Report to the US-Russia Polar Bear Commission: developed by the Scientific Working Group May 2010

PART 1: Harvest Management

I. Background

a. Bilateral Agreement and establishment of a Scientific Working Group

The bilateral "Agreement between the United States and the Russian Federation on the Conservation and Management of the Alaska-Chukotka Polar Bear Population (US-Russia Agreement)" was signed by the governments of the United States and the Russian Federation on October 16, 2000, and the U.S. Senate provided its advice and consent for ratification. The first meeting of the Commission formed to oversee implementation was held during September 23-25, 2009, in Moscow, Russia. Consistent with Article VIII.8. of the Agreement, the Commission identified Co-Chairs for a Scientific Working Group and directed the Co-Chairs to constitute their groups with up to 5 members by October 1, 2009; to hold their first meeting as soon as practical; to evaluate technical information and approaches and advise the Joint Commission regarding sustainable harvest levels per Article I of the Agreement; and to report to the Commission no later than 30 days prior to their next meeting (scheduled for June 7-9, 2010) on the results and recommendations from this effort.

b. Historical harvest and population status

Alaska

Prior to the 20th century Alaska's polar bears were hunted primarily by Alaskan natives for subsistence purposes although commercial sales of hides occurred primarily as a result of Yankee whaling and arctic exploration ventures. Polar bears were believed to have existed at or near carrying capacity, though no quantitative information is available to assess the status of the population at this time. During the 20th century polar bears were harvested for subsistence, handicrafts, and recreational purposes. Based on records of skins shipped from Alaska for 1925–53, the estimated annual statewide harvest averaged 120 bears and this take was primarily by native hunters. Recreational hunting by non-native sport hunters using aircraft became popular from 1951–72, increasing the statewide annual harvest to 150 during 1951–60 and to 260 during 1960–72 (Amstrup et al. 1986). During the late 1960s and 1970s the size of the Beaufort Sea stock declined substantially in (Amstrup *et al.* 1986) due to excessive sport harvest. Similar declines could have occurred for Alaska-Chukotka population, although there are no data to support this assumption.

Hunting by non-natives was prohibited in 1973 when provisions of the Marine Mammal Protection Act (MMPA) went into effect. The MMPA continued to allow Alaska natives living in coastal communities to harvest polar bears for subsistence and making of handicrafts provided that the hunt was not done in a wasteful manner. The prohibition of non-native sport hunting led to a reduction in the annual harvest of polar bears from the Alaska-Chukotka sea population (using a population boundary of Icy Cape, Alaska in the United States) from 189 ± 50 (standard deviation) bears/year for the period 1961-1972 to 80 ± 54 bears/year for the period 1973-1984 (Amstrup et al. 1986; Fig. 1). Starting in 1980, the U.S. Fish and Wildlife Service maintained more accurate records of native subsistence harvest in Alaska, although a low level of un-reported harvest occurs. From 1980 through the present, harvest of the Alaska-Chukotka population in the U.S. portion has declined (Fig. 1). Previous management documents have reported harvest for the Alaska-Chukotka population based on the IUCN boundary with the southern Beaufort Sea subpopulation (Aars et al. 2006), which reflects bears taken west and south of Icy Cape, Alaska (i.e., in Point Lay, Point Hope and villages further south and west; second row in Table 1). However, radiotelemetry studies indicate that many polar bears to the east of Point Hope, including those found near the communities of Wainwright and Barrow, Alaska, spend most of their time in the Chukchi Sea (Amstrup et al. 2000, 2004, 2005). Based on the population delineation work of Amstrup et al. (2005), approximately 100% of bears harvested west and south of Point Hope, 90% of bears harvested near Point Hope, 80% of bears harvested near Point Lay, 70% of bears harvested near Wainwright and 50% of bears harvested near Barrow are members of the biological Alaska-Chukotka population, and should be tallied in harvest numbers when making conservation decisions (first row in Table 1). The sex composition of 1830 polar bears harvested from 1980-2008 within the U.S. portion of the IUCN boundary for the Alaska-Chukotka population was approximately 31% females, 58% males, and 11% unknown sex. Reasons for a decline in the Alaska native subsistence harvest are currently unknown, but are currently being investigated. Possible causes include decreased polar bear numbers, changes in polar bear distribution, environmental conditions (e.g. unstable ice) that make polar bears less available to hunters, and decreased hunter effort.

Chukotka

Prior to the 20th century, similar to Alaska, polar bears were primarily hunted by indigenous native people residing in coastal areas for subsistence purpose. Some level of commercial sales of hides also occurred during this period; however the level of harvest was not believed to have had an effect on the overall population. During the early portion of the 20th century owing to expansion of Russian nationals in Arctic regions for purposes of exploration and development of natural resources, fur trapping and trading, and placement of military installation in the Arctic, the commercial take of polar bears increased substantially. Harvests at a significant level occurred for numerous years and then declined substantially based upon fur sale records. The declining harvest was believed to have resulted from decreased population size caused from overhunting (Belikov and Boltunov 1995). As a result in 1956, Russia banned all hunting of polar bears as a conservation measure. The ban on harvesting polar bears was actively enforced by Soviet authorities, although low levels of illegal hunting likely continued.

In the late 1980s and early 1990s the dissolution of the Soviet Union into autonomous regions and collapse of national support or subsidies for societal needs including food, fuel, and jobs created serious needs in arctic regions for basic necessities of food and fuel. Increased take of problem bears in Chukotka was acknowledged in the beginning of the 1990’s, along with an increase in illegal harvest (Belikov 1993). Decentralization of management authority, initiation of a free market economy, and increased economic pressures all likely contributed to the increase in illegal harvest. An exact quantitative estimate of the illegal polar bear harvest of the Chukotka-Alaska population in Russia is not possible since cases of illegal take are not documented. The number of illegally harvested polar bears in Chukotka varied between 70 and 300 bears per year according to expert estimates based on the information gathered through interviews in local villages from the early 1990's until 2005. Illegal hunting reached its peak in the late 1990's –early 2000's. The reduction in the number of illegally harvested bears has been reported in recent years. Likely causes of this reduction in harvest include lower demand and need, conservation efforts and environmental education as well as significantly lower accessibility of polar bears to hunters associated with changes in sea ice conditions. Based on the results of anonymous interviews taken from hunters in 1994-2003, 65% of the harvested bears were adult animals with the number of males being slightly higher than that of females. 35% were 1-3 year-old cubs.

c. Classification systems, status, and conservation designations

A number of national and international classification systems are in place and have been used to evaluate the status of polar bears. Using the Red List Criteria the IUCN/SSC has periodically evaluated the status of polar bears. Most recently on May 4, 2006, the IUCN/SSC Red List of Threatened Species was updated to include the "Vulnerable" classification of polar bears developed by the PBSG. Within Russia the Red Data Book is used to establish official policy for protection and restoration of rare and endangered species. Polar bears in the Alaska-Chukotka population are listed as Category V "restoring" in the second issue of the Red Data Book of the Russian Federation (2001). In the United States the Marine Mammal Protection Act (MMPA) and Endangered Species Act are the two primary statutes involved in the conservation and protection of polar bears. On May 15, 2008, the Service published a Final Rule in the Federal Register listing the polar bear range-wide as a threatened species under the Endangered Species Act (ESA). This listing is based on the best available science, which shows that loss of sea ice threatens and will likely continue to threaten polar bear habitat. Marine mammal species listed as either "threatened" or "endangered" under the ESA automatically convey a designation of a "depleted" species under the MMPA. The MMPA conditionally allows for subsistence harvest of marine mammals. Similarly the ESA includes provisions allowing for the continuation of harvest of threatened or endangered species provided that such take will not "materially or negatively" affect the species.

II. Approaches to identifying a sustainable harvest level

The Agreement defines sustainable harvest 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”. For wildlife populations the level of sustainable harvest is determined largely by population size, population growth rate, and species-specific dynamics such as the interaction of density-dependent and density-independent regulatory effects. Additionally, the level of sustainable harvest depends on the reproductive value (i.e., sex, age and reproductive status) of harvested individuals. If a population is declining in size due to environmental change, such as habitat loss, additional human-caused mortality may decrease the long-term viability of the population. Although it is possible that some level of harvest would be compensated for by density-dependent effects, human-caused mortality is likely to be at least partially additive to natural mortality. In this case, human-caused mortality may accelerate population declines and lower prospects for recovery should environmental conditions stabilize (e.g., Taylor 1994).

There are several methods of estimating sustainable harvest and evaluating the risks associated with different harvest strategies. These include simple equations based on population theory (e.g., Wade 1998) and more sophisticated methods that incorporate sex, age structure, and other dynamics (e.g., extended care of dependent young), such as matrix population models (Hunter et al. 2010) and life-table simulations (Taylor et al. 2009). Sophistication of the method used to model harvest should be consistent with the quality and resolution of the available data. When data are poor or characterized by large uncertainty, the extent of those uncertainties need to be identified at the outset and, the modeling method chosen should reflect the available data by remaining simplistic and incorporating uncertainty.

III. Available data on the ecology of the Alaska-Chukotka polar bear population relevant to:

a. Trends and projections in availability of sea ice habitat

The Intergovernmental Panel on Climate Change (IPCC 2007) concluded that warming of the climate system is unequivocal and that human produced greenhouse gases are playing a significant forcing role in global warming. As a result of this warming, the maximum ice cover of the Arctic Ocean declined significantly over the past 30 years both spatially and temporally (Comiso 2003, Rayner et al. 2003; Lemke et al. 2007). Using models developed from these observations over the past 30 years, the IPCC further projected that warming and associated declines in Arctic sea ice would continue throughout the 21st century (Meehl et al. 2007). Numerous scientists have provided additional support projecting significant loss of Arctic sea-ice over the next century (Serreze et al. 2003; Stroeve et al. 2005, Holland et al. 2006; Zhang and Walsh 2007). The rate of observed decline of summer sea ice has been occurring at a more rapid rate than predicted by climate model projections leading to increased concern over the rate of sea ice loss in the polar basin (Serreze et al. 2003; Comiso et al. 2008; Stroeve et al. 2005; 2007).

Concern regarding climate change and its associated effects on polar bears is broadly shared among the scientific community, including the IUCN Polar bear specialist group (PBSG) which issued a statement following their 2009 meeting stating that "documented changes in the pattern and timing of breakup and fluctuations in the seasonal distribution of sea ice significantly influence the condition, survival, and reproductive success of polar bears and their prey". As with any projection into the future, projections for sea ice conditions are associated with some uncertainty. Though models that include the effects of greenhouse gases are in agreement that future global temperatures will continue to increase and Arctic sea ice will continue to decline through at least 2050 (Holland et al. 2006; Meehl et al. 2007; Overland et al. 2007; Stroeve et al.

2007; Holland et al. 2008; Stroeve et al. 2008; Serreze et al. 2009), an alternative hypothesis has been presented which suggests that trends in climate and consequently ice cover will oscillate with the current warming period ending by 2015-2020 (Frolov et al. 2006). For the purpose of this report, we have assumed the broadly accepted scenario in which long-term warming will continue and have consequences for the habitat of polar bears.

Sea ice changes in the Chukchi Sea

Sea ice in the Chukchi Sea has exhibited some of the most extensive changes of any region in the Arctic in recent years (Rodrigues 2008; Durner et al. 2009; Markus et al. 2009). Scientific data (Rigor and Wallace 2004) and local observations suggest that reductions in sea ice in the Chukchi Sea became significant starting at the end of the 1980s. Rodrigues (2008) documented declines in sea ice extent and area in all Russian Arctic seas between 1979 and 2007. Loss was particularly high along the Alaskan and Chukotkan coasts. Markus et al. (2009) observed trends of earlier melt onset and later freeze up to be stronger in the Chukchi/Beaufort Seas than any other region in the Arctic. The melt season in the Chukchi and Beaufort Seas was estimated to have increased by 20 days between 1979 and 2007. These ice variables have been shown to be the primary drivers of reduced summer sea ice and therefore, likely reflect changes in a number of sea ice characteristics. The East Siberian and Chukchi seas have exhibited some of the most significant changes in the Arctic, including pronounced warming and thinning of the sea ice (Rigor et al. 2002).

The Chukchi sea many be particularly vulnerable to rapid sea ice loss due to the influence of warmer waters of the Pacific (Woodgate et al. 2006) as well as regional effects of atmospheric circulation (Rigor et al. 2002, Maslanik et al. 2007). Recently, it has been suggested that a positive feedback process exists between sea ice conditions and the ocean heat transport in the Chukchi Sea such that during years of reduced sea ice extent, heat transport is higher (Watanabe and Hasumi 2009). High index years of the Arctic Oscillation have been associated with a smaller Beaufort gyre and strong advection of fast ice away from the east Siberian Sea (and Chukchi Sea) (Rigor et al. 2002).

Observed and projected changes in the availability of polar bear habitat in the Chukchi Sea

Durner et al. (2009) used locations of radio collared polar bears to identify environmental and sea ice characteristics of habitats selected by polar bears in the Chukchi and Southern Beaufort Seas. Using those results, Durner et al. (2009) found that the Chukchi Sea has experienced one of the highest rates of decline in optimal polar bear habitat in the circumpolar Arctic between 1985 and 2006, at 8% per decade. Net annual habitat changes were characterized by dramatic losses during the summer with relatively little change during the winter. Durner et al. (2009) projected a continued rate of decline based on an ensemble of general circulation models as 7.8% per decade for the Chukchi Sea through 2050.

Documented population-level effects of sea ice loss on polar bears

Reductions in habitat over the past several decades have been associated with declines in bear body condition (Stirling et al. 1999; Obbard et al. 2006, Rode et al. 2010), vital rates (Regehr et al. 2007, 2009), and population growth rate (Hunter et al. 2007; Regehr et al. 2007). Polar bears are among the most ice-dependent Arctic marine mammals (Amstrup 2003; Laidre et al. 2008). They require sea ice as a substrate for long-distance movements, mating, and for access to their primary prey, ringed seals (*Pusa hispida*) and bearded seals (*Erignathus barbatus*). In western Hudson Bay, Canada, where the sea ice melts completely each year and forces polar bears to spend several months on shore, earlier sea ice breakup has been associated with declines in body condition, reproduction, survival of all age classes except prime-adults and population size (Stirling et al. 1999; Regehr et al. 2007). In the southern Beaufort Sea, declines in sea ice extent have been associated with changes in habitat use (Fischbach et al. 2007; Durner et al. 2009), indicators of nutritional stress (Regehr et al. 2006; Cherry et al. 2008; Rode et al. 2010), and reproduction and survival (Regehr et al. 2009; Rode et al. 2010). The size of the southern Beaufort population was recently estimated at 1526 (95% CI = 1,211; 1,841; Regehr et al. 2006). This suggests that the population has declined in size since the previous estimate of 1800 in the late 1980s (Amstrup et al. 2001), although differences in study methods and the low precision of abundance estimates prevent a definitive conclusion. Although the seasonal ecology of the Western Hudson Bay and Southern Beaufort Sea polar bear populations differ from the Alaska-Chukotka population, the fundamental dependence of polar bears on sea ice (Derocher et al. 2004), and the observed population-level effects of reduced sea ice on other polar bear populations suggest a cause for concern for the Alaska-Chukotka population.

b. Ecology

i. body condition

Quantitative data on the condition of polar bears in the Alaska-Chukotka population were collected during capture work between 1986 and 1994 and between 2008 and 2010. Data will continue to be collected as part of an ongoing capture effort, including a variety of potential indicators of bear condition (e.g., morphometric measures, body mass, and percent body fat). A comprehensive analysis of available data on body condition is not currently available but an effort has been initiated with the goal of presenting results at the 2nd meeting of the scientific working group.

ii. diet and foraging ecology

Polar bears in the Chukchi Sea have available to them a variety of prey species, including ringed seal, bearded seal, walrus (*Odobenus rosmarus*), spotted seal (*Phoca largha*), and ribbon seal (*Histriophoca fasciata*). Bowhead (*Balaena mysticetus*) and beluga (*Delphinapterus leucas*) whales also migrate through this area and are available as beached carcasses in both Russia (Ovsyanikov 2005; Kochnev 2006) and the United States (Kalxdorff 1998). Gray whales (*Eschrichtius robustus*) migrate along the cost of Chukotka and beached carcasses are available for polar bears. Aggregations of walrus in Russia have also resulted in the availability of carcasses to polar bears (Kochnev 2002; Ovsyanikov 2005), but availability and access to polar bears appears to vary year to year depending on local sea ice conditions.

Currently the contribution of various prey items to the diets of polar bears in the Chukchi Sea region has not been quantified. However, new techniques have become available, including stable isotope analysis of blood and hair and fatty acid analysis of fat biopsies, that will allow both retrospective diet analysis for blood samples collected from bears captured in the late 1980s and early 1990s and current diet analysis via stable isotopes and fatty acids for bears captured since 2008. Results of diet analyses are expected to be available in time for the next meeting of the scientific working group.

c. Movements and Distribution

Cooperative studies between the U.S. and Russia in the late 1980s and early 1990s, using telemetry to study movement, has revealed that polar bears in the area are widely distributed on the pack ice of the northern Bering, Chukchi, and eastern portions of the East Siberian seas (Garner et al. 1990, 1994). Based upon those early telemetry data, the western boundary of the population was set near Chaunskaya Bay in northeastern Russia. The eastern boundary was set at Icy Cape, Alaska, which also is the previous western boundary of the Southern Beaufort Sea population (Amstrup et al. 1986, Amstrup and DeMaster 1988, Garner et al. 1990, Amstrup et al. 1995, Amstrup et al. 2004, Amstrup et al. 2005). Data are incomplete for the western boundary of the Alaska-Chukotka population, but it is clear that the eastern boundary constitutes a large overlap zone with between Icy Cape and the Colville River with a portion of the bears in the from the Southern Beaufort Sea population (Amstrup et al. 2004, 2005). Movement data from satellite collars (Garner et al.1990, Amstrup 1995, 2000) confirm the internationally shared nature of the Alaska-Chukotka population between the US and Russia and more recent research by Amstrup et al. (2005) describes the probability of Alaska-Chukotka or Beaufort Sea stock of polar bears occurring geographically across the north slope of Alaska.

Adult female polar bears captured from the Southern Beaufort Sea stock may make seasonal movements into the Chukchi Sea in an area of overlap located between Point Hope and Colville Delta, centered near Point Lay (Garner et al. 1990, Garner et al. 1994, Amstrup 1995, Amstrup et al. 2002, Amstrup et al. 2005). Telemetry data indicate that these bears, marked in the Beaufort Sea, spend about 25% of their time in the northeastern Chukchi Sea, whereas females captured in the Chukchi Sea spend only 6% of their time in the Beaufort Sea (Amstrup 1995). Average activity areas of females in the Chukchi/Bering seas from 1986–1988 (244,463 km2, range 144,659–351,369 km2) (Garner et al. 1990) were more extensive than the Beaufort Sea from 1983– 1985 (96,924 km2, range 9,739–269,622 km2) (Amstrup 1986) or from 1985–1995 (166,694 km2, range 14,440–616,800 km2) (Amstrup et al. 2000). Radio collared adult females spent a greater proportion of their time in the Russian region than in the American region (Garner et al. 1990).

An on-going capture-based study started in 2008 has deployed 29 radiocollars on adult females to date. Once sufficient data become available from multiple years of study, new analyses can be conducted to determine whether current patterns of distribution, movement, and habitat use are similar to, or differ from, these historically observed patterns. Furthermore, these data will be used to identify the characteristics of selected habitats and to examine observed and projected changes in habitat availability.

d. Denning ecology

Distribution of polar bear dens on the Arctic coast of Chukotka

There are two major denning areas for female polar bears of the Alaska-Chukotka population: 1. Wrangel and Herald Islands; 2. the mainland coast of Chukotka, including coastal islands. The majority of female polar bears den in the first region. These islands are part of Wrangel Island Federal Nature Reserve. The number of polar bear dens on Wrangel and Herald Islands has varied in different years. Aerial surveys conducted on Wrangel Island in the 1980s estimated more than 300 dens on Wrangel Island alone (Stishov 1991). Though no systematic surveys have been conducted, anecdotal information suggest that less than 100 dens have occurred on Wrangel Island in recent years and that den numbers in several surveyed areas have declined.

The number and distribution of polar bear dens on the mainland coast is primarily influenced by variability of sea ice conditions, particularly patterns of ice break-up and retreat in summer and the timing of establishment of ice cover in late autumn (Belikov et al. 1986). Moreover, both accumulation of sufficient snow cover by the time female bears enter dens and the distribution of food sources on the coast have noticeable impact on the autumn distribution of pregnant females. Female bears that den on the mainland coast are females that do not travel north with the retreating ice, as well as female bears that return from their summer habitats with the establishment of ice cover. Females arriving on shore from marine areas in autumn have always constituted the majority of females denning on the coast. However, late re-establishment of ice cover between Wrangel Island and the pack ice in the southern Chukchi Sea (in late November-December) over the past decade has prevented females from reaching most of the Chukotka coast east of Cape Schmidt in time to den. This is likely the reason for evidence of considerably lower numbers of females denning on the coast in recent years compared to estimates of dens made in the 1980s, based on the results of aerial surveys (Stishov 1991), and estimates made in the late 1990s-early 2000s based on traditional ecological knowledge (Kochnev et al. 2003). On the mainland, females den not only on the coast but also farther inland (50-60 km) on the tundra.

Currently, the only denning areas that have protected status are those located on Wrangel and Herald Islands. Polar bear denning areas outside of protected areas are not protected from possible disturbance factors and poaching when entering and emerging from maternal dens.

e. Traditional knowledge

Kalxdorff (1997) conducted a study of local knowledge of polar bear habitat use in Alaska. This study also provided some information on feeding ecology. Similar studies were conducted in Chukotka as well (Kochnev et al. 2003). Local knowledge suggests that ringed seals are an important food resource for polar bears in the Chukchi Sea. Marine mammal carcasses were also identified as an important food source. Key habitats included recurring leads and active ice. The study supported scientific evidence that denning occurs primarily in Russia. However, hunters did identify some denning habitat in Alaska including areas on St. Lawrence Island, the east side of Little Diomede Island, east of the village of Wales, and at Cape

Thompson. A study is currently planned to provide updated information on the local knowledge of Alaskan Natives since negative trends in available sea ice and subsistence harvest level have occurred since the last study was conducted in 1997.

f. Sex and age composition.

Polar bears were captured off the US Chukchi Sea coastline between Cape Lisburne and the village of Shishmaref between 2008 and 2010 and will continue to be captured in future years as part of an ongoing research effort. Sex and age information from captured bears can be used to derive indices of survival and reproduction. Sex and age information for polar bears harvested in the US portion of the Chukchi Sea, and for polar bears captured in the region between 1986 and 1994, will be used for comparison. An analysis of available data on the sex and age composition of the capture and harvest samples is scheduled to be available for the 2nd meeting of the scientific working group.

IV. Harvest risk analysis

It is not possible to derive accurate estimates of sustainable harvest for the Alaska-Chukotka polar bear population because information on population size, status, growth rate, composition, and distribution are largely unknown. Nevertheless, it is possible to estimate harvest levels for a hypothetical, though plausible, range of conditions that if maintained for a specified time period will be unlikely to negatively affect the population. This can help resource managers evaluate the probability that current harvest levels are sustainable, and identify harvest levels that could be considered in the future when the population is better understood. A thorough harvest risk analysis that incorporates uncertainty in both known and unknown population parameters, and uncertainty in our understanding of polar bear population dynamics (e.g., the relationship between density and population growth), should be performed when new information on the Alaska-Chukotka population becomes available.

We evaluate harvest using a modified version of the Prescribed Take Level (PTL) method (Runge et al. 2009). The PTL method is derived from basic harvest theory and is similar to the Potential Biological Removals (PBR) method used in conjunction with the U.S. Marine Mammals Protection Act (Wade 1998). The level of prescribed (or allowable) take is calculated as:

$$PTL_t = F_0 \frac{r_{\max}}{2} N_t,$$

where the subscript t indicates that harvest level is specific to conditions in year t and should be recalculated periodically, F_0 is a factor that reflects management and conservation objectives, r_{max} is a discrete growth factor representing the maximum natural rate of increase (i.e., assuming the population is not limited by density effects) under existing environmental conditions, and N is population size (see details in Runge et al. 2009).

For the Alaska-Chukotka polar bear population we use $F_0 = 0.75$. We do this for two reasons. First, our calculations consider a range of values for r_{max} from a low value of 0, which represents no potential for positive growth, to a high value of 0.06, which is near the maximal population growth rate that has been observed for polar bears (Amstrup 1995; Hunter et al. 2007; Taylor et al. 1995, 2009). We take this approach because the data necessary to calculate r_{max} are not available for the Alaska-Chukotka population, and by varying r_{max} we explicitly acknowledge the potential for density-independent limitations on maximum natural growth due to changing environmental conditions. In other words, our modified PTL method achieves conservative management by lowering r_{max}, an ecological parameter that is easily interpreted, rather than by using a lower value of $F_0 = 0.50$ as recommended under the MMPA for threatened stocks or stocks of unknown status (Barlow et al. 1995). This reflects a slightly different interpretation of the management factor F_0 (also called the "recovery factor"; Runge et al. 2004), but does not reflect a substantive departure from the original PBR method. Similar modifications of the F_0 factor have been applied to the management of other threatened and endangered marine mammals (Wade and Angliss 1997). In our case, varying r_{max} has the same effect on the model outcome as using a lower value for F_0. For example, using $F_0 = 0.75$ and $r_{max} = 0.04$ leads to the same estimate of sustainable harvest rate as $F_0 = 0.50$ and $r_{max} = 0.06$. The second reason we use $F_0 = 0.75$ is because the PTL method estimates sustainable yield assuming that polar bear population dynamics follow a logistic growth pattern with linear density dependence (i.e., that observed population growth rate decreases linearly as population size increases from 0 to carrying capacity). Density-dependent effects have not been clearly identified for polar bears because they are difficult to detect and because harvest maintains many polar bear populations below carrying capacity (Derocher and Taylor 1994). However, several recent studies have suggested potential observed density dependent effects for polar bear populations with no harvest, low levels of harvest, or reduced habitat availability (Derocher 2004; Peacock 2009; Rode et al. 2010). When density-dependence is included in population models, the largest sustainable take occurs when a population achieves maximum net productivity. For the PTL method, this occurs at a growth rate of 50% of r_{max}, and a population size of 50% of K. However, density dependence for long-lived mammals is generally non-linear and only becomes important as the population approaches K (Fowler 1981, Taylor and DeMaster 1993). In other words, bear populations are likely capable of achieving population growth rates larger than 50% of r_{max} at population sizes larger than 50% of K. Thus, the use of $F_0 = 0.75$ allows for a logistic pattern of density-dependent growth and is a conservative representation of polar bear population dynamics relative to models that do not incorporate density-dependence.

The PTL method assumes non-selective harvest and equal reproductive value of all harvested animals. However, the reproductive value of adult female polar bears is higher than other sex and age classes (Taylor et al. 1987, Eberhardt 1990), and historic polar bear harvests have demonstrated the ability of hunters to select for certain sex, age, and reproductive classes (e.g., Derocher et al. 1997). To allow for different levels of harvest of adult males and females, we first calculated a base harvest level, which assumes an equal sex ratio, using PTL. We then allowed for additional male harvest to achieve a 2:1 male-to-female sex ratio in the total harvest. This approach is based on evidence that, if any female harvest level is sustainable, a 2:1 male-to-female sex ratio is generally conservative and sustainable, although it may reduce the number and age of males (Taylor et al. 2008).

When the maximum population growth rate is high ($r_{max} \approx 0.06$, the upper limit for polar bears) our modified PTL method is similar to, but more conservative than, the method of Taylor et al. (1987). Taylor et al. (1987) suggest that the number of female polar bears that can be harvested sustainably per year is 1.5% of the total population size, and that males can be harvested at twice this rate, for a total annual harvest rate of 4.5% of population size (Table 2). This approach has a long history of use throughout the Canadian Arctic (Aars et al. 2006). Our modified PTL method suggests that, when $r_{max} = 0.06$, sustainable harvest rates for females and males are 1.13% and 2.25%, respectively, for a total annual harvest rate of 3.38% of population size. Our method is more flexible than the method of Taylor et al. (1987) because it can be adjusted for populations with different maximum population growth rates.

Table 2 reflects uncertainty in the current status of the Alaska-Chukotka population by presenting hypothetical sustainable harvest levels for a range of population sizes (*N*) and maximum population growth rates (r_{max}). Although accurate information is lacking, some values of *N* and r_{max} are more biologically plausible than others. Belikov (1992) estimated the size of the Alaska-Chukotka population to be 2,000-5,000 based on an estimated 300-400 breeding females that comprised 8-10% of the population. More recently, based on historical studies, expert opinion among members of the IUCN Polar Bear Specialist Group estimated the size of the Alaska-Chukotka population to be 2000 bears (Aars et al. 2006). Although an estimate of maximum population growth rate is not available, documented reductions in sea ice (see Section IIIa) suggest that limits on the temporal availability of optimal polar bear habitat (Durner et al. 2009) and other factors may have reduced r_{max} to below the value of 0.06 estimated for polar bears. Recent studies indicate sea ice declines similar to, but less severe than, those observed in the Chukchi Sea have resulted in negative observed population growth for other polar bear populations (Regehr et al. 2007, Regehr et al. 2009, Hunter et al. 2010). These declines were likely the result of both density-dependence (i.e., reduction in *K*; Rode et al. 2010) and density-independent factors (i.e., reduction in r_{max}) although the actual mechanisms are unknown.

In the short-term, it is possible that a low (e.g., see below) level of harvest would not lead to declines in the size of the Alaska-Chukotka population, if we assume that the population is not severely depleted and that, despite losses in sea ice habitat, high biological productivity within the Chukchi Sea (Springer and McRoy 1993) and other ecological factors can support positive population growth. Using $N = 2000$ and $r_{max} = 0.04$ as plausible upper limits on the size and status of the Alaska-Chukotka population, we estimated that it may be possible that 15 females and 30 males could be taken sustainably each year (for a total harvest of 45 polar bears/year;

Table 2). Clearly, the recent reported harvest of 150-200 bears/year in Russia plus 58 bears/year harvested in the U.S. (this report) exceeds this level and is therefore likely causing the population to decline. Indeed, the recent reported harvest exceeds sustainable harvest levels under theoretically maximal values of population size and growth rate (Table 2).

If sea ice loss continues as projected, the Alaska-Chukotka polar bear population will likely exhibit severe population declines in the next 100 years (Amstrup et al. 2008). Under these conditions there is no long-term "sustainable harvest", which the Agreement defines as "a harvest level that . . . maintains the population at or near its current level". If future population declines are caused primarily by reduced environmental carrying capacity, and if the population maintains the potential for transient positive growth at sizes below carrying capacity (i.e., $r_{max} > 0$), it is possible that harvest could continue. In other words, it is possible that a low level of harvest would lead to smaller population sizes vs. an un-harvested population, but would not accelerate the rate of population decline. For this to be true, harvest could not be implemented at a fixed level (i.e., a fixed number of bears per year). Rather harvest levels would have to be re-evaluated periodically using updated information on sustainable harvest rate, calculated as a function of r_{max} and population size (*N*). However, given lack of current evidence that the population is capable of positive growth, uncertainty regarding the mechanisms of population regulation due to sea ice loss, and the increased risk of extirpation or other negative effects for smaller populations, any level of human-caused mortality likely decreases the long-term viability of the Alaska-Chukotka polar bear population.

V. Population projections under different harvest levels

We evaluate the potential effects of human-caused mortality on the Alaska-Chukotka polar bear population by projecting population size forward in time. These projections do not forecast the future status of the Alaska-Chukotka population. Rather, they evaluate the *relative effects* of different levels of human-caused mortality, given a number of assumptions. We do not consider uncertainty or variability in population status, population processes, or environmental conditions. Thus, the resulting projections are deterministic and do not estimate the risks of future population decline. We assume a simple and stationary relationship between habitat availability and polar bear population dynamics. This does not consider the potential for non-linear biological responses to changing habitat conditions (e.g., ecological effects at lower trophic levels). Also, we do not consider migration between the Alaska-Chukotka population and neighboring populations, although changing movement patterns for polar bears and the breakdown of historic population boundaries are potential effects of declining Arctic sea ice (Derocher et al. 2004). Given these assumptions, and others listed below, the population projections likely provide a useful perspective on the effects of human-caused mortality. It is recommended that future analyses formally incorporate uncertainty in both known and unknown population parameters, environmental conditions, and the underlying population models. If new information becomes available on the status of the Alaska-Chukotka population, or the ecological mechanisms by which sea ice loss affects polar bears, more detailed population models may be appropriate. For example, matrix-based models can explicitly consider the effects of survival, recruitment, and the multiple-year reproductive cycle of polar bears (e.g., Hunter et al. 2007).

Population size is projected forward in time using the model:

$$N_{t+1} = N_t + r_t N_t - h_t N_t,$$

where the subscript t denotes year, N is population size, r_t is the realized population growth rate, which is a function of r_{max} and population size relative to carrying capacity (see equation below); and h is harvest rate as a fraction of population size. We incorporate density-dependent limitations on the realized growth rate using the Mechalis-Menton equation:

$$r_t = r_{\max} \times \frac{\left[\left(K_t / N_t\right) - 1\right]}{\left[\left(K_t / N_t\right) - 1 + KS\right]},$$

where r_{max} is the maximum potential population growth rate, K is the estimated environmental carrying capacity, and KS is a Mechalis-Menton constant that defines the form of a nonlinear relationship between r_t and N. The Mechalis-Menton equation has been proposed as a realistic representation of density dependence for bears (Taylor et al. 1994). When $KS = 1.0$, this equation reduces to a logistic density-dependence curve (Fowler 1981). We use $KS = 0.5$, which results in maximum sustainable yield when population size (N) is approximately 60% of carrying capacity (K), based on previous studies for long-lived mammals. We assume that the starting size of the Alaska-Chukotka population (N_{2010}) is equal to $0.6K$. This represents the hypothesis that potentially high levels of human-caused mortality in the past 20 years (this report) have reduced abundance to below the current environmental carrying capacity. In other words, we assume that excessive harvests from the Alaska-Chukotka population in recent years have caused the population to decline faster than it would have because of habitat restrictions alone. Hence, although K may be declining, the numbers of bears in the population may have been held below even the population size associated with this declining K. The population could therefore exhibit some positive, although transient growth in the absence of human-caused mortality or in the presence of a limited human-caused mortality. Because females are the most important determinant of population growth for polar bears (Eberhardt 1990, Hunter et al. 2007, Taylor et al. 1987), we project population size forward using females only. Considering only females will underestimate the impacts of human-caused mortality on total population size, if actual harvest levels include the take of males at a 2:1 male-to-female sex ratio, as recommended by the modified PTL method (this report). In other words, our projections do not reflect the potential for a sex-selective harvest to reduce the number of males in the population relative to the number of females (Taylor et al. 2008). We include an arbitrary quasi-extinction threshold of 30% of starting population size, to emphasize the potential for reproductive collapse due to the depletion of males if the population becomes severely reduced (Molnar et al. 2007).

Our population projections include the potential negative effects of climatic warming by assuming a linear relationship between environmental carrying capacity (K) and habitat availability. The availability of optimal sea ice habitat for polar bears was defined by Durner et al. (2009) using resource selection functions constructed from the movements of radiocollared polar bears. We assume that K changes at a rate of -2% per year, based on the geometric mean rate of change in the availability of polar bear habitat in the Chukchi Sea for the period 1997-2006 (Durner et al. 2009). This decline is greater than predicted by the ensemble mean of global climate models (-0.61% per year for the period 2001-2050; Durner et al. 2009). This reflects that observed declines in summer sea ice extent have been “faster-than-forecasted” by climate models (Stroeve et al. 2007). Future analyses should consider multiple habitat metrics and multiple rates of habitat change. For example, polar bears may be affected by the seasonal availability of sea ice during important foraging periods in the spring and autumn (Regehr et al. 2007, 2009). In the Chukchi Sea, declines in seasonal sea ice availability (e.g., relating to the length of the ice-free season; Rodrigues et al. 2008) have been greater than declines in annual, integrated habitat availability as estimated by Durner et al. (2009). Similarly, future analyses should consider multiple relationships between habitat conditions and polar bear population dynamics. For example, our population projections only consider that sea ice loss affects polar bears via the density-dependent effects of reduced carrying capacity. However, evidence for the negative effects of sea ice loss on other polar bear population suggests that density-independent effects (i.e., reduction of r_{max}) may also occur. We believe that a -2% per year change in K represents a reasonable, initial approximation for the effects of sea ice loss on polar bears, for the purpose of evaluating the relative effects of different harvest levels (i.e., not of the purpose of accurately predicting future population status).

As described in the *Harvest risk analysis section*, we assume that N_{2010} = 2000 (1000 females and 1000 males) and r_{max} = 0.04 are the upper plausible limits on population parameters for the Alaska-Chukotka population. We use these starting parameters to project the population forward in time, recognizing that the resulting projections likely represent an optimistic view of the effects of harvest. Figure 2 shows the relative effects of different fixed-level harvests on the number of female polar bears in the population. Harvest at a fixed level (i.e., harvesting a constant number of bears per year, without re-evaluation) represents a risky approach and is not recommended. If harvest levels are too high, or if population size declines for reasons other than harvest, a fixed-level harvest will remove a progressively larger fraction of the population each year. This will lead to accelerated population declines. Harvest at a fixed level is shown here for comparison with the recommended *fixed-rate* harvest approach (Figure 3), which re-evaluates harvest levels periodically as a fraction of current population size. Given our assumptions about the size and status of the Alaska-Chukotka population (N_{2010} = 1000 females and r_{max} = 0.04),

Figure 2 indicates that the removal of 100 females per year, the highest level considered, would likely result in severe declines within the next decade. Human-caused removals of 62 and 34 females per year also appear to be unsustainable within the next decade. Removal at the recommended upper plausible limit of 15 females per year appears to be sustainable in the short-term. However, for both the scenario with no removals and with the removal of 15 females per year, the assumed effects of changing environmental conditions become apparent within 20 years as declining carrying capacity results in negative realized population growth and therefore in declining population size. As evidenced by the scenario with no removals, the population projection model exhibits a lag between declining *K* and declining *N* (i.e., for any given year, *N* is actually above *K*). This occurs because *K* is declining rapidly, and the low value of r_{max} used in our projections constrains the realized population growth rate for both positive and negative change. Because we have assumed that changing environmental conditions will affect polar bears via density-dependent mechanisms (i.e., reduced carrying capacity), a relatively low level of harvest at 15 females per year leads to smaller population sizes vs. an un-harvested population, but does not accelerate population declines. In this case, density-dependent effects partially compensate for human-caused removals. However, if future environmental changes affect polar bears via density-independent limitations (i.e., reduced r_{max}), human-caused removals would likely be additive to other population declines.

Figure 3 shows the relative effects of different fixed-rate harvests on the number of female polar bears in the Alaska-Chukotka population. In the first year of projections (i.e., 2010), these harvest rates produce harvest levels equal to Figure 2. However, using a fixed-rate approach, harvest levels are adjusted each year based on population size. Our modified PTL approach recommends that the upper plausible limit on female harvest rate is 0.015 (i.e., an annual removal of 1.5% of the female population). For example, harvest at this rate results in a harvest level of 15 females per year when N = 1000, 17 females per year when N = 1100, and 14 females per year when N = 900. Comparison of Figures 2 and 3 shows that harvest at a fixed-rate protects against accelerated harvest-reduced declines if harvest rates are too high, or if the population is declining for other reasons (e.g., declining carrying capacity). Figure 3 indicates that, given our assumptions for the current size and status of the Alaska-Chukotka population, the harvest of females at a rate above 0.015 is likely to be un-sustainable.

Table 3 shows the percent change in population size for different harvest rates, relative to a population with no harvest. This is the same information presented in Figures 2 and 3. However, the table emphasizes that the intention of the population projections is to evaluate the relative effects of different harvest strategies, not to provide accurate forecasts of the future status of the population. Table 3 suggests that removing females at a rate of 0.015 is likely to result in female population sizes approximately 14% lower than the un-harvested female population size.

VI. Harvest management options

Table 3 shows two qualitative management options and anticipated effects on the Alaska-Chukotka polar bear population. Option 1 would require a total moratorium of harvest. Option 2 is a regulated harvest at a level that is likely to be sustainable in Russia and the U.S. based on the best available information. Sustainable harvest level is up to 45 polar bears (Table 2). Both options would reduce harvests from existing levels and consequently both options would provide potential benefits to the status of the population. Both of these options assume that an active harvest monitoring and enforcement program will be implemented, and these programs will be effective and validated. Additionally, an adaptive management framework will be implemented to periodically re-evaluate harvest levels based on updated population information for both of the options. Given the current lack of quantitative scientific information regarding what may constitute a sustainable harvest, selection of either management option should be considered as short-term, 1-3 years, and contingent upon readjustment pending the results of future planned research.

Given the rapid rate of sea ice loss (Durner et al. 2009), projected long-term declines for the Alaska-Chukotka polar bear population (Amstrup et al. 2008), and reportedly high levels of harvest, a moratorium on harvest in both the U.S. and Russia is the management option consistent with a precautionary scientific approach, sustainability, and application of the "reliable scientific information" requirement of the treaty (Option 1 in Table 3). A moratorium would minimize the risk of harvest-induced declines while managers pursue the two highest conservation priorities: (1) research studies to understand the status of the population, and (2) reduction or elimination of illegal killing in Russia. Effective enforcement of the moratorium would be necessary in both Russia and the U.S. to achieve the anticipated conservation benefits under Option 1.

Support by local users in both the US and Russia for the selected management option may be most effectively achieved by allowing a regulated and low level of harvest in both countries, along with the maintenance (in the US) and establishment (in Russia) of mandatory harvest monitoring and enforcement systems. A harvest if allowed under Option 2 should not exceed 15 female and 30 male polar bears per year (see the Harvest risk analysis section). Option 2 would allow an equitable, yet limited, harvest in both the US and Russia and would potentially generate endorsement and support from user groups and hunters, which is likely to be essential to the long-term conservation of the Alaska-Chukotka population. Furthermore, data collected from harvest monitoring would provide data that is useful to inform future management decisions for the population. This option is consistent with the standards for "sustainable harvest" and it is based on what is considered to be the most reliable scientific information available in making this assessment. The Scientific Working Group did not consider the relationship of Option 2 with domestic legislations such as the U.S. MMPA and ESA. As noted earlier, any allowed harvest should be considered short-term for a period of prescribed duration, and should be discontinued or modified based on results of future studies.

PART 2: Research needed to improve estimation of sustainable harvest levels

Article VIII of the Agreement tasks the Commission with "considering scientific research programs, including jointly conducted programs, for the study, conservation, and monitoring of polar bears, and preparing recommendations for implementing such programs, and determining criteria for reporting on and verification of polar bears taken;" This task is important because determining sustainable harvest requires information on polar bear distribution, abundance, reproduction and survival, health and condition, and the status of their prey base and habitat. As a result, the Scientific Working Group is developing recommendations for research required to improve the accuracy of estimating sustainable harvest levels. This section outlines efforts that have been made to identify research goals, current research efforts, and possible approaches to address identified research needs. However, a comprehensive research plan for the Alaska-Chukotka population is needed and is a top priority for future meetings of the scientific working group.

A first step towards identifying research goals for the Alaska-Chukotka population occurred at a technical meeting between US and Russian biologists in August 2007 in Anchorage, Alaska. This group, which included 6 of the current members of the scientific working group (Stanislav Belikov, Andrei Boltunov, Anatoly Kochnev, George Durner, Eric Regehr, and Karyn Rode) identified a number of research priorities, including: estimating population size, estimating vital rates and the ecological processes that drive them, evaluating population delineation, determining patterns of seasonal distribution, and identifying essential terrestrial and sea ice habitats. Ongoing and future research was also discussed by some members of the scientific working group (Stanislav Belikov, Andrei Boltunov, Nikita Ovsyanikov, Eric Regehr) and others at an ad hoc workshop held in October 2008 in Odessa, Ukraine. The workshop recognized the importance of concurrent research programs in both the US and Russia, and the central role of radiotelemetry to the conservation of the Alaska-Chukotka population. Workshop participants identified possible collaborative studies to include, among other objectives, the application of radiocollars to polar bears on Wrangel Island, the Chukotka coast around Vankarem and Nutepelmen, or the western portion of the Chukotka coast.

Estimating population size has been identified as one of the most important research needs for the Alaska-Chukotka population. However, this is also one of the greatest challenges in wildlife management, even for relatively discrete and accessible populations (e.g., Williams et al. 2002). Estimating the size of the Alaska-Chukotka polar bear population is particularly challenging because the population is widely dispersed and difficult to access. Even if traditional methods of population estimation (e.g., aerial survey or capture-recapture) can be applied, future estimates of population size are likely to be characterized by low precision and substantial bias. Similarly, it is improbable that changes in estimates of population size will be detected in time to make management changes in response. Therefore, we propose that emphasis be placed on studies to evaluate whether existing conditions are likely to lead to population declines. This includes a broad research program to monitor demographic (e.g. sex and age) and ecological (e.g. bear condition, habitat use, and feeding ecology) trends, and a system to acquire accurate information on the level of human-caused mortality. A Bayesian Network, or related conceptual model, would benefit management by synthesizing data from these research and harvest monitoring programs. This approach would incorporate both quantitative and qualitative information, and the uncertainties in that information, to determine population status and identify management options for the Alaska-Chukotka population.

Several efforts have been made or are on-going to evaluate the application of capture-recapture and aerial survey techniques for estimating the size of the Alaska-Chukotka polar bear population. A recent pilot study to assess aerial survey as a method for estimating the size of the Alaska-Chukotka population (Evans et al. 2003) demonstrated the significant complexities of this approach. Neilson and Stahl (2008) concluded that estimation of population size using an aerial survey would require the following components:

1. An autumn aerial survey using helicopters based on an ice breaker, to estimate the number of bears in sea ice habitats. This would require an updated resource selection functions (RSF) to estimate habitat use. The study design includes a partial survey of available sea ice habitats, and use of the RSF to extrapolate polar bear densities from surveyed areas to areas that are not surveyed. Ongoing radiotelemetry studies prior to the survey would be required.
2. Simultaneous estimates of the number of bears on the Chukotkan coast, the US Chukchi Sea coastline, and Wrangel Island.

Under ideal conditions, this effort would produce a single estimate of the size of the population, with a coefficient of variation of approximately 21-25% (Nielsen and Stahl 2008). This approach would require optimal weather and sea-ice conditions during the year of the survey, preliminary efforts to fine-tune survey methods, significant resources, and extensive cooperation and coordination among a team US and Russian researchers. Thus, there is a high cost, both in terms of human and financial resources, and a high level of risk (i.e. that conditions during the year of the survey are not favorable) to obtain a single point estimate of the size of the population with a relatively large confidence interval.

Capture-recapture is also currently being evaluated as a potential approach to estimating population size and vital rates. This approach has the added benefit of providing additional data on bear movement patterns and habitat use via radio-tags deployed during capture efforts and data on bear health, condition, and feeding ecology via measures and samples obtained. In 2008 and 2009, 35 and 39 polar bears were captured and released, respectively, in the US portion of the Chukchi Sea. Currently, spring capture efforts are continuing in the Chukchi Sea and a total sample size of over 100 bears is expected by May of 2010. Data from captured bears will be used to evaluate the feasibility of using standard capture-recapture methods to estimate population size and vital rates and will simultaneously provide samples to evaluate the effects of changing environmental conditions on bear health, condition, incidence of disease, contaminant levels, and foraging ecology. In addition, this effort has provided the opportunity to deploy radio-collars on 21 adult females between 2008 and 2009 and additional radio-tags in 2010. Data from these radio-tags will be used to update seasonal distribution and habitat use patterns – information that is required prior to moving forward with traditional approaches to estimating population size or evaluating any potential approaches to index population size or status. This information will allow the scientific working group to identify the best approach to assess the size and the status of the Alaska-Chukotka population and to establish a comprehensive research plan in the near future.

Sampling efforts to quantify vital rates, condition, and health are currently focused along the US coastline in the eastern portion of the Chukchi Sea. In partner with this work, a study using spatial and genetic data is being initiated to aid in determining whether this geographically limited sample is representative of the Alaska-Chukotka polar bear population and to identify geographic locations that will provide the most representative sample of the population. Genetic analyses, combined with analysis of home range patterns from telemetry data, can be used to assess whether bears in the Alaska-Chukotka population exhibit local site fidelity or whether bears are likely to use habitats throughout most of the population's range. Although capture operations near the western boundary of the Alaska-Chuktoka polar bear population may be prohibitively challenging, genetic sampling is possible and has been demonstrated in recent years. The US Fish and Wildlife Service in collaboration with Andrei Boltunov, Viktor Nikiforov, Nikita Ovsyanikov, and others are developing a study to examine relatedness of individual polar bears in the Alaska-Chukotka population as a function of geographic distribution. Samples have already been collected from some locations and will ultimately come from bears on the Chukotkan coast, Wrangel Island, and sea ice off the US coastline.

An effort is also being made to expand capture efforts to Russia to improve the geographic distribution of the capture sample. Wrangel Island contains one of the highest known denning concentrations for polar bears and is a key terrestrial refuge for a significant component of the Alaska-Chukotka population during the ice-retreat season. This provides a unique opportunity for land-based captures in conjunction with continuation and expansion of ongoing observational studies. The Chukotka coast, around Vankarem and Nutepelmen, may also offer the opportunity to capture a limited number of polar bears, in conjunction with monitoring and community-oriented conservation programs currently underway.

Population delineation based on radiotelemetry and genetic studies is also relevant to the allocation of harvest between the Alaska-Chukotka and adjacent southern Beaufort Sea populations (Amstrup et al. 2005). This information improves estimates of vital rates (e.g., by identifying the effects of emigration on estimates of apparent survival from capture-recapture) and possibly population size (e.g, by extrapolating density estimates beyond the geographic area exposed to sampling). Radiotelemetry data will provide information on patterns of habitat use via home range models, resource selection functions, and individual-based models, as well as the response of polar bears to sea ice loss, which is necessary to improve long-term forecasts for polar bears (e.g., Amstrup et al. 2008). Movement information, including the seasonal segregation of polar bears onto land and sea ice, will aid in identifying areas of overlap with human settlements and activities (e.g., oil and gas development). In 2010, additional movement information will be obtained by applying ear-mounted radio tags to all independent polar bears during US-based captures. Advances in radiotelemetry methods, such as double-tagging and proximity tag systems, may eventually improve the ability to estimate survival and reproduction.

Indices of survival and reproductive success can be obtained from the sex, age, and reproductive composition of a population (Skalski et al. 2005). The composition of the US-based capture sample from 2008 to 2010 may provide information on the current status of the Alaska-Chukotka population, including the demographic effects of high levels of human-caused mortality in Russia. Comparison of the age and reproductive status of adult females in the current capture sample, to similar data collected by Gerald Garner in the late 1980s and early 1990s, may indicate temporal trends in population composition associated with human take or habitat change. Similar signals may be apparent in a comparative and longitudinal analysis of approximately 500 cementum-annuli ages for polar bears harvested in the US portion of the

Chukchi Sea since 1980. The USFWS and USGS are currently working to begin these analyses, with the goal of presenting results at the 2011 scientific working group meeting. Simulation methods such as population trend reconstruction and retrospective analyses of changes in environmental carrying capacity may be important to this effort.

Bear health and condition data can be used as indices of survival and reproductive success, which are important determinants of population growth rate and therefore relevant to sustainable harvest. Trends in health and condition can also provide an initial assessment of potential population responses to environmental change (Derocher and Stirling 1998; Rode et al. 2009). In the Chukchi Sea, where sea ice has declined substantially over the past several decades, comparative analyses of body condition and feeding ecology may indicate how the population is responding to this change. Data collected by Gerald Garner in the late 1980s and early 1990s during captures of polar bears in the Chukchi Sea allow the opportunity to compare body condition, health, and feeding ecology over a time frame when changes in the sea ice occurred. Relatively new techniques that examine fatty acids and stable isotopes in bear tissues can be used to reconstruct diets from samples of captured and harvested bears and provide important information on the potential changes in the food web associated with trends in habitat availability. Currently the US Fish and Wildlife Service and US Geological Survey are working to begin these analyses now that three years of data will be available between 2008 and 2010 for comparison with data collected in the 1980s and 1990s. An effort will be made to have results available for the next scientific working group meeting.

Studies that provide information on individual movement patterns and habitat use are critical to identifying the best approach to monitoring the status of the Alaska-Chukotka population. Because of this need, current research efforts have focused on obtaining these data and working to evaluate the feasibility of traditional approaches to monitoring population trends. However, several other aspects of study require further consideration. Denning is a critical component in the lifecycle of bears. Current information on denning behavior of female bears in the Alaska-Chukotka population suggests that the majority, if not nearly all, denning occurs on land. Access to denning habitat as sea ice patterns change should be an important area of future research. Additionally, traditional knowledge of Alaskan and Chuktoka Natives will be critical in developing research hypotheses, monitoring seasonal distribution patterns, identifying areas of bear-human conflict, and understanding trends in subsistence use. A recent study was conducted in Russia and an effort is currently being made to update local knowledge in Alaska. Continued gathering of local knowledge will be a critical part of a comprehensive research program.

Long-term harvest management for the Alaska-Chukotka population will require an adaptive management system (e.g., Williams 2001) that uses new information on population status to periodically re-evaluate harvest regulations and other management actions. It is unlikely that any single research method (e.g., capture-recapture) will be sufficiently accurate and comprehensive to serve as the sole basis for management decisions. Rather, inference regarding the size and status of the population will be derived from a broad research program, as summarized above, from the traditional knowledge of native peoples, and from information on changes in polar bear habitat (Durner et al. 2009). Each of type of information will be characterized by a different form, scope of inference, and level of uncertainty. We suggest the development of a heuristic model, such as a Bayesian Network (e.g., Amstrup et al. 2008), to synthesize current and future information on the status of the Alaska-Chukotka polar bear population. This would allow for consistent and transparent management decisions and could potentially be an important part of the regulatory framework for this population.

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	1980-1989		1990-1999		2000-2008	
	mean	sd	mean	sd	mean	sd
Estimate of U.S. harvest from biological population.*	107	50	72	21	57	22
Harvest from within U.S. portion of the IUCN subpopulation boundary.**	89	43	56	26	43	20

Table 1. Estimated U.S. harvest from the Alaska-Chukotka polar bear population, 1980-2008 (source U.S. Fish and Wildlife Service database).

*Estimated harvest for the biological Alaska-Chukotka population, including 50%, 70%, 80%, 90%, and 100% of bears harvested around Barrow, Wainwright, Point Lay, Point Hope, and south and west of Point Hope, respectively, as coming from the Alaska-Chukotka population. This allocation of harvest is based on Amstrup et al. (2005), which identified areas of overlap between the southern Beaufort Sea and Alaska-Chukotka polar bear populations.
**Estimated harvest for areas within the IUCN boundary of the Alaska-Chukotka population (Aars et al. 2005), which includes Point Lay and areas farther south and west.

Assumed population size (*N*)	Modified PTL method for assumed values of maximum natural population growth rate (r_{max})								Method of Taylor et al. (1987)	
	$r_{max} \leq 0$		$r_{max} = 0.02$		$r_{max} = 0.04$		$r_{max} = 0.06$			
	F	M	F	M	F	M	F	M	F	M
1000	0*	0*	4	8	8	15	11	23	16	31
1500	0	0	6	11	11	23	17	34	23	47
2000	0	0	8	15	15†	30†	23	45	31	62
2500	0	0	9	19	19	38	28	56	39	78
3000	0	0	11	23	23	45	34	68	47	94
3500	0	0	13	26	26	53	39	79	55	109
4000	0	0	15	30	30	60	45‡	90‡	62	125

Table 2. Estimated sustainable harvest levels of female (F) and male (M) polar bears for the Alaska-Chukotka population, for a range of assumed values for population size (*N*) and maximum natural population growth rate (r_{max}).

*A harvest of 0 (i.e., no harvest) is the option consistent with a precautionary scientific approach, given observed and forecasted loss of sea ice habitat and the current lack of information on population size and trend.
†A harvest of 15 females and 30 males would be sustainable assuming plausible upper limits for population size and growth rate. Harvest at this or any other level likely increases the risk of population declines and must be justified on non-biological grounds.
‡A harvest of 45 females and 90 males is the highest theoretically sustainable harvest for the Alaska-Chukotka polar bear population, requiring unrealistic assumptions about population size and growth rate. Actual harvest levels for the period 2000-2008 likely exceeded this level, resulting in population declines.

Harvest rate (fraction of females/year)	2020	2030	2040	2050	2060
0 (no harvest)	0	0	0	0	0
0.015	-12	-16	-15	-13	-12
0.034	-25	-36	-37	-36	-35
0.062	-42	-60	-66	-70	-73
0.10	-60	-80	-88	-92	-95

Females only; N(1) = 1000 females = 0.6K; dK/dt = -2% per year
Mechalis-Menton density dependence with KS = 0.5; rmax = 0.04

Table 3. Percent change in population size for different fixed harvest rates, relative to a population with no harvest. This is a tabular summary of the projection results in Figure 3. Rows correspond to different harvest rates, expressed as a fraction of the female population that is harvested per year. Columns correspond to future points in time. For example, if female polar bears are harvested at a fixed-rate of 0.015, the projected population size in year 2040 will be 15% lower than the projected population size for an un-harvested population.

Management option	Anticipated effect on total removal from the population (relative to current removal)	Risk of population decline (relative to current removal)	Conditions and/or requirements
1. Moratorium on US harvest in addition to continued moratorium on Russian harvest	Significantly reduced	Lowest	Compliance with moratorium
2. Establish a regulated harvest in the US and Russia, that is likely to be sustainable, based on best available information	Reduced[1]	Low	Action plans for local-level management and monitoring

Table 4. Recommended management options and qualitative potential effects on the level of human-caused mortality in the Alaska-Chukotka polar bear population, and population response.

[1] Assumes total removal from Russia would not increase with legalization of harvest.

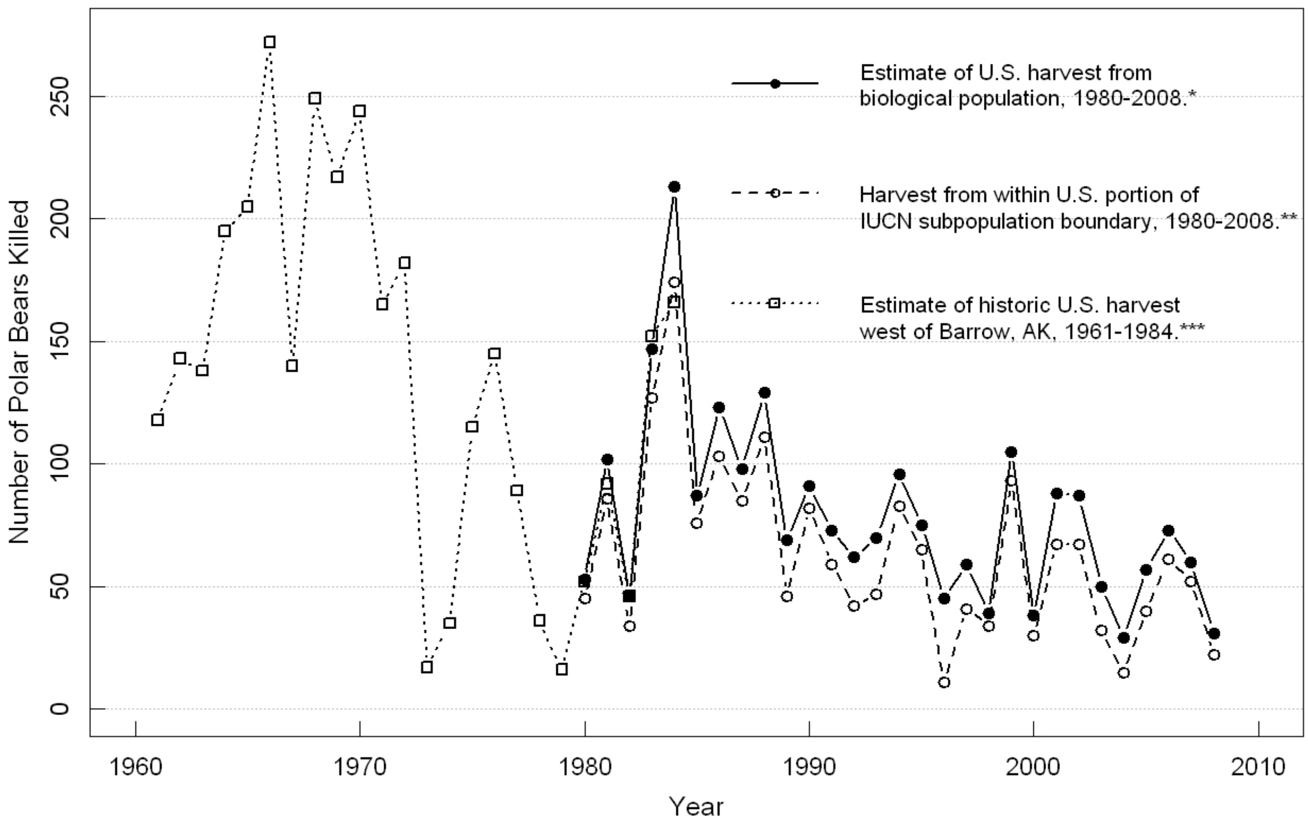

Figure 1: Estimated U.S. harvest from the Alaska-Chukotka polar bear population, 1961-2008.

*Estimated harvest using data from the U.S. Fish and Wildlife Service database for the biological Alaska-Chukotka population, including 50%, 70%, 80%, 90%, and 100% of bears harvested around Barrow, Wainwright, Point Lay, Point Hope, and south and west of Point Lay, respectively, as coming from the Alaska-Chukotka population. This allocation of harvest is based on Amstrup et al. (2005), which identified areas of overlap between the southern Beaufort Sea and Alaska-Chukotka polar bear populations.
**Estimated harvest from the U.S. Fish and Wildlife Service database for areas within the IUCN boundary of the Alaska-Chukotka population (Aars et al. 2005), which includes Point Lay and areas farther south and west.
*** Estimated harvest from Table 6 in Amstrup et al. (1986), which uses Barrow, Alaska, as the eastern boundary for the Alaska-Chukotka population.

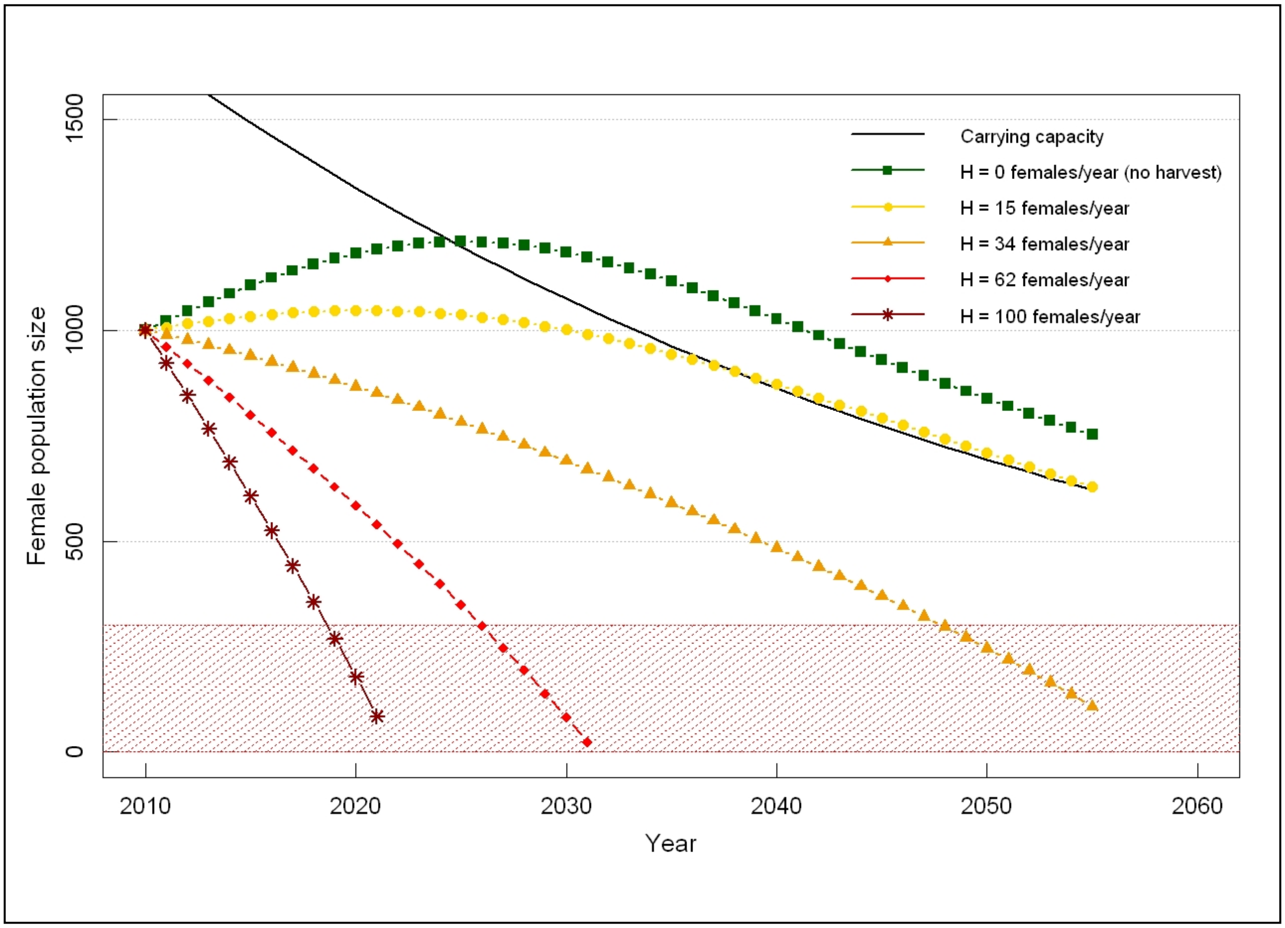

Figure 2. The relative effects of different fixed-level harvests on the future status of the number of female polar bears in the Alaska-Chukotka population. Harvest at a fixed level represents a risky approach and is shown here for comparison with the recommended *fixed-rate* harvest approach, which re-evaluates harvest levels periodically using new information on population size and growth rate. The shaded area at the bottom of the graph represents a quasi-extinction threshold at 30% of initial population size, below which additional factors associated with small population size could accelerate population declines.

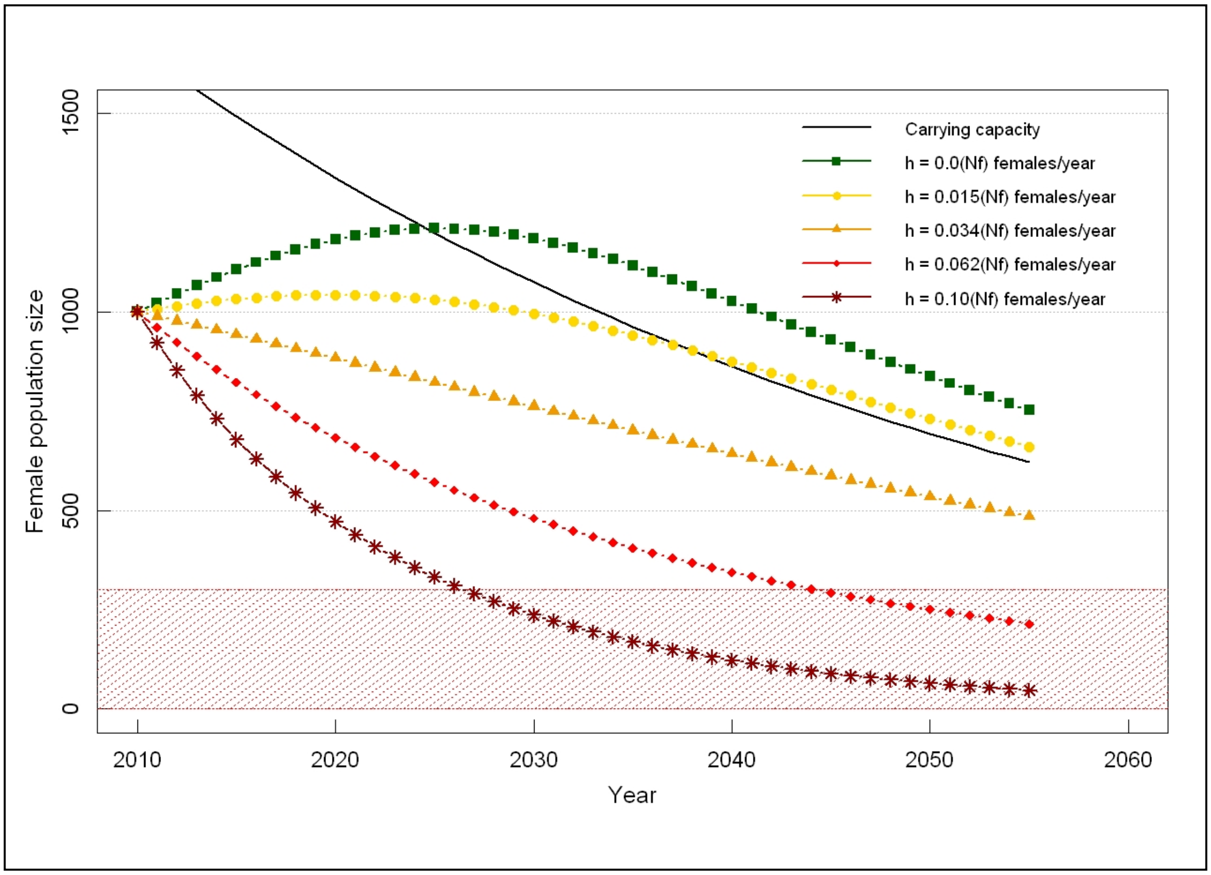

Figure 3. The relative effects of different fixed-rate harvests on the future status of the number of female polar bears in the Alaska-Chukotka population. Harvest at a fixed rate (i.e., a fixed percentage of current population size) is the recommended approach and requires harvest levels to be re-evaluated periodically using new information on population size, and potentially on maximum growth rate. A fixed rate of 0.015 (i.e., the annual removal of 1.5% of the female population) is upper limit of the plausible range of harvest rates calculated using the modified Prescribed Take Level approach. The shaded area at the bottom of the graph represents a quasi-extinction threshold at 30% of initial population size, below which additional factors associated with small population size could accelerate population declines.