS subpopulation from villages, industry, and any other causes	
Total cost: $154,000 per year	

b. ESA demographic criteria

1. The mean adult female survival rate (at a density corresponding to *mnpl* 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.
2. The ratio of yearlings to adult females (at a density corresponding to *mnpl*) in each recovery unit is at least 0.1-0.3, both currently and as projected over the next 100 years.
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%.
4. Total direct human-caused removals in each recovery unit do not exceed a rate *h* (relative to the subpopulation size) that maintains the population above its *mnpl* relative to carrying capacity.

Monitoring Activity	Data Obtained / Output
Conduct spring capture-based and genetic sampling work on the sea ice in the southern Beaufort subpopulation	Adult female survival rate Ratio of yearlings: adult females
Conduct spring capture-based and genetic sampling work on the sea ice in the Chukchi Sea subpopulation	Adult female survival rate Ratio of yearlings: adult females
Demographic parameter estimation	Index or estimate of subpopulation size, index or estimate of subpopulation capacity for positive growth (e.g., r_{mnpl}, the per capita growth rate at *mnpl*), relationships between vital rates and environmental conditions
Develop Bayesian hierarchical estimation methods	Estimates of carrying capacity
Develop ecoregion- and subpopulation-specific demographic modeling and population viability assessment, for the ecoregions and subpopulations that partially fall within the United States	Projected values of demographic criteria into the future, probability of population persistence in the future
Total cost: approximately $1,545,000 per year	

c. ESA Threats-based criteria

The 2008 final listing of polar bears as threatened under the ESA summarized the best available scientific and commercial information regarding threats to the polar bear. The conclusion of that analysis was that the polar bear is threatened throughout its range by habitat loss (i.e., sea-ice declines). No known regulatory mechanisms in place at the national or international level were identified that directly and effectively address the primary threat to polar bears—the range-wide loss of sea-ice habitat. While not identified as factors currently threatening polar bears, overutilization, disease and predation, and contaminants were identified as potential future threats as habitat loss occurs, declining population levels are realized, and nutritional stress becomes more prevalent. Given that context, the sea ice threats-based criterion below addresses the factor determined to be currently threatening polar bears whereas the criterion for human-caused removals is intended to monitor and manage that factor to ensure it does not threaten polar bears in the future.

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.

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.[1]

Additional factors of potential future concern: At this point, the potential for disease, shipping, oil and gas development, and oil spills to become threats is relatively distant or low. However, recognizing the rapidly changing Arctic environment and the adaptive nature of this Plan, monitoring these potential avenues of stress is warranted to an extent that recognizes higher priorities described in this section.

[1] The level of human-caused removal is needed to calculate the effect of those removals on persistence, but collecting data on human-caused removals is captured in the previous table of monitoring activity so is not repeated here.

Monitoring Activity	Data Obtained / Output
Update sea ice projections as substantial new research, data, or tools become available	Projected duration of the ice-free period in each recovery unit over the next 100 years
Continue analysis and monitoring to further refine and track the potential effect of human-caused removals on persistence	Probability of persistence with and without human-caused removals
Total cost: $10,000 per year per subpopulation	

d. Other measures of achievement

As stated previously, fundamental Goals 4, 5, and 6 are not derived directly from statute, but instead are expressions of other societal values that could be affected by polar bear management. Performance requirements do not need to be prescribed for these goals (as they do for ESA recovery criteria and MMPA conservation criteria). It will be important, however, to address achievement of these goals, particularly to provide an adaptive feedback loop for improving future conservation actions. If we are successful in managing other threats to polar bears such that populations persist, then we will be better positioned to successfully recognize the nutritional and cultural traditions of Native peoples with connections to polar bears (Fundamental Goal 4). Monitoring the MMPA Demographic Criteria specified above requires collection of data on the number of lethal removals of polar bears, but to put this into context data should be collected on the broader effort to manage human-polar bear interactions and the relative success of various deterrence strategies (Fundamental Goal 5). Finally, there should be a qualitative assessment of our success at achieving polar bear conservation while minimizing restrictions to other activities, including economic development (Fundamental Goal 6).

2. Research needs for United States polar bear subpopulations

The previous section focused on monitoring demographic and threats-based criteria to inform management actions and adjustments. This section focuses on research designed to develop or refine the criteria that serve as proxies for our fundamental goals, improve monitoring of these criteria, and improve our understanding of the relationships (e.g., between sea-ice availability and vital rates) and ecosystem dynamics that cumulatively determine polar bear persistence. We divide research into the following five areas: (1) population dynamics and distribution; (2) habitat ecology; (3) health and nutritional ecology; (4) nutritional and cultural use of polar bears; and (5) human-polar bear interactions. We briefly review these areas of research and a list of representative research projects is attached (Appendix B). Specific priorities and cost estimates for these areas will be developed by the Recovery Implementation Team and Team members. We envision a dynamic and adaptive process through which this Plan is updated to reflect new information, and research planning is updated to reflect the living Conservation Management Plan document. We also envision the active engagement of current and new partners in these activities including Universities, other Federal, State, and local agencies along with industry and non-governmental entities.

Population dynamics and distribution. Research in this area is intended to improve our understanding of the relationship between polar bears and the environment. This research will provide insights into how factors such as sea ice and prey abundance and availability affect polar bear distribution and vital rates. We have learned from research and monitoring on the two polar bear subpopulations shared by the United States that physical and biological differences among populations may affect how polar bears respond to habitat loss associated with climate change, especially in the near term. Long-term studies of subpopulation status (e.g., including vital rates used as demographic criteria) and trends are needed to measure progress towards persistence-based goals. Where possible and appropriate, we will pursue research on population dynamics and distribution of our shared populations with our international partners.

Habitat ecology. Under this research area, we will study the response of polar bear subpopulations to biotic and abiotic changes in the environment, including intermediate effects on primary (seals) and alternate (e.g., stranded marine mammals) prey. This will provide an improved understanding of the mechanistic links between habitat and demographics. Further research is also needed to understand linkages between atmospheric concentrations of GHG, sea ice, and polar bear resource selection and demographics.

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Health and nutritional ecology. This research will attempt to identify causal links between factors that determine health and population-level processes, which are difficult to establish for marine mammals that inhabit Arctic or subarctic ecosystems.

Nutritional and cultural use of polar bears. Historically, native communities throughout the coastal Arctic have relied upon polar bears as both a nutritional and cultural resource. Research, including through Traditional Ecological Knowledge, may help to better understand the cultural and nutritional significance of polar bears to communities that have historically relied upon them, and how climate change may affect the use of polar bears as a renewable resource in the future.

Human-polar bear conflict. There is a need to continuously improve our understanding of human-polar bear interactions including the causes and consequences (both positive and negative outcomes). Understanding the factors that cause an interaction to result in success or a conflict, with consequences to humans, polar bears, or both, will provide essential feedback to evaluate the effectiveness of existing mitigation measures.

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VI. GLOSSARY

Allee effect. A negative population growth rate that occurs at low population density. There are a number of mechanisms that could give rise to this effect; in polar bears, the most likely mechanism is difficulty in finding mates (Molnár et al. 2014).

Conservation. As defined under the MMPA, conservation is "the collection and application of biological information for the purposes of increasing and maintaining the number of animals within species and populations of marine mammals at their optimum sustainable population" (16 USC §1362(2)). In this Plan, we use the term "conservation" to refer to the activities designed to achieve the purposes of the MMPA. Note that the ESA also contains a definition of the term, "the use of all methods and procedures which are necessary to bring any endangered species or threatened species to the point at which the measured provided pursuant to this Act are no longer necessary (16 USC §1532(3)). To avoid confusion, in this Plan, "conservation" is used in reference to the MMPA and "recovery" is used in reference to the ESA.

Demographic stochasticity. Variation in demographic rates due to the random events that happen to individual animals. This type of variation becomes important at small population sizes.

Distinct population segment (DPS). Under the ESA, a "species" includes "any subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature" (16 USC 1532(16)). Under policy guidance issued by USFWS and NMFS (61 FR 4722–4725), three elements should be considered in deciding whether a population qualifies as a DPS: the discreteness of the population in relation to the rest of the species; the significance of the population segment to the species; and the population segment's status in relation to the standards for listing under the ESA.

Ecoregion. Amstrup et al. (2008) defined polar bear ecoregions on the basis of temporal and spatial patterns of sea-ice dynamics, observations of the patterns of polar bear responses to these dynamics, and forecasts of future sea-ice patterns. There are four ecoregions: the Seasonal Ice Ecoregion (SIE), the Archipelago Ecoregion (AE), the Polar Basin Convergent Ecoregion (PBCE), and the Polar Basin Divergent Ecoregion (PBDE). The two subpopulations found in United States territory both fall within the PBDE.

Endangered. Under the ESA, an endangered species is "any species which is in danger of extinction throughout all or a significant portion of its range" (16 USC 1532(6)). This classification represents the highest level of concern for a species under the ESA.

Health of the marine ecosystem. In the MMPA, Congress found that the "primary objective of [marine mammal] management should be to maintain the health and stability of the marine ecosystem" (16 USC 1361(6)). The term "health of the marine ecosystem" is not otherwise defined, although the definition of OSP makes reference to it. In this Plan, we assume that the health of the marine ecosystem is reflected in its ability to support marine mammals, and use the intrinsic growth rate of a polar bear subpopulation as its measure.

Human-caused removal rate. In this Plan, under MMPA Demographic Criterion 2, we define a satisfactory human-caused removal rate as a fixed-rate removal of polar bears, *h*, that maintains a subpopulation above its *mnpl*. Under this definition, continued take is possible even when the carrying capacity and the population size are declining, provided the take is adjusted annually to account for the change in the population size, and the population size at all times is maintained above its *mnpl* relative to carrying capacity. This definition is offered for the broader purposes of this Plan, but does not preclude more protective criteria being used for specific subpopulations (e.g., "sustainable take" under the United States-Russia bilateral agreement for the Chukchi Sea subpopulation).

Inbreeding depression. A negative consequence of small population size. Inbreeding depression can arise through breeding of related individuals, the consequent reduction in genetic diversity, and the expression of deleterious recessive genes.

Intrinsic population growth rate. The rate of growth of a population in the absence of human-caused removals and at a low density relative to the carrying capacity. This growth rate is a measure of resilience—the higher the intrinsic rate of growth, the quicker a population can rebound from a short-term impact.

Maximum net productivity level (*mnpl* and MNPL). The population size that results in "the greatest net annual increment in population numbers or biomass resulting from additions to the population due to reproduction and/or growth less losses due to natural mortality" (50 CFR 403.02).

Optimum sustainable population (OSP). As defined in the MMPA, OSP is "the number of animals which will result in the maximum productivity of the population or the species, keeping in mind the carrying capacity of the habitat and the health of the ecosystem of which they form a constituent element" (16 USC 1362(9)). Congressional reports and agency policies have further clarified that OSP represents a range of population sizes between the maximum net productivity level and the carrying capacity of the ecosystem. One of the primary purposes of the MMPA is to restore and maintain marine mammal populations at OSP.

Population. A group of animals in the same taxon below the subspecific level, in common spatial arrangement that interbreed when mature (50 CFR 17.3). Specific populations have not been identified for polar bears. The smallest groupings recognized by the Polar Bear Specialist Group are referred to as "subpopulations." In this Plan, we avoid using the term "population," except as a generic term to refer to a group of polar bears.

Recovery. Under the ESA, the Secretary (of the Interior or of Commerce) is required to develop recovery plans "for the conservation and survival of endangered species and threatened species listed pursuant to this section" (16 USC 1533(f)(1)). The term "recovery" is not defined in the ESA, but is interpreted to be similar to "conservation" under the ESA (see above), namely, improvement in the status of a listed species to the point at which listing is no longer appropriate under the criteria set out in section 4(a)(1) of the ESA (50 CFR 402.02). We use the term "recovery" to refer to the purposes of this Plan under the ESA (and "conservation" to refer to the purposes of this Plan under the MMPA).

Recovery unit. Under the ESA, "a special unit of the listed entity that is geographically or otherwise identifiable and is essential to the recovery of the entire listed entity, i.e., recovery units are *individually necessary* to conserve genetic robustness, demographic robustness, important life history stages, or some other feature necessary for long-term sustainability of the *entire listed entity*" (NMFS and USFWS 2010). In this Plan, the four polar bear ecoregions are identified as recovery units.

Significant functioning element of the ecosystem. In the MMPA, Congress found that "species and population stocks should not be permitted to diminish beyond the point at which they cease to be a significant functioning element in the ecosystem of which they are a part, and, consistent with this major objective, they should not be permitted to diminish below their optimum sustainable population" (16 USC 1361(2)). The term is not otherwise defined. In this Plan, the maintenance of polar bears as a significant functioning element of the Arctic marine ecosystem is an important conservation goal. As a top predator, polar bears have a significant role in the energy flow in the ecosystem, and in the distribution and behavior of prey species. Potential measures for their function in the ecosystem are proposed in the Plan.

Stability of the marine ecosystem. In the MMPA, Congress found that the "primary objective of [marine mammal] management should be to maintain the health and stability of the marine ecosystem" (16 USC 1361(6)). The term "stability of the marine ecosystem" is not otherwise defined. In this Plan, we assume that the stability of the marine ecosystem is reflected in its ability to support marine mammals, and use the carrying capacity of a polar bear subpopulation as its measure.

Stock. Under the MMPA, a stock is "a group of marine mammals of the same species or smaller taxa in a common spatial arrangement, that interbreed when mature" (16 USC 1362(11)). The Southern Beaufort Sea and Chukchi Sea polar bear subpopulations have been identified as stocks under the MMPA. In this Plan, we assume that all subpopulations could be identified as stocks.

Subpopulation. The Polar Bear Specialist Group has identified 19 relatively discrete "subpopulations" of polar bears (Fig. 1). In this Plan, we reserve this term to refer specifically to those groupings of polar bears.

Take. Under the MMPA, "take" means "to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal" (16 USC 1362(13)). Under the ESA, "take" means "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct" (16 USC 1532(19)). This Plan primarily addresses lethal take of polar bears, and is less specific about non-lethal take. Thus, for the purpose of brevity, unless otherwise noted, "take" refers to all anthropogenic lethal removals of polar bears, but the broader definitions remain the legal standard.

Threatened. Under the ESA, a threatened species is "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range" (16 USC 1532(20)). Polar bears were classified as threatened under the ESA in 2008.

Traditional ecological knowledge (TEK). The cumulative body of knowledge about local natural resources accumulated by indigenous, aboriginal, or local people and often passed down through generations through practice and oral traditions. This Plan recognizes that there is an appropriate role for TEK in science and management of polar bears, just as there is an appropriate role for the empirical methods of Western science; indeed, these sets of knowledge can often enhance each other.

APPENDIX A—BACKGROUND

Brief Overview/Species Status

Polar bears (*Ursus maritimus*) occur in 19 relatively discrete subpopulations (Plan 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 status of each of these subpopulations varies (Polar Bear Specialists Group 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. 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.*)(ESA) 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).

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. 2007b). 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. 2007a). 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. 2010; 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. 2010, Gormezano and Rockwell 2013). However, new studies (Rode et al. 2010b, 2014, 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.

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). Both the 2008 listing and this 5-year review are based on the Polar Bear Specialist Group (PBSG) delineation (Plan 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 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 (Plan 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 annual sea ice that converges towards shoreline allowing bears to access nearshore ice year-round.

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 to 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, May 15, 2008), 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. 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. 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). This 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.

Habitat Characteristics and Needs

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. 2007b).

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 topographic features that catch snow on their 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. 2015). Liston et al. (2015) 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 el 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).

Threats Assessment/Reasons for Listing under the ESA[1]

The primary threat to polar bears is the loss of sea ice habitat due to climate change (USFWS 2008). 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. 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.

[1] Additional details regarding the threats and stressors described herein can be found in the Polar Bear Status 5-Year Review: Summary and Evaluation (USFWS 2017).

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.

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. 2016a).

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).

Below, we discuss the various threats that have been identified, organized by the ESA listing factors (section 4(a)(1)) addressed in the Final Rule. In addition to the factors identified in the listing, additional threats were investigated during development of this Plan.

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

A.1. Loss of access to prey

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 year (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. 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 (Derocher et al. 2004, p. 167; Stirling et al. 1999, pp. 302–303). A recent study (Ware et al. in review) 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). Additionally, 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 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). Polar bears have two options to respond to these changes, 1) remain on the sea ice as it moves over less productive waters, or 2) move to land. In both instances, polar bears are likely to find limited prey items and employ similar energy saving strategies (Whiteman et al. 2015). While observations exist of polar bears eating terrestrial-based foods (e.g., 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. 2015b); with rare exceptions (e.g., 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. 2007b; Rode et al. 2012). This is highlighted by Rode et al. (2014) 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 et al. 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 (Atwood et al. 2016b, Rode et al. 2015b, 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 the changes in sea ice dynamics has 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. 2007a). Similar findings have occurred in other areas. Rode et al. (2010a) suggested that declining sea ice has resulted in reduced body size and reproductive rate 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 (Rode et al. 2007).

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 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, p. 169, Rode et al. 2010b, Smith et al. 2010). Polar bears are not known to regularly hunt musk oxen (*Ovibos moschatus*) or snow geese (Lunn and Stirling 1985, p. 2,295). 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 as the bears' use of land increases, as sea ice extent and duration continues to decline (Kochnev 2002; Rode et al. 2015b).

A.5. Inadequate conditions for successful denning

Climate change could negatively influence 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. 2016) 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. 2015a). Female polar bears can repeatedly return to specific denning areas on land (Harrington 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. 2015a). 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. Overutilization

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 (USFWS 2008). 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).

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 described in “Current Conservation Measures and Management Efforts” towards the end of this Appendix. Reviews of international and national management of human-caused removals of polar bears are available in Schliebe et al. (2006), USFWS (2008), Obbard et al. (2010), Shadbolt et al. (2012), and Polar Bear Range States (2015).

B.2. Subsistence harvest 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 (USFWS 2008; 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). 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 (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.

For the SB subpopulation, subsistence harvest is regulated through an agreement between the Inuvialuit of Canada and the Inupiat of Alaska (I-I Agreement; Brower et al. 2002). For the most recent 10-year period 2006–2015, an average of 19 bears per year were removed from the U.S. portion of the SB subpopulation (Figure 3). The average sex composition of removals during this period was 27% female, 50% male, and 22% unknown.

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.

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

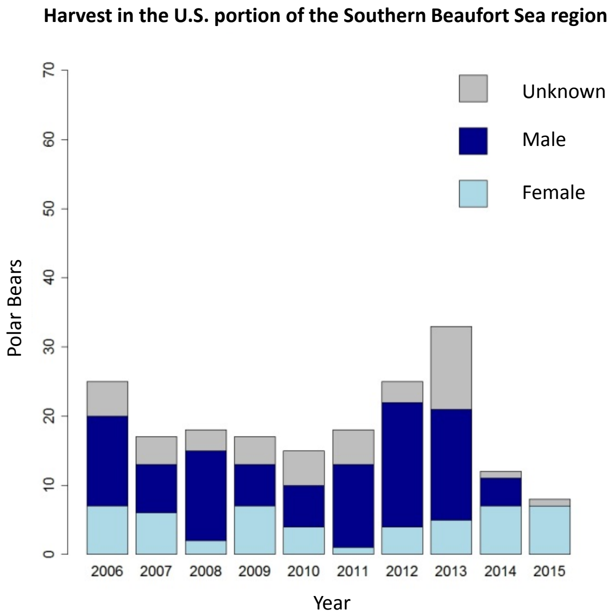

Figure 3. Polar bear harvest in the U.S. portion of the Southern Beaufort Sea subpopulation 2006–2015.

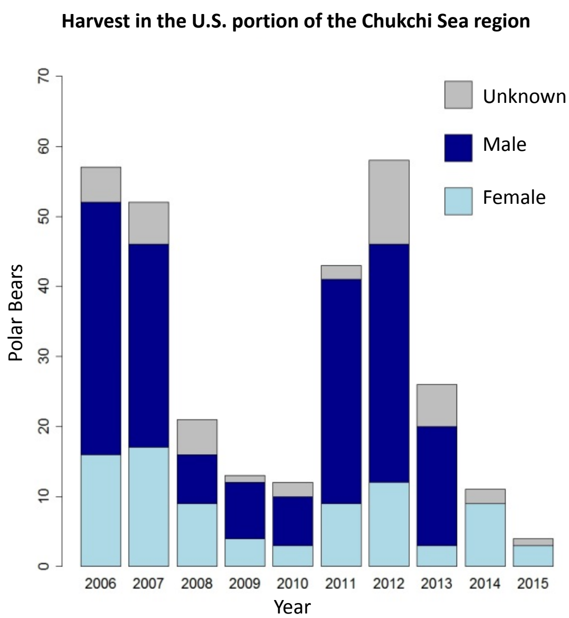

Figure 4. Polar bear harvest in the U.S. portion of the Chukchi Sea subpopulation 2006–2015.

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. 2007a; 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.

A primary management goal of the Range States is to ensure the safe coexistence of polar bears and humans in the face of accelerating climate change. In order to monitor human-polar bear interactions throughout the Arctic, the Range States initiated development of a database to track and analyze human-polar bear conflicts. The Polar Bear-Human Information Management System (PBHIMS) database will document, quantify, and evaluate human-bear interactions and other information relevant to bear management (PBRS 2015). This information will then be analyzed and the findings used to develop improved management strategies to reduce human-bear conflicts and the number of bears killed.

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 4401 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 1260 captures, or .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, a security guard for an oil company 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 (USFWS 2008). 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 (USFWS 2008).

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. This hybrid was the result of the cross-breeding between a female polar bear and male grizzly bear (Paetkau, pers. comm. May 2006). 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 2012). Further, in April 2012, an adult female polar bear was harvested with two older first generation hybrid cubs (Species at Risk Committee 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. Inadequacy of existing regulatory mechanisms

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 28293, May 15, 2008).

As noted above, since 2008, there are no known mechanisms that effectively regulation 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 (EC 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.

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).

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.

Industrial development. 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.

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 2009) 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.

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 (BOEM 2011, 2014; respectively). 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).

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 2009) that focused on ship uses of the Arctic Ocean and their potential impacts on humans and the Arctic marine environment (AMSA 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. 2010), and voluntary guidelines to reduce underwater noise to avoid adverse impacts on marine biota have been developed (PAME 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 (USCG 2014), 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).

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.

Current Conservation Measures and Management Efforts

Many governmental and non-governmental agencies, institutions, and organizations are involved in polar bear conservation. These entities provide an active conservation constituency and are integral to the conservation/recovery of the species. The following conservation agreements and plans have effectively addressed many threats to polar bears from direct and incidental take by humans. However, as noted in the "Threats" section, 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.

A. International Conservation Agreements and Plans

- **Agreement on the Conservation of Polar Bears (1973 Agreement).** All five range countries are parties to the 1973 Agreement. The 1973 Agreement requires the Range States to take appropriate action to protect the ecosystem of which polar bears are a part, with special attention to habitat components such as denning and feeding sites and migration patterns, and to manage polar bear subpopulations in accordance with sound conservation practices based on the best available scientific data. The 1973 Agreement relies on the efforts of each party to implement conservation programs and does not preclude a party from establishing additional controls (Lentfer 1974, p. 1). In 2009, the Range States agreed to initiate a process that would lead to a coordinated approach to conservation and management strategies between the parties. A Circumpolar Action Plan for the polar bear (Polar Bear Range States 2015) was developed to synthesize and coordinate management and conservation activities among countries, in conjunction with National Action Plans developed by individual range states.
- **Inupiat—Inuvialuit Agreement for the Management of Polar Bears of the Southern Beaufort Sea**. In January 1988, the Inuvialuit of Canada and the Inupiat of Alaska, groups that both harvest polar bears for cultural and subsistence purposes, signed a management agreement for polar bears of the Southern Beaufort Sea (I-I Agreement) (Brower et al. 2002). This agreement is based on the understanding that the two groups harvest animals from a single population shared across the international boundary. The I-I Agreement provides joint responsibility for

conservation and harvest practices (Treseder and Carpenter 1989; Nageak et al. 1991). In Canada, recommendations and decisions from the I-I Commissioners are implemented through Community Polar Bear Management Agreements, Inuvialuit Settlement Region Community Bylaws, and NWT Big Game Regulations. In the United States, the I-I Agreement is implemented at the local level. Adherence to the agreement's terms in Alaska is voluntary, and levels of compliance may vary.

- **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). I**n October 16, 2000, the United States and the Russian Federation signed a bilateral agreement for the conservation and management of polar bear subpopulations shared between the two countries. The Bilateral Agreement expands upon the progress made through the multilateral 1973 Agreement by implementing a unified conservation program for this shared population. Beginning in 2007, parties to the treaty established a joint U.S.-Russia Commission responsible for making management decisions concerning polar bears in the Alaska-Chukotka region. The Commission is composed of a Native and federal representative from each country. The Commissioners have appointed a scientific working group (SWG) and tasked this SWG with a number of objectives, with the top priority being identifying a sustainable harvest level for the Alaska-Chukotka population.

In response to this initiative, the SWG provided the Commission with a peer-reviewed report of their recommendations regarding harvest and future research needs. At a meeting in June 2010, the Commission decided to place an upper limit on harvest from the CS population of 19 female and 39 male (for a total of 58) polar bears per year based on the recommendation of the SWG and subsistence needs. Harvest will be split evenly between Native peoples of Alaska and Chukotka. The Service and the Alaska Nanuuq Commission (ANC) will work in partnership with local communities to implement the harvest quota.

- **Memorandum of Understanding between Environment Canada and the United States Department of the Interior Concerning the Conservation and Management of Shared Polar Bear Populations**. In May 2008, the Canadian Minister of Environment and the U.S. Secretary of the Interior signed a Memorandum of Understanding to facilitate and enhance coordination, cooperation, and the development of partnerships between the Participants, and with other associated and interested entities, regarding the conservation and management of polar bears and to provide a framework for the development and implementation of mutually agreeable immediate, interim, and long-term actions that focus on specific components of polar bear conservation.

- **The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES**) is a treaty designed to protect animal and plant species at risk from international trade. CITES regulates international wildlife trade by listing species in one of its three appendices; the level of monitoring and regulation to which an animal or plant species is subject depends on the appendix in which it is listed. Polar bears were listed in Appendix II of CITES on July 7, 1975. As such, CITES parties must determine, among other things, that any polar bear, polar bear part, or product made from polar bear is legally obtained and that the export will not be detrimental to the survival of the species, prior to issuing a permit authorizing the export of the animal, part, or product. All five range states are CITES signatories and have the required Scientific and Management Authorities. CITES is effective in regulating the international trade in polar bear parts and products, and provides conservation measures to minimize that potential threat to the species.

B. Domestic Regulatory Mechanisms

- The **Marine Mammal Protection Act (MMPA)** was enacted on October 21, 1972. All marine mammals, including polar bears, are protected under the MMPA. The MMPA prohibits, with certain exceptions, the "take" of marine mammals in U.S. waters and by U.S. citizens on the high seas, and the importation of marine mammals and marine mammal products into the U.S. (http://www.nmfs.noaa.gov/pr/laws/mmpa/).

Passage of the MMPA in 1972 established a moratorium on sport and commercial hunting of polar bears in Alaska. However, the MMPA exempts harvest, conducted in a non-wasteful manner, of polar bears by coastal dwelling Alaska Natives for subsistence and handicraft purposes. The MMPA and its implementing regulations also prohibit the commercial sale of any marine mammal parts or products except those that qualify as authentic articles of handicrafts or clothing created by Alaska Natives.

Section 119 of the MMPA was added to allow the Secretary to "enter into cooperative agreement with Alaska Native organizations to conserve marine mammals and provide co-management of subsistence use by Alaska Natives." This also authorizes grants to be made to Native organizations in order to carry out agreements made under the section.

The MMPA Incidental and Intentional Take Program (IITP) allows for the incidental non-intentional take of small numbers of marine mammals during specific activities. The MMPA also allows for intentional take by harassment of marine mammals for deterrence purposes. The Service administers an IITP that allows polar bear managers to work cooperatively with stakeholders (i.e., oil and gas industry, the mining industry, the military, local communities, and researchers) working in polar bear habitat to minimize impacts of their activities on bears. The IITP has been an integral part of the Service's management and conservation program for polar bears in Alaska since its inception in 1991. The program's success depends on its acceptance by our conservation partners

- The **Endangered Species Act** was passed to provide a mechanism to conserve threatened and endangered plants and animals and their habitat. Listing implements prohibitions on the take of the species. Under section 7 of the ESA, all Federal agencies must ensure that any actions they authorize, fund, or carry out are not likely to jeopardize the continued existence of a listed species, or destroy or adversely modify its designated critical habitat. Consultations occur with Federal action agencies under section 7 of the ESA to avoid and minimize impacts of proposed activities on listed species.
- The **Alaska National Interest Lands Conservation Act of 1980** (16 U.S.C. 3101 et seq.) (ANILCA) created or expanded National Parks and National Wildlife Refuges (NWRs) in Alaska, including the expansion of the Arctic NWR. One of the establishing purposes of the Arctic NWR is to conserve polar bears. Section 1003 of ANILCA prohibits production of oil and gas in the Arctic NWR, and no leasing or other development leading to production of oil and gas may take place unless authorized by an Act of Congress.

The Bureau of Land Management (BLM) is responsible for vast land areas on the North Slope, including the National Petroleum Reserve, NPRA. Habitat suitable for polar bear denning and den sites have been identified within NPRA. The BLM considers fish and wildlife values under its multiple use mission in evaluating land use authorizations and prospective oil and gas leasing actions. Provisions of the MMPA regarding the incidental take of polar bears on land areas and waters within the jurisdiction of the United States apply to activities conducted by the oil and gas industry on BLM lands.

- **The North Slope Borough Polar Bear Deterrence Program.** The North Slope Borough (NSB) Department of Wildlife Management has maintained a polar bear hazing program in Barrow and surrounding villages to protect residents since 1992. Patrols have been a collaborative effort by the NSB and the Native Village of Barrow and Kaktovik. This program has been very successful in Kaktovik and Barrow in limiting the number of bears killed in recent years due to public safety concerns. Efforts to formalize training and hazing programs have been an important step in making the program successful. Continued efforts are needed to implement training programs annually, and to provide funds needed to support the program.

In summary, existing international and domestic agreements have been in place for 40 years to guide the conservation and management of polar bears. Their main strength to date has been to help regulate the harvest and trade of polar bears, as well as non-lethal take of bears. While these agreements have addressed direct take of polar bears, they are currently insufficient to reduce the main threat to polar bears- the range wide loss of their sea ice habitat. However, they remain an important foundation on which to implement this Plan.

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APPENDIX B— SPECIFIC CONSERVATION AND RECOVERY ACTIONS CONSIDERED

Proposed Actions — The entries below were proposed by Recovery Team members during development of the Plan; categorized as action, education or research; and used to develop and refine the high priority conservation and recovery actions that appear in the Plan text.

Proposed Actions — *Support international conservation efforts through the range states relationships*
(Action) Participate in circumpolar efforts to reduce human-bear conflicts.
(Action) Participate in circumpolar efforts to track and reduce international illegal trade in polar bears and polar bear parts.
Proposed Actions — *Manage human-bear conflicts*
(Action) Convene a community-based working group – including whaling captains — to explore options for managing bone piles. Develop best management practices that can be shared with communities.
(Action) Remove or disperse bone piles to reduce bear concentrations (i.e., reduce risk of harmful impacts from disease transmission, oil spills).
(Action) Develop and share best practices for managing bear viewing to minimize impacts on polar bears and potential human-bear conflicts. Build on existing efforts, e.g. NSB program.
(Research) Assess the highest temporal/spatial risk areas for negative human-bear encounters. Monitor changes in the human-bear interactions hotspots/focal points.
(Action) Develop emergency response plans for extreme events such as mass bear strandings, low immune response to pathogens, and an absence of whale carcasses at Kaktovik.
(Research) Monitor effectiveness of deterrence programs, collect data to differentiate cause of bear deaths, and analyze polar bear mortalities.
(Action) Scholarship programs/work with ANSEP/Ilasagvik College to develop professional bear expertise in local communities.
(Education) Work with local residents and other experts to effectively communicate the importance of minimizing human-bear conflicts.
(Research/Education) Standardize a community-based monitoring & data management program for polar bears and for human-bear conflicts. Engage residents, industry, researchers, NGOs and others living & working in Arctic. Communicate what is being monitored and why. Share the results.
(Education) Work with local residents to communicate the value of reporting human-bear interactions.
Proposed Actions — *Collaboratively manage subsistence harvest*
(Education) Develop clear, understandable materials for conveying harvest management principles; include clarification of the various interpretations of the term "sustainable." Update existing information for user-group audiences.
(Action) Pass on knowledge to future generations regarding responsible and effective hunting and harvest management.
(Action) Implement Chukchi harvest quota in U.S. (US/Russia bilateral agreement).
(Action) Work with Russian colleagues to implement Chukchi harvest quota in Russia.
(Research) Monitor input parameters needed to estimate maximum net productivity (i.e. within optimum sustainable population).
(Education) Work with partners and subsistence users to communicate relationship between maximum net productivity and harvest; if a subpopulation declines due to declining carrying capacity, subsistence harvest will continue but harvest levels will go down.
(Research) Develop separate harvest rate estimates for male and female bears.
(Action) Consistent with existing agreements, prohibit all harvest of females with cubs.

(Research) Ensure on-going, long-term, adequate basic monitoring of Chukchi Sea & SBS populations.
(Research) Support the on-going, long-term, and consistent monitoring of polar bears across the entire range. (PBSG)
(Research/Monitoring) Improve subsistence harvest monitoring, e.g., tagging, genetic sampling, bio-sampling etc.
Proposed Actions — *Protect denning habitat*
(Action) Protect polar bear travel corridors and seasonal habitat areas (e.g., barrier islands).
(Action) Create denning opportunities in prime habitat (i.e., barrier islands) through use of snow fences to create snow drifts.
Proposed Actions — *Minimize risk of contamination from spills*
(Action) Improve spill response capability—deterrence, rescue & handling of oiled bears. Train local community members as first responders. Stage equipment and supplies in villages.
(Action) Minimize risk of oil spills (e.g., collaborate with Industry and other regulatory agencies on better inspections and maintenance of pipelines, production facilities, etc.).
(Action) Work with Arctic Council, Russia, USCG, and others on improving spill response plans for Chukchi and Southern Beaufort Seas.
(Research) Map current and future overlap of bear distribution with resource extraction activities.
Proposed Actions — *Effects of shipping*
(Research) Study the effects of shipping on bears.
(Action) Encourage greater Coast Guard presence in Arctic (Arctic Marine Mammal Commission is working on this issue).
(Action) Support the commercial fishing moratorium north of the Bering Straits until marine mammal management protection plans and mitigation measures are in place.
(Action) Ratify law-of-the-sea treaty
(Action) Expand observer program on ships to document marine mammal interactions. Engage and train local communities to staff such a program.
(Action) Work with international partners to improve off-shore development & shipping regulations to minimize potential impacts on bears, especially with Russia and Canada.
Proposed Actions — *Effects of Contaminants*
(Research) Monitor contaminants and their effects on bears through harvest monitoring programs and minimally invasive sample collection from live animals; potential partners include Range States.
(Action/Education) Reduce potential for exposure from acute, lethal contaminant exposure (e.g., ethylene glycol).
(Action) Develop, assess, update best practices for handling contaminants, and responding to inadvertent exposures.
(Action) Manage landfills via fencing and other actions to reduce exposure to contaminants.
(Research) Assess current contaminant threat to bears and where the greatest risks are.
(Action) Clean up legacy oil wells.
(Research/Action) Determine whether contaminant levels in polar bears have implications for human consumption (food safety, food security).
Proposed Actions — *Effect of research impacts*
(Action) Evaluate and manage the cumulative effects of research on polar bears.

(Action) Evaluate specific research protocols by examining value to polar bear conservation and direct impact on bears. i.e. cost-benefit analysis.
(Action) Develop safe-handling protocols for polar bears.

Research Actions — The entries below were proposed by Recovery Team, Science and TEK workgroup during development of the Plan. The list consists of representative projects supporting research areas identified in Plan. Implementation of these or of other projects will flow from the dynamic and adaptive process associated with implementing and updating the Plan.

Population dynamics and distribution. Information on population dynamics and distribution informs most aspects of wildlife management, including subsistence harvest and human-bear interactions, and is key to understanding current and future conservation status. The ecological dependence of polar bears on sea-ice as a platform from which to access energy-rich marine prey has shown for some populations that changes in the physical sea-ice environment can induce declines in population vital rates, and thus must be considered when evaluating future persistence. Because of this, long-term studies of subpopulation status, including the vital rates used as demographic recovery criteria, are needed to measure progress towards persistence-based goals. Research and monitoring on the two polar bear subpopulations shared by the U.S suggests that physical and biological differences between populations may affect how polar bears respond to habitat loss, especially in the near term, underscoring potential spatial and temporal variation in the response of polar bears to climate change.

Research actions — *Population dynamics and distribution*
1. Estimation of population status and trend: a. via estimation of demographic parameters including population size, population growth rate, survival, and recruitment, or indices of these parameters. b. via biological and ecological indices. c. via the sex, age, and reproductive composition of human-caused removals.
2. Determine current distribution of populations and implications for population size estimation, harvest allocation, and meta-analysis of data from overlapping populations.
3. Evaluate the mechanistic relationships between sea-ice, prey abundance, and polar bear vital rates over timeframes relevant to the Conservation Management Plan.
4. Estimate the numbers of bears coming on shore in late summer and assess differential survival and fitness for bears that spend time on shore versus remaining on sea-ice. a. Expand onshore non-invasive genetic sampling,
5. Monitor the level and type (e.g., sex and age) of human-caused lethal removals
6. Develop models to evaluate future population status and management actions, perform sensitivity analysis with respect to management actions, perform risk assessments with respect to human-caused removals, and identify key information needs. a. Develop a standardized and adaptive approach for estimating sustainable harvest rates, communicating the risks and tradeoffs of different harvest strategies to managers, and evaluating the effects of harvest on population status.
7. Analyze optimal study design, sample size, and spatial and temporal distribution of sampling effort to answer key demographic questions; perform cost-benefit analyses.
8. Evaluate emerging technologies (e.g., high-resolution satellite imagery and other technological advancements) for integration into existing monitoring plans.
9. Develop effective and less-invasive research and monitoring techniques.
10. Evaluate circumpolar patterns in genetic, behavioral, life-history, and ecological diversity for polar bears in relation to the groupings of polar bears considered in FG2.
11. Improve our understanding of why polar bear populations differ in their response to sea-ice loss and based on that understanding identify representative populations in different ecoregions for monitoring responses to sea-ice loss.

12.	Improve our understanding of the physiological response of polar bears to environmental and anthropogenic stressors and develop methods for monitoring those responses.

Habitat ecology. Understanding how bears respond to functional changes in their environment is necessary to predict the consequences of loss of sea-ice habitat to population status, distribution, and ultimately the likelihood of persistence. Improving our understanding of the links between environmental change and polar bear persistence will allow decision-makers to determine future policies regarding the chances of enhancing persistence.

Research actions— *Habitat Ecology.*
1. Improve our understanding of the environmental and biological characteristics (e.g., bathymetry, ice concentration, benthic productivity) of important polar bear habitats, identify key habitat areas (including denning areas), and projected future availability of habitats. a. Incorporate resource selection information from prey species into analyses
2. Determine the behavioral and demographic responses of polar bear prey, primarily ringed and bearded seals, to sea-ice loss and changes in late-winter and spring snow depths on the sea-ice. Evaluate whether such responses affect the accessibility of prey to polar bears.
3. Identify the ecological mechanisms by which polar bears are responding to sea-ice loss to improve short-term and long-term projections of population-level responses.
4. Determine the relationship between sea-ice conditions, the proportion of bears using land, and the duration of time spent there. Develop predictions for the rate at which increased numbers of bears may occur onshore and the necessary management responses.
5. Characterize the spatial overlap of activities and the potential response of polar bears to on- and off-shore resource exploration and extraction activities. a. Study potential disturbance of polar bears by shipping and other development activities, with attention to high-use areas such as the Bering Strait b. Evaluate data submitted on observations of polar bears in the oil fields to detect spatial and/or temporal changes
6. Model the distribution of large- and small-scale oil spills relative to on- and off-shore habitats and polar bear distribution. Evaluate potential effects of spills on the availability of suitable habitat.
7. Use local observations and traditional ecological knowledge to evaluate seasonal distribution patterns and polar bear behavior, including denning and movements. a. Standardize objectives and methods for community-based monitoring
8. Continue and expand den detection, mapping, and monitoring activities throughout the range of polar bear population in Alaska.
9. Model and forecast cumulative impacts on polar bears using a Bayesian Network approach.

Health and nutritional ecology. An individual's health reflects the interaction between its behavioral choices and the environment. Because of this, measuring changes in health over time has great potential for revealing important associations between environmental stressors and population dynamics.

Research actions— *Health and Nutritional Ecology.*
1. Determine if polar bears are being increasingly exposed to diseases and parasites and the potential impact of disease on body condition, reproduction, and survival.
2. Characterize baseline exposure to hydrocarbons, atmospherically-transported contaminants, and industrial pollutants associated with resource extraction practices. 3. Evaluate methods to decontaminate oiled polar bears
4. Characterize the physiological stress response of polar bears relative to life history, physiological states, and environmental conditions, and determine if a relationship exists between stress responses and measures of body condition and reproduction.
5. Improve our understanding of the relationships between polar bear feeding ecology and behavior, body condition and food intake, demography, and sea-ice availability.

6. Evaluate the potential cumulative impacts of research, hunting, industry, tourism activities on polar bear health, behavior, and vital rates

Nutritional and cultural use of polar bears. Historically, native communities throughout the coastal arctic have relied upon polar bears as both a nutritional and cultural resource. Research, including through Traditional Ecological Knowledge, may help to better understand the cultural and nutritional significance of polar bears to communities that have historically relied upon them, and how climate change may affect the use of polar bears as a renewable resource in the future.

Research actions— *Nutritional and Cultural Use of Polar Bears*
1. Periodically assess key community perspectives, values and needs regarding: human-polar bear interactions, sustainable use of polar bears, and incentives associated with polar bear harvest. Also, evaluate the cultural and traditional uses of polar bears. a. Evaluate the cultural effects of harvest management decisions b. Return to key communities to verify and present findings
2. Evaluate the use of polar bears from human nutritional health and food security perspectives. (e.g., dietary quality of polar bear in comparison to store bought meat, implications of the presence and potential effect(s) of contaminants in the meat). a. Evaluate the effects of restrictions/quotas on the food security and nutritional status of coastal native communities b. Evaluate the influence of harvest management on the availability, types, and quality of food resources
3. Ongoing polar bear health assessments through samples and observations by local communities and hunters. Combine polar bear sampling program as part of larger marine arctic ecosystem and other marine mammal sampling (e.g., ice seal biomonitoring). a. Analyze hunter samples b. Analyze agency capture samples c. Compare results to global polar bear health studies

Human-polar bear interactions. There is poor understanding of how conflict affects polar bear populations and concomitantly how conflict affects humans living and working in polar bear range. The goal of this work is to better understand the dynamics of human-polar bear conflict by gaining insight about potential drivers of interaction and conflict. This information is needed so that mitigation actions can be developed, implemented, and evaluated.

Research actions— *Human-Polar Bear Interactions*
1. Collect, process, and synthesize all existing records of human-polar bear interactions to gain insight on the quality of conflict records, spatial and temporal trends in conflicts, severity of conflict, potential biases in conflict reporting, and types of management strategies used to mitigate conflict. a. standardize operating procedures for polar bear patrols and the reporting methods used to document human-bear conflicts b. maintain central database (i.e., Polar Bear Human Information Management System) c. monitor the effectiveness of all deterrence programs including non-lethal methods used in Chukotka
2. Characterize environmental, spatial, and anthropogenic factors that contribute to human-polar bear conflict around industrial activity centers and villages. a. develop best practices for polar bear viewing and ecotourism b. develop best practices for attractant management (e.g., ice cellars, dumps, drying racks, dog lots)
3. Develop models for predicting the risk of human-polar bear conflict given scenarios of environmental change, increased use of terrestrial habitat, and increased anthropogenic activities.

4.	Evaluate the effects of concentrated attractants (e.g., dumps) and supplemental feeding (e.g., remains of subsistence-harvested whales) on polar bear distribution, habitat use, nutritional status, and human-bear interactions.
5.	Expand non-invasive genetic sampling around seasonally abundant, concentrated food sources (e.g., bone piles).

APPENDIX C—POPULATION DYNAMICS AND HARVEST MANAGEMENT

The harvest strategy described in the Conservation Management Plan is founded on an extensive literature on harvest theory (Wade 1998, Runge et al. 2009) and a detailed population model for polar bears (Regehr et al. 2015, Regehr et al. in press), and is customized to reflect the cultural practices of Alaska Native people and the principles of the Marine Mammal Protection Act. This Appendix describes the underlying harvest theory and technical details of the harvest strategy.

Harvest Theory

Sustained removal of animals from a population, whether for subsistence harvest, sport harvest, incidental take, or population control, is possible because of density-dependent feedback mechanisms. A reduction in the population size via removals can—through any of a number of processes—free up resources (food, space, breeding territory, etc.) for the remaining individuals, increasing their survival rates, reproductive rates, or both. The increase in the demographic rates provides a surplus of individuals relative to what is needed to maintain the population at a constant size. This surplus can be sustainably removed, as long as a number of conditions are met.

The simplest model that can capture these population dynamics is the discrete logistic model, which describes the trajectory of a population using the formula,

$$N_{t+1} = N_t + rN_t\left(1 - \frac{N_t}{K}\right) - hN_t \qquad \text{(C1)}$$

where N_t is the population size at time t, r is the intrinsic rate of growth of the population, K is the carrying capacity, and h is the rate of removal (the harvest rate). If such a population is subjected to a fixed rate of removal for some period of time, it will eventually settle to an equilibrium population size

$$N_{eq} = K\left(1 - \frac{h}{r}\right) \qquad \text{(C2)}$$

that allows a sustained annual removal (annual harvest) of a number of individuals as calculated by the formula:

$$H_{eq} = hN_{eq} = hK\left(1 - \frac{h}{r}\right) = hK - h^2\frac{K}{r} \qquad \text{(C3)}$$

Plotting H_{eq} against N_{eq} depicts a "yield curve" (Fig. C-1). For a given harvest rate, h, there is a corresponding equilibrium population size and annual harvest. The yield curve traces the combinations of N_{eq} and H_{eq}: when $h = 0$, $N_{eq} = K$ and the annual harvest is, of course, 0. As h increases, N_{eq} decreases and H_{eq} increases until a maximum sustainable annual harvest is reached. (For the discrete logistic model, this maximum occurs at $h = r/2$, $N_{eq} = K/2$, and $H_{eq} = rK/4$.) The harvest rate can continue to increase, pushing the equilibrium point over to the left side of the yield curve; now N_{eq} continues to decrease, but so does H_{eq}. When $h \geq r$, $N_{eq} = 0$, that is, the harvest rate is greater than the fastest-possible population growth rate, and the only resulting equilibrium condition is extirpation of the population.

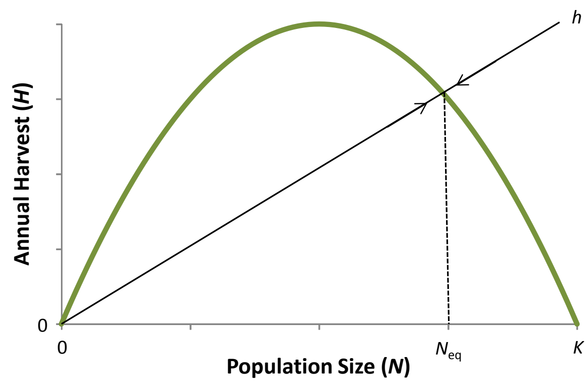

Figure C-1. The yield curve for a population that is described by a discrete logistic population model. If the annual harvest is a fixed fraction, *h*, of the population size (black line), the population size will converge to a stable equilibrium point.

When the harvest *rate* is fixed, the equilibrium point is a stable attractor for the population dynamics: if the population size is lower than N_{eq}, the surplus production (as indicated by the yield curve) will be greater than the annual harvest (which occurs on the thin black line), and the population will increase back toward N_{eq}; if the population size is greater than N_{eq}, the annual harvest (on the black line) will exceed the surplus production, and the population will decrease back toward N_{eq}. The stability of the equilibrium point is the reason that using a sustainable, fixed harvest rate is a robust strategy—the population dynamics are self-correcting in the face of stochastic fluctuations. The critical thing to note, however, is that this stability works for a fixed harvest *rate* (i.e., percentage of current population size), not a fixed harvest quota (i.e., a fixed number of individuals removed each year, regardless of changes in population size). To achieve a fixed harvest rate, the harvest quota needs to be able to change in response to changes in the population size on a regular basis.

The population dynamics described above and the stability of the fixed-rate removal strategy depend on a few assumptions: first, that the environment remains constant on average (the mean r and mean K do not change); second, that changes in N can be monitored without bias and used to adjust the number of animals removed; third, that there are no Allee effects, or at least that the population never drops low enough that they are realized; and fourth, that eq. C1 adequately describes the dynamics. Note that although the model in eq. C1 looks deterministic, it can also serve as the central tendency of a stochastic model, and under reasonable assumptions about the nature of the annual variation, the fixed-rate removal strategy will still robustly maintain a stochastic population near an equilibrium point, provided there is not also some change in the environment.

The effect of environmental change on the yield curve

What happens to the yield curve (and the harvestable surplus) if the environment changes? It's not easy to see the answer to this question in the formulas for the discrete logistic model, because the underlying density-dependent processes are not explicitly written out in the formula. Instead, consider the following population model,

$$N_{t+1} = \phi N_t(1 + R_t) - hN_t \qquad \text{(C4)}$$

where ϕ is the survival rate and R is the recruitment rate (the number of offspring produced per adult). Let's assume that the survival rate, ϕ, is density independent (this can be a reasonable simplifying assumption for the adults of a large, long-lived mammal species). But let recruitment be density dependent and given by the linear function

$$R_t = a + bN_t \qquad \text{(C5)}$$

where a is the reproductive rate at very low densities (when there is no competition for resources), and $b < 0$ describes how much recruitment decreases for each unit increase in the population size. Then, substituting eq. C5 into eq. C4,

$$N_{t+1} = \phi N_t(1 + a + bN_t) - hN_t = \\ \phi(1 + a)N_t + \phi bN_t^2 - hN_t \qquad \text{(C6)}$$

Now, by comparing eq. C6 to eq. C1 and making the following substitutions,

$$\phi(1 + a) = 1 + r, \text{ and } \phi b = -r/K \qquad \text{(C7)}$$

we calculate

$$N_{t+1} = (1 + r)N_t - \frac{rN_t^2}{K} - hN_t = \\ N_t + rN_t\left(1 - \frac{N_t}{K}\right) - hN_t \qquad \text{(C8)}$$

which is identical to eq. C1. Thus, this new model, built from the underlying density-dependent relationships, is identical to the discrete logistic model. What's helpful about this is that we can use the substitutions in eq. C7 to solve for the parameters of the discrete logistic (r and K) in terms of the parameters in the density-dependent formulation (a, b, and ϕ),

$$r = \phi(1 + a) - 1 \\ K = \frac{1 - \phi(1 + a)}{\phi b} \qquad \text{(C9)}$$

A graphical depiction of the model in eq. C4 gives an intuitive sense of why it has the same behavior as the model in eq. C1 (Fig. C-2). In a population that is below its carrying capacity, the reproductive rate will exceed the level needed to offset mortality, so the population will grow. As the population grows, competition for resources increases, and the reproductive rate decreases. When the reproductive rate matches the mortality rate, there is a stable equilibrium point (K_0). Suppose now that there is a change in the environment such that the extent of habitat decreases, but the habitat that remains is the same quality as before. In this case, we could reason that b will decrease, because the competition for resources will be felt sooner as the population grows; but a will stay the same, because the reproductive rate at very low density would remain unchanged (Fig. C-2, top panel). The equilibrium point at which reproduction offsets mortality decreases (K_1).

Another way in which the environment could change is that the extent of habitat doesn't change, but the quality of it decreases. In this case, we might surmise that the reproductive rate decreases equally for all densities (Fig. C-2, bottom panel), thus a decreases, but b stays the same. Again, the equilibrium point at which reproduction offsets mortality decreases (K_1).

Although the effect of these two types of environmental change on the carrying capacity looks similar, the effect on the yield curve is profoundly different (Fig. C-3). In the case of the effect of habitat quantity, b changes but not a; looking at eq. C9, this means that the carrying capacity (K) changes, but the intrinsic rate of growth (r) does not. Thus, the yield curve shrinks to the new carrying capacity, but does not change its proportions (Fig.

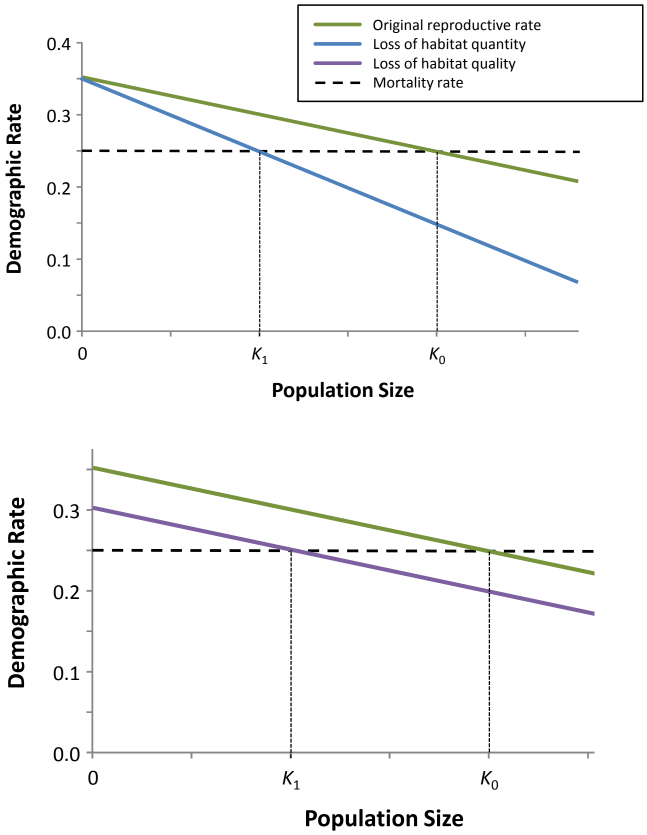

Figure C-2. Density-dependent demographic rates, carrying capacity, and environmental change. As the population size increases, the density-dependent reproductive rate decreases until is just matches the mortality rate; at this point, additions and subtractions from the population are equal and the population size is stable (K_0). Changes in the environment that affect the reproductive rate (here we assume a negative effect) can shift the carrying capacity to a new level (K_1), either through an effect on habitat quantity (top panel) or through an effect on habitat quality (bottom panel).

C-3, aqua curve). On the other hand, in the case of the effect of habitat quality, the change in a affects both K and r; the yield curve becomes flatter as well as smaller (Fig. C-3, purple curve). These two changes will affect harvest management differently. In the case of the habitat quantity change (change in b only), the fixed harvest rate strategy (using the desired harvest rate from before the change) will still work, and will maintain the population at the same proportion of its carrying capacity as it did previously, because only K (but not r) is affected. In the case of the habitat quality change (change in a), the fixed harvest rate strategy that worked before the environmental change will no longer hold the population at the same proportion of K and might not even be sustainable. Thus, the demographic mechanism of environmental change matters to the management of harvest.

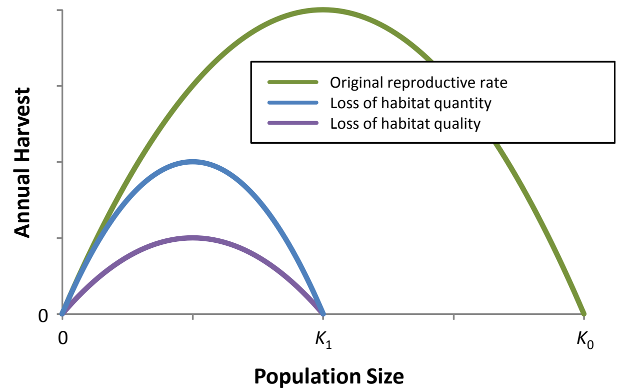

Figure C-3. The effect of environmental change on the yield curve, for a discrete logistic population model.

A note about the intrinsic rate of growth

In the models described above, the intrinsic rate of growth (r) is the growth rate the population would have if its density were close to 0; that is, it is a descriptor of the underlying dynamics of a particular population in a habitat of a particular quality. Further, eq. C9 shows that the intrinsic rate of growth for a particular population could change, if the survival rate or the reproductive rate at low density changed as a result of changes in the environment. Thus, the way we are using the term, the intrinsic rate of growth is not a property of the species as a whole (i.e., it is not the theoretical maximum growth rate that the species could experience under the best possible conditions).

Maximum Net Productivity Level

The phrase "maximum net productivity level" arises from language in the MMPA, but invokes the population theory described by yield curves. The maximum net productivity is "the greatest net annual increment in population numbers or biomass resulting from additions to the population due to reproduction and/or growth less losses due to natural mortality" (50 CFR 403.02); this annual increment corresponds to the surplus production that allows annual harvest, thus, the maximum net productivity is the value on the y-axis that corresponds to the peak of the yield curve (Fig. C-1). The maximum net productivity *level*, then, is the population size (the value on the x-axis) that corresponds to this peak.

The harvest theory derivations shown above demonstrate that the equilibrium population size that produces the greatest sustainable annual harvest will change if the underlying demographic dynamics change. The policy distinction between MNPL (referenced to a historic value K_0 that could potentially be reduced by habitat effects) and *mnpl* (referenced to a new value K_1 that has been reduced by habitat effects) discussed in section III.b in the Plan is centered around whether the MMPA term "maximum net productivity level" refers to the peak of the historical yield curve (MNPL) or the peak of the altered yield curve (*mnpl*). Taking into account the unique circumstances of polar bears and in an effort to advance conservation of polar bears, we have adopted the *mnpl* interpretation, for the reasons explained in the body of the Plan. MMPA Demographic Criterion 2 requires that total human-caused removals do not exceed a rate h (relative to the subpopulation size) that maintains the subpopulation above *mnpl*. The remainder of this Appendix discusses some of the technical considerations in evaluating this criterion.

It is important to note that MMPA Demographic Criterion 2 focuses on a human-caused removal *rate*, not a fixed quota. Fixed-rate harvest, and by extension variable-rate harvest under a state-dependent framework (Regehr et al. 2015, Regehr et al. in press), has a sound basis in theory and practice (Hilborn and Walters 1992), including for management of polar bears (Taylor et al. 1987). Further, it can be responsive to changing conditions, notably, a changing carrying capacity (Walters and Parma 1996). If a subpopulation declines because of a decline in carrying capacity, in the absence of other legal constraints[1], take can continue but absolute take levels would decline. For example, at a fixed removal rate of 4.5% (Taylor et al. 1987), subpopulation sizes of 800 and 400 would lead to removal levels of 36 and 18 bears per year, respectively. The key to managing with a fixed removal rate is ongoing monitoring of the population size, the annual take, and the demographic parameters that affect the intrinsic population growth rate (to evaluate whether the mean value of r remains unchanged). Further, to ensure that the criterion is met with high probability, the data quality and precision must be taken into account (Regehr et al. 2015, Regehr et al. in press). Such a management program calls for the collaborative partnership of Alaska Native entities and federal agencies.

The specific demographic thresholds referenced in the Plan are initial proposals; further work is being undertaken to refine them, and they should be revised over time as additional data become available. Further, the risk tolerance associated with uncertainty in the estimates of these thresholds has not yet been established; there should be a high probability that the actual rate of take is less than or equal to the rate needed to achieve *mnpl*, but further deliberation is needed to establish what size buffer is needed to account for uncertainty in estimates of abundance and removal rate, and still produce reasonable performance relative to both Fundamental Objectives 3 and 4 (see Regehr et al. 2015).

Maximum net productivity level and structured populations

The discrete logistic population model (eq. C1) is a simplified representation of population dynamics and leaves out a number of properties that are important in the context of polar bears. One of these properties is the structure of the population, as described by the age, sex, and size of the individuals. Long-lived, large mammals have a relatively late age of first reproduction and the reproductive rate can vary with age. The individuals in the younger age classes do not breed and can be more vulnerable to mortality factors. Animals of different sexes may be different sizes and require different amounts of resources. These patterns have been studied extensively in bears; survival, mortality, and reproduction vary significantly by age and sex. As a result, the density-dependent dynamics in such populations are often non-linear, and the yield curve reflects additional ability to compensate for removals. A modification to the logistic model that captures some of these dynamics is known as the θ-logistic model, described by

$$N_{t+1} = N_t + rN_t\left[1 - \left(\frac{N_t}{K}\right)^{\theta}\right] - hN_t \qquad \text{(C10)}$$

where the parameter θ controls the non-linearity in the dynamics. The population size that produces the greatest net productivity (annual harvest) is

$$N_{eq}^{*} = mnpl = K\left(\frac{1}{1+\theta}\right)^{1/\theta}, \qquad \text{(C11)}$$

which occurs when the harvest rate is

$$h_{mnpl} = \frac{\theta r}{1+\theta}. \qquad \text{(C12)}$$

1 The U.S.-Russia bilateral agreement concerning management of the Chukchi Sea subpopulation defines a sustainable harvest level as a "harvest level which does not exceed net annual recruitment to the population and maintains the population at or near its current level, taking into account all forms of removal, and considers the status and trend of the population, based on reliable scientific information." In most cases, this definition of sustainable take is more conservative (it restricts take more) than the proposed approach to take in this Plan. Thus, management of human-caused removals in the Chukchi Sea under the pre-existing bilateral agreement is also likely to meet the criteria for human-caused removals under this Plan.

Thus, the effect of an increasing θ on the yield curve is to increase the maximum yield and to shift the yield curve to the right, so that the peak (*mnpl*) occurs closer to the carrying capacity (Fig. C-4).

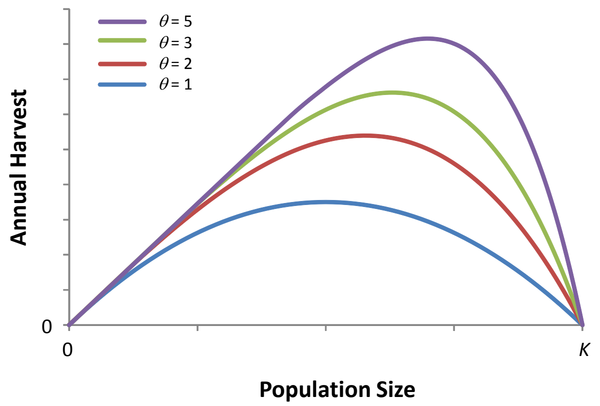

Figure C-4. Yield curves for a θ-logistic population model. The four curves share the same carrying capacity (*K*) and intrinsic rate of growth (*r*), but differ in the θ parameter.

The polar bear population model described by Regehr et al. (2015) and Regehr et al. (in press) explicitly accounts for the age- and sex-structure of the population, as well as non-linearity in the density-dependent relationships, so it is much more detailed than the θ-logistic model, but the yield curve is roughly approximated by a θ-logistic model with $r = 0.07$ and $\theta = 5.045$. It is the intent of the Plan that MMPA Demographic Criterion 2 be assessed with a population model that incorporates the best available scientific information about polar bears at the time of assessment; such a model should account for the shift in the yield curve brought about by population structure and non-linear dynamics.

Maximum net productivity level and selective harvest

The removal rate that achieves MMPA Demographic Criterion 2, h, depends on the underlying demographic rates for the subpopulation, the sex and age composition of the subpopulation, as well as the sex and age composition of removals. A valuable reference point is the removal rate, h_{mnpl}, that achieves *mnpl* at equilibrium when removals are in direct proportion to the sex and age composition of the subpopulation (i.e., when removals do not select for certain sex or age classes of animals).

In practice, the removal rate h can be different from the reference rate h_{mnpl} for a variety of reasons. For example, it is possible to adjust h based on the sex and age class of bears removed to allow for a 2:1 male-to-female ratio in the removals (Taylor et al. 2008), based on biological (e.g., the different reproductive value of females vs. males) or management considerations. The intent of Demographic Criterion 2 is to establish *mnpl* on the assumption of asymptotic population dynamics and unbiased removals, and then to ensure that the actual removals, whether biased or unbiased with regard to sex and age of the individuals removed, maintain the subpopulation size above *mnpl*.

For the purposes of this Plan, several details about the interpretation of *mnpl* are specified. First, *mnpl* is understood to be proportional to the carrying capacity. If the carrying capacity changes, whether owing to anthropogenic or non-anthropogenic causes, *mnpl* changes in proportion. Second, *mnpl* is calculated by assuming that removals are unbiased with regard to age and sex of polar bears, that is, polar bears of different ages and sexes are removed in proportion to their relative abundance. Third, the proportions of actual removals need not be unbiased with regard to age and sex, provided that the total population size relative to the carrying capacity, as specified by *mnpl*, is achieved. These interpretations of *mnpl* represent the views of USFWS for the purpose of conserving polar bears. This approach does not necessarily preclude other approaches to determining the maximum net productivity level in other conservation plans.

The Compatibility of Harvest with Conservation and Recovery

It is not unusual to authorize incidental take of a species protected under either the MMPA or the ESA, and the standards for such authorization are well described and well implemented. It is, however, much less common to purposefully seek to harvest species that need the protections of the ESA or the MMPA, but it does occur in a small number of special cases. Subsistence harvest of polar bears for a variety of cultural purposes is a central tradition for Alaska Native people, as well as other native Arctic peoples. The ESA and MMPA both recognize the importance of subsistence harvest for Alaska Native people. In fact, both laws allow certain subsistence harvest by Alaska Native people even when a species is "threatened" or "depleted." In this Plan, we recognize continued subsistence harvest as a fundamental goal associated with polar bear conservation and recovery. We also provide conditions for harvest to ensure (i) under the ESA, that harvest does not appreciably reduce the likelihood of survival or recovery; and (ii) under the MMPA, that harvest does not affect our ability to achieve the conservation goals of the Act.

But the question remains, how can harvest be compatible with the conservation and recovery of a species that is expected to decline throughout parts of its range in the near- and mid-term? In this Plan, we address both the scientific and conservation basis for maintaining such harvest opportunity.

There are many ways that changes in the environment could affect polar bear population dynamics and harvest opportunity; we consider two scenarios here to illustrate the considerations that this Plan recommends for management of removals. In the first scenario ("habitat quantity"), reduction in the extent of the sea-ice platform may reduce access to prey and create a greater competition for resources, reducing the carrying capacity. But if some bears are able to access prey, and thus retain high survival and reproductive rates, the intrinsic population growth rate might remain the same, even if the overall population number declines. In this situation, harvest can be maintained if the total rate of human-caused removals remains at or below *h* (the removal rate that maintains a population above its *mnpl*). Annual quotas for human-caused removal would need to be reduced in proportion to the decrease in the population size, but the rate of removal could remain the same. For example, if the removal rate was 3.0% and the subpopulation size was 2,000, up to 60 bears could be taken; if the subpopulation size was only 1000, no more than 30 bears could be removed while meeting MMPA Demographic Criterion 2. This would maintain the population size at roughly the same ratio relative to changing carrying capacity, even as the carrying capacity decreased (Fig. C-5, top panel).

In the second scenario ("habitat quality"), an increase in the ice-free period could, for example, increase the fasting period for *all* bears, reducing reproductive rates (and possibly also survival rates) across the board. In this case, the intrinsic population growth rate and population resilience would decrease. If this happened, the rate of harvest would need to decrease to meet MMPA Demographic Criterion 2. For example, if the intrinsic population growth rate is 7%, then an appropriate removal rate might be 4.5%; but if density-independent effects of climate change caused the intrinsic population growth rate to fall to only 2%, then the removal rate necessary to maintain the population size above *mnpl* would have to be below 1.5% (Fig. C-5, bottom panel). If the intrinsic growth rate is negative, then a population is incapable of maintaining its current size or growing. In this case, there is no removal rate that can meet MMPA Demographic Criterion 2 and ESA Demographic Criterion 4 (thus, *h* is 0); indeed, the population would be expected to become extirpated even in the absence of harvest.

In reality, some combination of these two effects is also possible. In addition, the precise mechanisms by which climate change effects will affect polar bears are not well understood at this time. Research and monitoring will clarify these issues. But the Plan's MMPA and ESA criteria relative to human-caused removals take into account both potential mechanisms for the effects of climate change on polar bear populations. The framework for management of human-caused removals will need to be responsive to changes in both the growth rate and carrying capacity. But, provided that the growth rate remains positive, a sustained opportunity for removal remains possible, even with a decline in carrying capacity. Provided that climate change—the threat that is driving the changes in growth rate and carrying capacity—is addressed to the extent described in this Plan, the framework established in this Plan would allow for recovery under the ESA and conservation under the MMPA.

The concepts underlying this framework for management of human-caused removals are founded in harvest theory (Wade 1998, Runge et al. 2009) and can be illustrated with yield curves. Yield curves show the annual total removals and the corresponding equilibrium population size for a range of sustainable harvest rates (Fig. C-5). The peak of the yield curve is the maximum net productivity, and removals that keep the population above *mnpl* will fall somewhere on the right shoulder of the yield curve. An impact on habitat quantity will shrink the yield curve by reducing the carrying capacity (Fig. C-5, top panel), while otherwise allowing the same rate of removal (although the allowable quota decreases). An impact on habitat quality will flatten the yield curve by reducing the intrinsic growth rate (Fig. C-5, bottom panel), thereby reducing the allowable *rate* of removal as well as the allowable quota.

In principle, the strategy for managing human-caused removals described above could work even if the carrying capacity decreased to low levels, but at some point, additional considerations would arise, including the increasing risk of chance events (stochasticity) on small populations and the possibility of Allee effects. Because of these considerations, the Plan recommends a three-level approach to management of human-caused removals, such that the rate of removal would decrease as the risk to the population of removal increased (red and yellow zones of Fig. 8).

The framework for managing human-caused removals also needs to be sensitive to the quality of data that supports it, and to our ability to distinguish the different mechanisms that might change the dynamics. The management strategy described above is predicated on being able to monitor the population size and the number of removals on a regular basis, ideally annually. Regehr et al. (2015) and Regehr et al. (in press) show that as the sampling error and interval between monitoring events increase, removal is still possible, but the removal rate needs to be set at a more cautionary level to guard against dropping below *mnpl*. Further, changes driven by loss of habitat quantity as opposed to loss of habitat quality will be difficult to distinguish, yet they have different effects on the sustainable level of removal (Fig. C-5). The Plan recommends that these considerations be included in the deliberations of co-management groups as they establish guidelines for removal of polar bears.

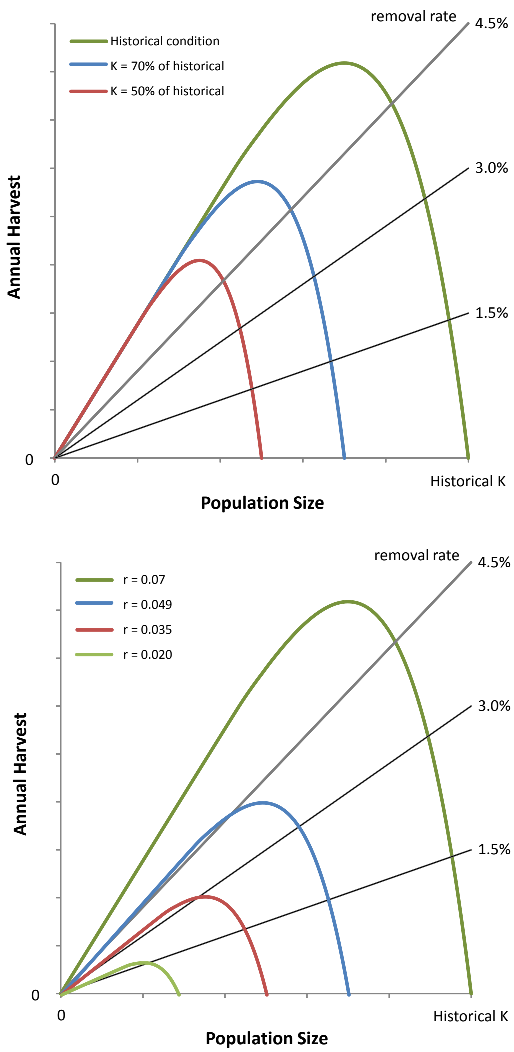

Figure C-5. The effects of reduced carrying capacity and reduced growth rate on harvest yield curves. Each graph shows the sustainable annual harvest against the corresponding equilibrium population size; three reference lines show removal rates of 4.5%, 3.0%, and 1.5%. The top panel shows three scenarios where the carrying capacity changes, but the intrinsic rate of growth remains the same ($r = 0.07$). The bottom panel shows four scenarios where the intrinsic rate of growth changes in the same proportion as the carrying capacity. The graphs were derived using a theta-logistic population model with $\theta = 5.045$, which roughly corresponds to dynamics for polar bears (Regehr et al. 2015, Regehr et al. in press).

APPENDIX C — LITERATURE CITED

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