

Rapid ecosystem change and polar bear conservation

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Abstract

Anthropogenic global warming is occurring more rapidly in the Arctic than elsewhere, and has already caused significant negative effects on sea ice-dependent species such as polar bears. Although observed effects have thus far been gradual, the large amount of annual variation in the climate system may cause habitat changes in individual years that exceed the long-term trend. Such years may be below critical thresholds necessary for feeding and result in unprecedented reductions in survival, reproduction, and abundance in some populations. Here, in anticipation of sudden negative population-level effects, we provide an overview of proactive conservation and management options. Preplanning, consultation, and coordination of management responses will be necessary to reduce the risks to human safety and other effects of catastrophic declines in habitat. Advance consideration of the costs, legality, logistical difficulties, likelihood of success, and invasiveness of potential responses will be critical to minimizing short-term negative effects while laying the groundwork for longer-term conservation objectives.

Introduction

Throughout the circumpolar Arctic, polar bear (*Ursus maritimus*) management has been guided by the 1973 Agreement on the Conservation of Polar Bears that states that Contracting Parties "... shall manage polar bear populations in accordance with sound conservation practices based on the best available scientific data." Historically, harvest was the primary threat to polar bears (Prestrud & Stirling 1994), but the situation has changed dramatically. The sea ice habitat upon which polar bears de-

pend for successful foraging is rapidly declining in response to greenhouse gas (GHG)-driven global warming. The widespread loss of sea ice, along with changes in patterns of breakup and freeze-up, has already resulted in significant negative impacts on polar bears (review by Stirling & Derocher 2012).

There are 19 populations of polar bears worldwide (Figure 1). Some populations (e.g., Western Hudson Bay, Davis Strait) experience complete sea ice melt in summer that forces polar bears onto land where they must rely on their stored fat for energy until the ice refreezes

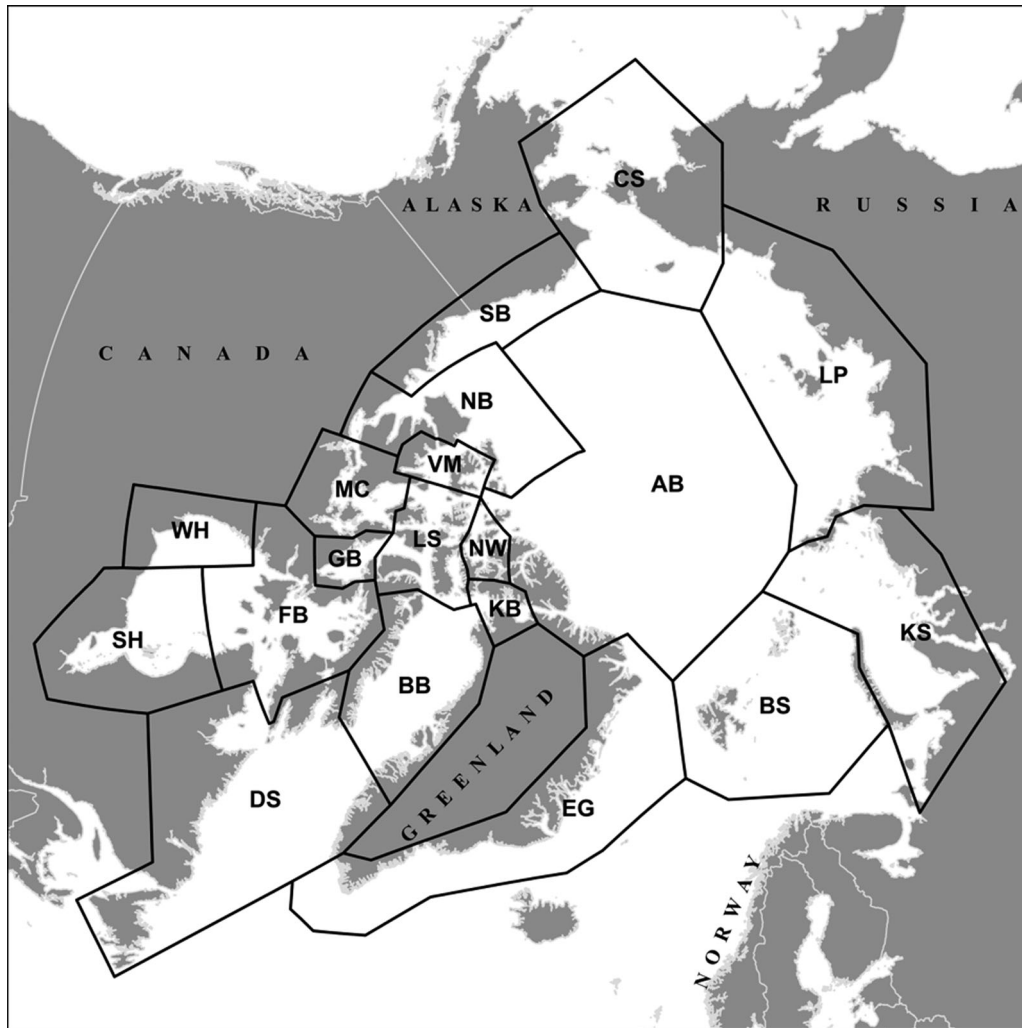


Figure 1 Polar bear populations identified by the International Union for the Conservation of Nature/Species Survival Commission Polar Bear Specialist Group. Counterclockwise from the top: CS = Chukchi Sea; SB = Southern Beaufort Sea; NB = Northern Beaufort Sea; VM = Viscount Melville Sound; MC = M'Clintock Channel; NW = Norwegian Bay; LS = Lancaster Sound; GB = Gulf of Boothia; FB = Fove Basin; WH = Western Hudson Bay; SH = Southern Hudson Bay; DS = Davis Strait; BB = Baffin Bay; KB = Kane Basin; EG = East Greenland; BS = Barents Sea; KS = Kara Sea; LP = Laptev Sea; AB = Arctic Basin.

(Ramsay & Stirling 1988). In contrast, in populations of the polar basin (e.g., Chukchi Sea, Laptev Sea, and Barents Sea), many bears remain on drifting pack ice and multiyear ice year round. Productivity and prey are higher over the continental shelf (Sakshaug 2004; Harwood *et al.* 2012) but pack ice is now retreating beyond this area. Multiyear ice is also rapidly declining (Maslanik *et al.* 2011). When forced ashore in summer or far offshore on multiyear ice, polar bears experience greatly reduced energy intake, rely on stored fat, and decline in mass. Documented negative effects on polar bears from changing sea ice include declines in body condition, body size, reproductive and survival rates, popula-

tion size, sea ice denning habitat, as well as altered movements and distribution (Stirling *et al.* 1999; Fischbach *et al.* 2007; Regehr *et al.* 2007; Rode *et al.* 2010; Derocher *et al.* 2011). Documented effects and the projection that similar patterns will occur throughout their range with continued warming, resulted in polar bears being listed as Vulnerable by Norway, Greenland, and the International Union for the Conservation of Nature, and as globally Threatened by the United States (US Fish and Wildlife Service 2008; Vongraven 2009).

Although the relationship between increasing temperatures and availability of sea ice habitat may be linear from a multiannual perspective (Amstrup *et al.* 2010),

substantial natural fluctuations in climate alter polar bear hunting success among years (Amstrup *et al.* 1986; Stirling *et al.* 1999). Amstrup *et al.* (2008) predicted extirpation of polar bears in two-thirds of their distribution by midcentury because the frequency of low ice years with reduced hunting success will increase as long as GHG-induced warming continues (Hunter *et al.* 2010) until almost all years will be bad for polar bears (Amstrup *et al.* 2010). An especially long reduction in ice availability in any particular year means that polar bears could face a rapid nonlinear decrease in survival and reproduction (Molnár *et al.* 2010, 2011). For example, adult male mortality from starvation was predicted to increase to 28–48% in any year the fasting period is 30 days longer than in past decades (Molnár *et al.* 2010). The possible effects on other age and sex classes have not been modeled but are predicted to be more severe (*op cit.*). Because the significant level of interannual variation in both habitat and biological features (Stirling *et al.* 1999; Comiso *et al.* 2008), will continue as the world warms, some years will continue to be better for polar bears and others poorer (Amstrup *et al.* 1986; Stirling *et al.* 1999). The first occurrences of these exceptionally poor years are likely to present a near-term critical challenge to polar bear conservation. When superimposed over the long-term declining trend, annual variability in sea ice makes it increasingly likely that we will soon see a year where sea ice availability for some polar bear populations is below thresholds for vital rates. Malnutrition at previously unobserved scales may result in catastrophic population declines and numerous management challenges.

The timing of particularly bad years cannot be predicted. Furthermore, both temporal patterns of change in the sea ice and subsequent responses by polar bears will vary greatly among populations. Regardless of the inability to predict such events, ongoing research makes it clear they are coming (Stirling & Derocher 2012). Yet, none of the five nations with jurisdiction over polar bears (Norway, Russia, United States, Canada, and Greenland) has a plan for responding to sudden changes in polar bear populations caused by nutritional stress.

In this article, we discuss issues that need consideration if large numbers of polar bears are forced to remain on land, or on offshore ice, with inadequate energy reserves to survive a prolonged open water period. We work within the framework that several polar bear populations will be extirpated due to habitat loss but may persist at high latitudes in Canada and Greenland (Durner *et al.* 2009) and, that the conservation goal is to maximize the probability of maintaining natural or seminatural self-regulating populations where possible. We have grouped concerns into three categories: human safety, conservation planning (i.e., objectives, harvest

management, and consultation), and possible management responses (i.e., diversionary feeding, supplemental feeding, rehabilitation, translocation, rescue, population reduction, and population assessments). We emphasize that responses must be supported by the best available science and the most relevant traditional knowledge. The intensity of responses that may be chosen, the costs, and the logistical difficulties of dealing with catastrophic declines in sea ice habitat supporting polar bears, will require coordinated planning. Some jurisdictions may choose not to interfere with populations or individual bears whereas others may prefer active intervention. Regardless, it is critical to contemplate and discuss options ahead of the need to respond, and to recognize that priorities may change over time with population status. Our goal is not to prescribe priorities or objectives for others but to review anticipated concerns, options, and challenges. Although some of the topics may seem radical in the context of current polar bear management, future conditions may be well outside the range of past circumstances and necessitate very different actions than today. The success of interventions will be partly determined by the degree of advanced planning.

Human safety

Human safety will be at the forefront of many decisions and may conflict with species conservation goals. As sea ice availability has declined, forcing bears onshore for progressively longer periods, the number of human-bear interactions has increased (Stirling & Parkinson 2006; Towns *et al.* 2009). The most intensive program for dealing with human-bear interactions, the Polar Bear Alert program in Churchill, Manitoba, Canada, includes extensive hazing, relocation, and temporary housing of bears to mitigate conflict during the ice-free period. That program is expensive and may not be easily applied in small northern communities with limited resources. Nonetheless, we encourage alternatives to killing problem bears, which is a common outcome in northern communities (Stenhouse *et al.* 1988). The Churchill program was established before the effects of climate change were recognized and it is unclear whether it will remain adequate as warming continues. Bears temporarily held in captivity are not currently fed so the cost of temporary holding will increase when the ice-free period extends beyond the fasting capacity of captive bears. Less-expensive options such as reducing attractants and securing storage of food should be included along with plans for increased deterrent capabilities. Training and equipping community polar bear monitors, along with extensive public education

and interjurisdictional agreements, should be planned to help assure human safety.

Conservation planning

Objectives

Clearly articulated short- and long-term conservation objectives for each population are needed to guide decisions on responses to rapid ecosystem change. Each response will require logistical, financial and political effort, appropriate legislation, and public support, and may not be easily abandoned once initiated. Population-specific conservation goals may range from a managed decline in an area where the habitat can no longer sustain a viable population to an intensive program to maintain a semiwild population with supplemental food. In the worst-case scenario, a primary goal may be conservation of genetic structure in artificially maintained *in situ* or *ex situ* populations. Priorities and implementation guidelines need to be determined *a priori* to facilitate scenario-specific responses. Although political and stakeholder priorities will influence objectives, the strategies to achieve these objectives should be based on the best available scientific evidence. For example, integration of sea ice monitoring into population management (Sahanation & Derocher 2012) and habitat-linked population viability analyses (Hunter *et al.* 2010), or energetics modeling (Molnár *et al.* 2010) may facilitate early detection of risk and its potential extent. Evaluating environmental carrying capacity and determining when problem-specific intervention might be needed would assist determining the possible timing and scale of an intervention to obtain a desired outcome. Ultimately, the effectiveness of intervention needs to be assessed and adjusted to achieve conservation goals (Bottrill & Pressey 2012).

Harvest management

Polar bears are legally harvested throughout their range except in Norway and Russia. Historically, polar bear management was based on the premise that habitats were stable and thus allowed long-term sustainability of harvest levels. Projection models based on stable demographic rates (Taylor *et al.* 2008) were used to guide harvests, and polar bear management has been fairly successful at achieving sustainable harvests in most populations (IUCN SSC Polar Bear Specialist Group 2010). Harvest quotas were adjusted when new population inventory data became available. Excessive harvest, however, has caused population declines and remains a short-term threat in some areas (IUCN SSC Polar Bear Specialist Group 2010). The concept of perpetually sustainable harvests, however, no longer applies with continuing neg-

ative changes to sea ice. Existing harvest management methods are inadequate for declining populations that, by definition, have no sustainable harvest. In populations with a sudden decline in abundance, cessation of harvest may be needed to increase the likelihood of population persistence. New means of setting harvest levels will require a more dynamic approach with consideration of current environmental conditions, population objectives, and longer-term conservation targets.

Consultation

Consultation between managers, policy makers, scientists, local residents, subsistence hunters, and other stakeholders (e.g., ecotourism operators, tourists, ecotourism operators' industry, animal welfare groups, sport hunters, and the general public) is essential for effective conservation planning. Polar bears are co-managed in many jurisdictions and aboriginal harvesting rights are often entrenched in land claims agreements or treaties (Brower *et al.* 2002; Peacock *et al.* 2010). Consequently, it is critical that local communities are involved in the decision-making process before undertaking management actions. Although northern consumptive users of polar bears are already involved in polar bear management, there is no formal mechanism for participation of other stakeholders in polar bear conservation. Such stakeholders have an increasing voice in conservation issues and should be involved in planning.

Management responses

Diversionsary feeding

Human-bear conflicts will increase as the body condition of individual bears in a population declines, and as greater numbers of bears are stranded ashore for longer periods (Schliebe *et al.* 2008; Towns *et al.* 2009). The objective of diversionsary feeding is to alter the distribution of a population. Diversionsary feeding could be a viable short-term tool to draw bears away from settlements or industrial facilities, thus reducing mortality risk to both humans and bears. Decisions about food type, energy content, distribution, amount, and cost all require planning. For example, overly concentrated food resources might increase intraspecific conflict (e.g., infanticide), resulting in unintended demographic consequences. Because fed bears are likely to return in subsequent years, as currently occurs at bowhead whale (*Balaena mysticetus*) carcasses in Alaska (Schliebe *et al.* 2008), diversionsary feeding may require a long-term commitment.

The possible negative consequences of feeding wildlife also need to be considered in planning such actions. For example, the potential for disease and parasite

transmission as well as human-wildlife conflicts may increase as other species such as Arctic fox (*Vulpes lagopus*), wolves (*Canis lupus*), and grizzly bears (*U. arctos*) are drawn into diversionary feeding locations. Disease and parasite concerns might be exacerbated if wild food sources from other ecosystems, such as harp seal (*Phoca groenlandicus*) carcasses from commercial harvest, were used. Therefore, commercial bear chow developed for zoos, or other agricultural products that are easier to ship and store, might offer a less complicated diversionary feeding strategy.

Supplemental feeding

In contrast to diversionary feeding, supplemental feeding aims to provide sufficient short-term energy to help individuals survive periods of food deprivation. As such, supplemental feeding could be viewed as an artificial increase in carrying capacity. If resources were available, polar bears might be maintained in regions where they otherwise would not persist.

Similar to diversionary feeding, supplemental feeding raises concerns. For example, if climate and ice projections suggest an area will not support a polar bear population into the future, supplemental feeding may only forestall extirpation. Accomplishing a supplemental feeding program at the population level also presents economic and logistical challenges. Harvesting natural foods to feed to polar bears is unlikely to occur for a variety of reasons. For example, sea ice-dependent seals that form the majority of polar bear diet are also being negatively affected by global warming (Laidre *et al.* 2008). There are also ethical questions around killing one marine mammal species to supplement the diet of another. Therefore, commercially prepared animal foods are the most likely supplemental food source.

Population composition and assessment of body condition (Molnár *et al.* 2009) could be used in energy-budget models (Molnár *et al.* 2010, 2011) to estimate how much supplemental energy would be needed to alter polar bear survival and reproduction by a desired amount. Even a simplified calculation illustrates that the costs of supplemental feeding would be high. Polar bears in zoos fed commercial chow as a maintenance diet are provided 1 kg of chow for each 50 kg of mass (<http://www.mazuri.com/mazuripolarbeardiet.aspx>). Roughly, the mean mass of bears in the Western Hudson Bay population in autumn is about 200 kg, which would require 4 kg of chow per day per bear. At approximately 900 animals (Regehr *et al.* 2007), 3,600 kg of chow would be needed each day to maintain body condition. At US\$1.65 per kg, the chow would cost \$5,900 per day. Food transportation could double the cost, and delivery to feeding locations would add about \$20,000

per day for staff and aircraft. Conservatively, it might cost \$32,000 per day or nearly a million dollars per month to supplement the most accessible of all populations. It is possible that several months of feeding would be required.

The significant costs and logistical difficulties of any supplemental feeding program would require careful consideration as it may not aid long-term polar bear persistence. Such a program could result in commitment to a semimanaged bear park model if habitat conditions continue to decline. Once feeding begins, ceasing a program could result in increased human-bear conflicts and acute mortality events. Nonetheless, given the importance of polar bears to local economies in many parts of the Arctic, supplemental feeding to sustain populations may have an economic incentive. We believe supplemental feeding will be a conservation option for some populations.

Rehabilitation

Other bear species have, on occasion, been successfully rehabilitated and returned to the wild (Huber 2010). Because such actions are predicated on suitable habitat being available, and because warming-induced habitat loss will be the main reason polar bears need rehabilitation, returning rehabilitated polar bears to the wild may not be an option. Movement of animals into captivity and then back into the wild also raises concerns about disease, parasite transmission, and possible habituation to humans. Because public pressure to “rescue” at-risk bears may be intense, we consider rehabilitation and release into the same population as a possible, if less likely to be successful, means of increasing population persistence. Such efforts, however, would only confer short-term benefits and likely only for the first crisis episodes in any given population.

Because facilities for short-term housing of animals are limited and remote from wild population, it would be preferable to establish temporary in situ facilities where any rehabilitation might be attempted. Selecting individuals for rehabilitation should be based on population objectives, potential conservation value (e.g., reproductive value), and prior experience of wild individuals. Overall, we consider this option to have low utility for polar bear conservation.

Translocation

Translocation of wild animals has been used with varying success for many species but is most successful when applied after the cause of the population decline is removed (Fischer & Lindenmayer 2000). For those polar bear populations with declines in carrying capacity,

success of translocations is likely to be minimal. One option may be to translocate bears from areas of declining habitat to areas where habitat persists if the recipient population is below carrying capacity (perhaps due to harvest). However, a population below carrying capacity would be expected to recover naturally without translocations. Translocation, however, might assist in achieving population goals (e.g., adding genetic diversity) but would require careful assessment from a genetic perspective. Animals from one population may have different local behaviors and seasonal cycles. These traits, taught to young bears by their mothers, could reduce survival of translocated animals. Potential for introducing diseases and parasites is also a concern. It is probable that many translocations would fail because polar bears show strong geographical fidelity and many would try to return to their source population. Translocations are fraught with many difficulties (Wolf *et al.* 1996) and for the reasons noted above, we do not advocate this as a viable conservation tool for polar bears.

Rescue

There is capability to house a limited number of polar bears rescued from the wild in high-quality zoos. It is common for some polar bears to be relocated to zoos where captive rearing and reproduction are possible although the laws, politics, and cultural sensitivity of relocation to zoos varies across jurisdictions. For example, there is resistance in parts of Canada to placing polar bears in zoos and Norway has not relocated polar bears to zoos for several decades, but Russia has allowed removal of polar bear cubs for zoos and circuses (IUCN SSC Polar Bear Specialist Group 2010). To some interest groups, keeping polar bears in captivity is unacceptable and euthanasia of compromised individuals may be preferred. Nonetheless, others will advocate for rescue of as many animals as possible. Some carnivores (e.g., giant pandas, *Ailuropoda melanoleuca*) have benefited from captive rearing programs. Relocations of animals from a wild source, however, have much higher success than captive raised animals (Fischer & Lindenmayer 2000). There is potential to use zoos to help preserve genetic diversity should polar bear range be substantially reduced and require genetic rescue. However, a significant loss of genetic diversity in the wild is only likely where a small refugium hosts a small isolated population. Should rescue and reintroductions be considered, it would require a coordinated and consultative approach at all levels along with significant financial commitments.

Polar bear conservation is predicated on the existence of suitable habitat and the protection of such habitat cannot be accomplished unless GHG emissions are suffi-

ciently reduced to stop the rise in global temperature. Although polar bears placed in zoos may not immediately benefit wild populations, they may aid conservation of wild bears by virtue of associated education efforts about climate change.

Intentional population reduction

Controlled reduction of population size through harvest might be necessary to ensure both human safety and a viable but smaller polar bear population as a result of declining habitat (Peacock *et al.* 2011). Such a change in harvest policy may require new or amended legislation and regulations, community consultation, and discussion with comanagement boards. Stabilizing a population at a lower carrying capacity would require intensive monitoring to set and modify new harvest levels as needed.

Euthanasia may be the most humane option for individual bears in very poor condition that are unlikely to survive. Under these circumstances, it will be important to develop clear guidelines for identification of starving animals.

Adequacy of population assessments

Ongoing rapid ecosystem change requires that managers reassess populations more frequently than in the past. For example, in Nunavut, Canada, the inventory cycle is every 15 years (Peacock *et al.* 2011). Such inventory frequencies are insufficient when habitat is changing rapidly. If management is to adapt to rapidly changing ice conditions, shorter monitoring intervals, using the best available protocols (Vongraven *et al.* 2012) are required. Furthermore, the precautionary principle must be applied wherever there is insufficient information to ensure conservation objectives are met.

Conclusions

Considering the global attention paid to polar bears, managers will be forced to respond to sudden changes in environmental conditions that negatively affect polar bears. We believe that managers and policy makers, who have anticipated the effects, consulted with stakeholders, defined conservation objectives, created enabling legislation, and considered possible management actions will be most able to effectively respond to large-scale negative changes.

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