Demographic and Ecological Perspectives on the Status of Polar Bears

by

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Table of Contents

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Dr. Mitchell Taylor[1] and Dr. Martha Dowsley[2]

Abstract

Although two polar bear subpopulations (Western Hudson Bay and Southern Beaufort Sea) no longer appear to be viable due to reduction in sea ice habitat, polar bears as a species do not appear to be threatened by extinction in the foreseeable future from either a demographic or an ecological perspective. Ecological perspectives that suggest the reductions to survival and recruitment rates for two populations (Western Hudson Bay and Southern Beaufort Sea) have occurred because of a long-term decline in sea ice due to climate warming. These populations occur where summer ice coverage is seasonal (WH) or divergent (SB). The perspective that the impacts of sea ice reductions experienced in WH and SB subpopulations can be generalized to the remainder of the polar bear subpopulations depends entirely on the IPCC GCMs that predict continued reductions to sea ice due to CO2 driven climate change. Current and historical polar bear subpopulation performance demonstrates that viable polar bear subpopulations have persisted and generally increased throughout the current period of climate warming. The mean generation time of polar bears as defined by the IUCN/SSC Redbook criteria and the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) is 12 not 15 years. The time-frame for three generations for polar bears is 36 not 45 years as indicated by the IUCN/SSC Polar Bear Specialists Group. Based on the assumption of a linear relationship of population numbers to sea ice habitat, extrapolation of IPCC GCM sea ice predictions over a thirty-six year interval does not support the contention that polar bears are threatened with extinction over the next three generations. Extrapolation of IPCC GCM sea ice predictions over a hundred year interval does not support the contention that polar bears are threatened with extinction in the foreseeable future. Population viability analyses (PVA), using demographic estimates from polar bear populations where the data are sufficient, indicate that population status is affected by both anthropogenic removals and vital rates. PVAs that employ current demographic and removal rates indicate that most polar bear populations could sustain the current removal rate indefinitely. Management action for populations where removal rates exceed the estimated sustainable levels has occurred and is ongoing.

The popular notion that polar bears are declining or already expatriated worldwide has been initiated and perpetuated by environmental organizations and individuals who apparently believe that current subpopulation numbers and trends are an insufficient basis for an appropriate status determination. These individuals and organizations suggest that an ecological consideration constitutes more appropriate methodology to assess status of polar bears and presumably all species. Observations of natural mortality, intra-specific aggression, poor condition, and even healthy bears in good condition on ice floes have been cited as evidence of a population impacts on polar bears due to declining sea ice. Anecdotal information, although useful and interesting, is not equivalent to scientific information based on valid statistical analysis of sample data. Simultaneously, traditional ecological knowledge (TEK) from Inuit has been largely ignored because TEK is mostly oral, and because TEK generally does not support the assertion that polar bear populations are in general, or even local decline.

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Introduction

The prognosis that polar bears will become extinct because of greenhouse gas-induced climate-warming reductions to their sea ice habitat has become accepted as established fact by many scientific researchers and much of the general public. The following excerpt from the Endangered and Threatened Wildlife and Plants; 12-month Petition Finding and Proposed Rule to List the Polar Bear (*Ursus maritimus*) as Threatened Throughout its Range (USFWS 2007) states the rationale for this position:

" *...In making this finding, we recognize that polar bears have evolved to occur throughout the ice-covered waters of the circumpolar Arctic, and are reliant on sea ice as a platform to hunt and feed on ice-seals, to seek mates and breed, to move to feeding sites and terrestrial maternity denning area, and for long-distance movements. Under Factor A ("Present or threatened destruction, modification, or curtailment of habitat or range"), we find that the diminishing extent of sea ice in the Arctic is extensively documented. Further recession of sea ice in the future is predicted and would exacerbate the effects observed to date on polar bears. It is predicted that sea ice habitat will be subjected to increased temperatures, earlier melt periods, increased rain on snow events, and positive feed back systems. Productivity, abundance and availability of ice seals, a primary prey base, would then be diminished by changes in sea ice. Energetic requirements of polar bears would increase for movement and obtaining food. Access to traditional denning areas would be affected. In turn, these factors will cause declines in the condition of polar bears from nutritional stress and productivity. As already evidenced in the Western Hudson Bay and Southern Beaufort Sea populations, polar bears would experience reductions in survival and recruitment rates. The eventual effect would be that polar bear populations will continue to decline. Populations would be affected differently in the rate, timing, and magnitude of impact, but within the foreseeable future, the species is likely to become endangered throughout all or a significant portion of its range due to changes in habitat. This determination satisfies the definition of a threatened species under the Act.*"

Environmental Groups helped develop and have subsequently capitalized on this perception to assert that the continued existence of polar bears is dependent on wide-sweeping changes (restrictions) in how G8 nations (especially the United States) use fossil fuels. Actual and potential impacts on polar bears have been used by climatologists to draw attention to the implications of continued climate warming (Stirling et al. 1999; Comiso 2002, 2006; Holland et al. 2006; Obbard et al. 2006; Stirling and Parkinson 2006; Amstrup et al. 2007; Durner et al. 2007; Regehr et al. 2006, 2007a,b). Many polar bear researchers have used IPCC climate model projections of ice coverage as the foundation/rationale for their recommendations on status (Stirling et al. 1999; Derocher et al. 2004; Aars et al. 2006; Obbard et al. 2006; Stirling and Parkinson 2006; Amstrup et al. 2007; Regehr et al. 2006, 2007a,b; USFWS 2007).

The concern that polar bears will decline if the climate continues to warm is valid. However, the assertion that polar bears will become extinct unless immediate measures are taken to curb greenhouse gas emissions is irrational because it is inconsistent with the long-term persistence of polar bears through previous periods of warming and cooling; and because the IPCC climate model predictions 50 and 100 years into the future do not suggest a future with insufficient sea ice to support polar bears as a viable species. Currently, polar bears are abundant and in no danger of extinction thanks to coordinated research and management programs developed and implemented under the International Agreement for the Conservation of Polar Bears and their Habitat (Brower et al. 2002; Fikkan et al. 1993, Prestrud and Stirling 1994). During the last 30 years, it is generally agreed that polar bear numbers have increased as a response to improved conservation measures (harvest controls). Climate warming has occurred continuously during that period and consequent reductions in sea ice have been to the detriment of polar bear populations in at least two areas (Regehr et al. 2006, 2007a,b). However, the assertion that polar bears as a species are in imminent danger of extinction or even threatened with extinction in the foreseeable future is both unproven and unlikely. We provide a current status assessment of polar bears from both a demographic and ecological perspective, and examine some of the popular and scientific arguments put forward in support of the notion that climate change threatens polar bears with extinction in the foreseeable future.

Polar Bear Biology and Ecology:

Class Mammalia
Order Carnivora
Family Ursidae
Subfamily Ursinae
Scientific name *Ursus maritimus* Phipps (1774), no subspecies
Common names Polar bear, L'ours blanc, Nanuk, Nanuq, Wapusk, ice bear

Linnaeus (1758) referred to the polar bear as "*Ursus* maritimus *albus-major*, *articus*," but he did not consider the polar bear to be a distinct species from the brown bear (*Ursus arctos*). The first to describe the polar bear as its own species was Phipps (1774). Alternative generic names have included *Thalassarctos*, *Thalarctos*, and *Thalatarctos*. However, since the 1960s, most authors have used the name *Ursus maritimus*.

Morphology and Genetics

Polar bears are most comparable in size and shape to the brown or grizzly bear. Polar bears lack the characteristic shoulder hump, have a smaller and less dish-shaped head, a longer rostrum, and an elongated neck compared to grizzly bears. The grinding surfaces of the cheek teeth of polar bears are more serrated for shearing, which is an adaptation to a mainly carnivorous (marine mammals) diet. The claws of the polar bear are smaller and sharper than those of the brown bear, and polar bear claws hook with extension pressure (like a cat's claws) to assist in capturing prey. Polar bear forepaws are enlarged, which acts to spread their weight (like snow-shoes) when walking over thin ice and snow crust. Larger paws are also useful for swimming. Polar bear skin is black, but the fur is translucent which makes the pelage appear white. Polar bears may appear yellow when ambient light is rich in red and yellow wavelengths (sun is low on the horizon) or off-white (grey) during the summer molt when the black skin can be partly visible through the reduced fur. Sexual dimorphism is pronounced. Male polar bears can weigh up to 800 kg and reach 2.8 m in length from nose to tail (DeMaster and Stirling 1981). Females are smaller, usually not exceeding 400 kg and 2.5 m (Amstrup 2003). Inuit knowledge speaks of polar bears that are considerably larger than this, but these bears are rarely seen because they stay mainly in the sea (M. Dowsley field notes 2005; M. Taylor personal observation 1987).

Based on fossil evidence Thenius (1953) and Kurtén (1964) suggest that polar bears evolved from brown bears sometime within the last 400,000 years (late Pleistocene). Fossil polar bears are much larger than today's polar bears indicating there has been a trend toward a decrease in body size (Kurtén 1964). Molecular genetics linking polar bears to a contemporary clade of brown bears in the Alexander Archipelago of southeast Alaska suggests that polar bears diverged from brown bears as recently as 200,000–250,000 years ago (Cronin et al. 1991; Talbot and Shields 1996a,b). Cronin et al. (1991) reported that mitochondrial DNA (mtDNA) of polar bears and brown bears of the Alexander Archipelago differ by only 1%; however, more than 2.5% divergence separates polar bears from brown bears in other areas. Brown bears are thought to have survived in refugia in the southern Alexander Archipelago during the Late Wisconsin glacial maximum of 20,000 years ago (Heaton and Grady 1993); however, since the polar bear evidently separated from this clade long before the first of the Wisconsin glaciations (commencing ca. 70,000 years ago), it is unlikely that polar bears evolved specifically in the Alexander Archipelago. A hybrid polar-grizzly bear was recently harvested near Banks Island which demonstrates that polar and grizzly bears can interbreed and produce viable offspring in the wild (VanderKlippe 2006, R. Gau personal communication 2006). Successful brown bear-polar bear matings in captivity have been observed for many years, with clear evidence of first- and second-generation fertility in offspring (Martin 1876, 1882; Kowalska 1962, 1965, 1969).

There are varying degrees of genetic differences between most subpopulations of polar bears (Figure 1, Figure 2, Table 1); however, these differences do not identify them as genetic subunits or subspecies (Paetkau et al. 1995, 1999; Crompton 2004, and Saunders 2005). No genetic discontinuities have been identified that support evolutionarily significant periods of isolation between groups of polar bears (Paetkau et al. 1999).

Distribution

Polar bears are circumpolar in the northern hemisphere (Figure 1). Initially, polar bears were believed to occur as a single, homogeneous population of nomadic individuals that ranged throughout the sea ice areas of the Arctic and moved passively as the sea ice drifted based on winds and predominant currents (Pedersen 1945). However, recent studies based on satellite telemetry and mark-recapture demonstrate that, although some movements may be exceptionally large (Messier et al. 2001), polar bears show seasonal fidelity to local areas which produces demographic segregation (Taylor and Lee 1995; Bethke et al. 1996; Taylor et al. 2001). The circumpolar distribution of the polar bear is usually divided into 19–20 "subpopulations" (Aars et al. 2006) of which 13 are shared with or are entirely within Canada and 12 are shared with or entirely within the Nunavut Territory (Figure 2, Taylor et al. 2001).

Polar bears are classified as marine mammals because their principal habitat is the sea-ice surface and their main prey are marine mammals. In most areas, polar bears dig maternal dens on shore, mainly in coastal areas and mainly in terrain where snow accumulations are sufficient but stable throughout the winter and early spring. However, in some areas (i.e., the Beaufort and Chukchi Seas) some females den and give birth to their young on drifting pack ice (Amstrup and Gardner 1994). During the ice-covered seasons, polar bears are most abundant in continental shelf waters where currents and upwellings increase productivity and keep the ice cover from becoming too solidified in winter (Smith and Stirling 1975; Stirling et al. 1981; Amstrup and DeMaster 1988; Stirling 1990; Stirling and Øritsland 1995; Stirling and Lunn 1997; Amstrup et al. 2000; Taylor et al. 2001, 2002, 2005, 2006, 2008a,b,c). Despite apparent preferences for the more productive waters near shorelines, floe edge areas, and areas of persistent open water (polynyas); polar bears occur throughout the polar basin, occasionally at latitudes >88◦N (Stefansson 1921; Papanin 1939; Durner and Amstrup 1995).

Because the sea ice provides access to their main prey species (ringed seals), the distribution of polar bears in most areas changes with the seasonal extent of sea-ice cover. In winter, for example, sea-ice extends as much as 400 km south of the Bering Strait, which separates Asia from North America, and polar bears extend their range to the southernmost extreme of the sea ice. Throughout the polar basin, polar bears spend their summers concentrated along the edge of the persistent pack ice. Significant northerly and southerly movements appear to be dependent on seasonal melting and refreezing of ice near shore (Amstrup et al. 2000). In other areas (i.e., Hudson Bay, Foxe Basin, Baffin Bay, Davis Strait, Hudson Bay, James Bay, and portions of the Canadian High Arctic) polar bears are forced onto land (summer retreat areas) for several months during the open water season while they wait for winter and new ice to form (Jonkel et al. 1976; Schweinsburg 1979; Prevett and Kolenosky 1982; Schweinsburg and Lee 1982; Ferguson et al. 1997; Lunn et al. 1997; Taylor et al. 2001, 2005, personal observation).

The range of the polar bear extends from the southern edge of the permanent multi-year pack ice of the Arctic Ocean (Arctic Basin) to include sea ice, arctic islands, and coastal areas of Greenland, the Svalbard Archipelago, Siberia, Alaska, and the Canadian Arctic Archipelago, east to the Labrador coast, south to James Bay, and west to the Bering Sea. In Canada, a few polar bears regularly appear as far south as the island of Newfoundland, and polar bears have occasionally been noted in the Gulf of St. Lawrence in years when heavy pack ice drifts farther south than normal. The East Greenland current sometimes carries polar bears on drifting ice south of the land mass of Greenland and occasionally to Iceland. There are incidental sightings of polar bears that stray far inland (e.g., northeast Saskatchewan: Goodyear, 2003). The present range of polar bears approximately corresponds to the historic area of occupancy after the end of the last major glacial retreat (10,000 years ago). However, polar bears were more common in southern Labrador and Newfoundland in previous centuries than they are today (Townsend 1911; Stirling and Kiliaan 1980). In the 1770s, Cartwright observed polar bears feeding on salmon at the mouth of the Eagle River (Townsend 1911). Historic reductions in the abundance of polar bears in the most southern parts of their range may have been caused by European settlement and associated hunting, or may be a response to climate warming after the climax of the cooling events commonly referred to as the “Little Ice Age”, particularly the substantial glacial (and sea ice) advances in North America of 1711–1724 and 1835–1849 (Lamb 1977).

Delineation of polar bear subpopulations (Figure 1, Figure 2) has been largely based on hierarchical cluster analysis of movements of radio-collared females (Bethke et al. 1996; Taylor et al. 2001; Amstrup et al. 2004; Mauritzen et al. 2002). Population dynamics within subpopulation boundaries depend on subpopulation specific rates of birth and death rather than emigration/immigration, although annual rates of exchange between adjacent subpopulations in Canada have been observed to range from 0.4–8.9% (Taylor et al. 2001). Genetic distances between sampled individuals from subpopulations based on correlation of allele frequencies between populations suggest the possibility of 4 population clusters among identified subpopulations (Paetkau et al. 1999); however, misclassification rates in assignment tests among clusters and subpopulations do not support definitive boundaries in terms of genetic isolation across the range of the polar bear (Paetkau et al. 1999). Aboriginal Traditional Knowledge (ATK; Keith et al. 2005) and results of genetic analysis (Saunders 2005) question movement-derived boundaries between the identified subpopulations of M’Clintock Channel and the Gulf of Boothia (Figure 1, Figure 2). Using 9 microsatellite loci Saunders (2005) found no support for a genetic discontinuity between the Gulf of Boothia and M’Clintock Channel subpopulations (also analyzed and confirmed by P.J. van Coeverden de Groot, 2007). Crompton (2004) concluded that there was poor genetic support for differences between movement-derived subpopulations of Western Hudson Bay, Foxe Basin, Davis Strait, and Southern Hudson Bay (Figure 1, Figure 2). Interchange of individuals between the subpopulations of the Southern Beaufort Sea and Northern Beaufort Sea (Figure 1) is considerable (Amstrup et al. 2004). The subpopulations described in Figure 1 (Aars et al. 2006) are demographic units, not genetic units.

Habitat and Prey

The physical attributes of sea ice are the primary determinants of the quality of polar bear habitat. Changes in sea ice and associated snow cover affect light transmission and thermodynamic processes important to lower trophic levels of the arctic marine ecosystem (Welch et al. 1992; Barber et al. 1995). In addition to productivity effects, changes in sea ice and snow cover also influence the distribution and number of ringed seals (Stirling and Lunn 1997; Barber and Iacozza 2004. Polar bear habitat is closely associated ringed seal distribution and abundance (Stirling and Øritsland 1995). Optimum ringed seal and polar bear habitat includes areas of consolidated pack ice, areas immediately adjacent to pressure ridges, between multi-year and first-year ice floes, and at the floe edge between marginal and land-fast sea ice (Stirling et al. 1982; Kingsley et al. 1985; Stirling and Derocher 1993; Stirling et al. 1993; Ferguson et al. 2000a). Polar bears hunt seals through breathing holes, in birth lairs, when hauled out on ice (Stirling and Archibald 1977; Smith 1980) and with reduced success in active pack ice and open water (Furnell and Oolooyuk 1980; M. Taylor personal observation 1986-2007).

Bearded seals, harp seals (*Pagophilus groenlandica*), spotted seals (*Pusa largha*), hooded seals (*Cystophora cristata*), walrus (*Odobenus rosmarus*), beluga whales (*Delphinapterus leucas*), and narwhal (*Monodon monoceros*) also feature in the diet of polar bears (Stirling and Archibald 1977; Kiliaan et al. 1978; Fay 1982; Lowry et al. 1987; Calvert and Stirling 1990; Smith and Sjare 1990; Derocher et al. 2002); however, scientific knowledge and ATK suggest that naïve post-weaned juvenile ringed seals form a high proportion of the annual energy intake of polar bears (Best 1984; Stirling and Archibald 1977; Smith 1980; McDonald et al. 1997; Stirling and McEwan 1975) Ringed seals, which live exclusively in association with sea ice for at least part of the year (as do bearded and harp seals), have apparently been the principal prey of polar bears for much of their co-evolutionary history, and many ringed seal behaviours appear to be adaptations to avoid predation by polar bears (Stirling 1977; Amstrup 2003). Changes in the distribution of ice-dependent phocids in response to climate warming can be expected to affect the distribution of polar bears (Stirling and Derocher 1993; Barber and Iacozza 2004; Derocher et al. 2004). Polar bears occasionally catch belugas (*Delphinapterus leucas*), narwhals (*Monodon monocerus*), walrus (*Odobenus rosmarus*), and harbor seals (*P. vitulina*) (Smith 1985; Calvert and Stirling 1990; Smith and Sjare 1990; Stirling and Øritsland 1995; Derocher et al. 2002). Walruses can be seasonally important in some parts of the polar bear range (Parovshchikov 1964; Ovsyanikov 1996). Bearded seals (*Erignathus barbatus*) can be a large part of their diet where they are common and are probably the second most common prey of polar bears (Derocher et al. 2002).

Polar bears that summer in areas that have sea ice all year long typically remain on the sea ice during the summer sea ice minimum. In areas where the sea ice disappears entirely for a portion of the year, polar bears seek onshore retreats islands or coastal area. Polar bears onshore tend to be segregated by sex, age, and family status. Adult males displace females and cubs inland and away from the coast (Stirling et al. 2004). The summer retreat period has been considered a time of fasting by most researchers, and polar bears may rely entirely on fat reserves (Ramsay and Hobson 1991; Derocher and Stirling 1990). In some areas (e.g., Western Hudson Bay, Davis Strait) polar bears feed opportunistically on blueberries (*Vaccinium uliginosum*) and crowberries (*Empetrum nigrum*) (Derocher et al. 1993; Dyck 2001; Davis Strait, M. Taylor personal observation 2005-2007). Polar bears may also prey on coastal waterfowl nests (Smith and Hill 1996; M. Taylor personal observation 1997-2007), Svalbard reindeer (Derocher et al. 2000), and caribou (Brook and Richardson 2002, M. Taylor personal observation 1995-1997). In Labrador, feeding on salmon by bears has also been observed (Brazil and Goudie 2006). Whale and walrus carcasses attract large numbers of bears during the open-water season (Kalxdorff 1997, Perham 2005, M. Taylor personal observation). In more recent times, polar bears are also being observed actively diving and preying on Arctic char (*Salvelinus alpinus*) and other fishes (Dyck and Romberg 2007). The attraction of bears to garbage during the ice-free season is a significant concern to the management of polar bears and human safety in the Arctic. As the ocean freezes in late autumn, polar bears leave onshore retreat areas and redistribute themselves throughout subpopulation ranges except for pregnant females, which excavate maternity dens and remain onshore until they emerge from their dens in late March.

Life Cycle and Reproduction

The productivity of polar bears varies among subpopulations, probably as a function of available prey. Age at first reproduction may be as early as 4 years, with most subpopulations having females producing litters at relatively high rates by age 6 (Table 2). The latest recorded age at first reproduction is from the Norwegian Bay population (age 7).

Male polar bears likely become physiologically mature at 5–6 years of age. Fully formed spermatozoa appear only in low concentrations in testes of bears aged 2–4 years; concentrations asymptote at 5.8 years of age (Lentfer and Miller 1969; Lønø 1970; Rosing-Asvid et al. 2002). Despite physiological maturity, younger males are not likely to reproduce because older males form mating pairs with estrous females and prevent them from doing so. Saunders (2005) recently demonstrated using paternity analysis that older adult male bears sire a disproportionately high number of cubs compared to their representation in the population. It appears that most males do not enter the reproductive segment of the population until they are 8–10 years old (Ramsay and Stirling 1988; Derocher and Stirling 1998; Saunders 2005). Taylor (personal observation) captured a 3 year old male accompanied by three adult females in estrous condition in a population that had been depleted by over-hunting (Taylor et al. 2002). Each of the females had physical evidence of recent mating activity. One of the females was the mother of the 3 year old male. Older males can garner and defend estrous females; however younger males are physiologically and behaviorally capable of mating with adult females of all ages.

Females enter estrus in March, which may lasts until June for some individuals, but usually peaks in late April and early May (Palmer et al. 1988; Amstrup 2003). Ovulation is induced by coitus (Wimsatt 1963; Ramsay and Dunbrack 1986), and implantation is delayed until October (Palmer et al. 1988). Pregnancy rates appear to vary markedly among subpopulations, with as few as 50% of the adult females (>5 years) that are available to mate (i.e., having no cubs or cubs that are about to be weaned) producing cubs the following year (e.g., Kane Basin; Table 2) to as many as 100% (e.g., Baffin Bay; Table 2).

Pregnant females enter maternity dens in late October and the young, normally 1–2, are born between November and early January (Harington 1968; Derocher et al. 1992). Dens are generally excavated in snow (although snow covered dens in frozen earth and peat are common in some southern populations (Clark et al. 1997, 2001). Maternity dens are frequently located on islands or land in close proximity to the coast and adjacent to areas with high seal densities in spring (Harington 1968; Brice-Bennett 1977, Stirling and Andriashek 1992; Messier et al. 1994; Kalxdorff 1997; Ferguson et al. 2000b; Van de Velde et al. 2003; Lewis et al. 2006), although in Western Hudson Bay polar bears may den up to 120 km inland at traditional denning areas (Kolenosky and Prevett 1983; Ramsay and Stirling 1990; Clark et al. 2001; Lunn et al. 2004; Richardson et al. 2005). Amstrup and Gardner (1994) observed that in the Beaufort Sea maternal dens on drifting pack ice were common, and Amstrup (2003) suggested that sea ice denning could be common in other arctic basin populations. Polar bear maternity dens on sea ice have not been reported in the Canadian Archipelago or elsewhere. All dens on sea ice observed by Messier et al. (1994) and Ferguson et al. (2000b) were classified as temporary shelter dens, rather than maternity dens.

At birth, cubs weigh approximately 0.6 kg. They are nursed inside the den until sometime between the end of February and the middle of April, depending on latitude. By this time, cubs weigh 10–12 kg (Ramsay and Stirling 1988; Derocher and Stirling 1995). As observed for brown bears (Ferguson and McLoughlin 2000), litter size varies little according to subpopulation (Table 2).

Lentfer et al. (1980) and Taylor et al. (1987) estimated an average inter-litter interval of approximately 3.6 years. The exception is Western Hudson Bay where, in the early 1980s, up to 40% of females weaned their young at 1 year of age (Ramsay and Stirling 1988), although this proportion has subsequently declined (Derocher and Stirling 1995, Table 2).

Like most other species of bears, polar bears experience and require relatively high (p(adult)> 0.93) total survival rates to persist (Taylor et al. 1987). Polar bear survival rates appear to be age specific or stratified (Table 3). Generally, researchers assess survival rates separately for cubs-of-the-year (COYs), yearlings and subadults (ages 1–4), prime-age adults (ages 5–20), and senescent adults (ages 21+). Maximum age is often considered to be 30 years for bears in the wild, although bears as old as 33 have been observed in nature and as old as 36 in captivity. COYs exhibit survival rates that are lower than subadults, but yearlings appear to survive at the same rate as adults in many populations. Subadult survival is lower than prime adult survival and senescent adults also have lower survival rates than prime adults. Total survival rates include anthropogenic removals (e.g., harvest) while natural survival rates (Table 3) are estimated by considering the fates of bears that die only of natural causes. Males often have lower total survival rates than females, due to purposeful sex-selectivity in the harvest and a greater propensity for sub-adult males to become problem animals.

Intra-specific Interactions

Polar bears have no natural predators. However, intra-specific predation is a well documented source of natural mortality and could be a potential limiting factor of population growth. The killing of cubs to bring females into estrus (infanticide), or killing of cubs and adults for food is not uncommon in other species of bears and occurs occasionally in polar bears (Taylor et al. 1985; Derocher and Taylor 1994; Taylor 1994; Derocher and Wiig 1999; Dyck and Daley 2002; Amstrup et al. 2006). Vulnerable sex and age classes of polar bears minimize intra-specific conflicts by avoiding contact (spatial segregation) with larger males that can attack them successfully. Nutritional stress and proximity could increase if seasonal polar bear densities increased due to either increased numbers or reduced habitat. If climate change acts to reduce available habitat and concentrates polar bears in summer retreat areas or on a reduced platform of multi-year sea ice, intra-specific conflict could increase (Amstrup et al. 2006). Polar bears feeding on whale/walrus carrion, at dumps, or at times when prey is superabundant are sometimes found in aggregations with little or no intra-specific aggression. Females with family groups will sometimes remain in proximity, and cubs have been recorded to change litters. Groups of up to 5 -7 males (2 or 3 is more common) will sometimes band together after the breeding season in summer retreat areas. Polar bears are known as solitary except for mating pairs and family groups, however Inuit knowledge suggests that polar bear social behavior may be more developed than what has been documented by scientists to date.

Physiology and Contaminants

Polar bears are known to fast for long periods when forced to seek onshore summer retreats during the ice-free season. Currently, about 50–60% of bears in Canada summer onshore and their access to seals is greatly reduced during this period. These bears must primarily rely on stored energy reserves until the sea ice forms again in late autumn (Ramsay and Hobson 1991; Derocher et al. 1993; Atkinson and Ramsay 1995). Pregnant females must also wait until young are born and old enough to be moved from the den before ending their fast; in doing so pregnant females may not eat for up to 8 months, while having to meet the energetic demands of gestation and lactation (Atkinson and Ramsay 1995). Adult polar bears lose approximately 1 kg of body mass per day during fasts (Derocher and Stirling 1995; Polischuk et al. 2002), and pregnant females may lose as much as 43% of their body mass (Atkinson and Ramsay 1995). Because offspring body mass is closely tied to the amount of body fat carried by females (Atkinson and Ramsay 1995), reproductive success likely depends on the mass of pregnant females when they begin periods of fasting. Inability to put on sufficient fat reserves prior to break-up of sea ice may be a major determinant of the southern limit of the distribution of polar bears.

Polar bears are at the top trophic level and bio-accumulate environmental pollutants and contaminants that have the potential to affect survival and reproduction (Amstrup 2003). In recent years, significant levels of various contaminants (organochlorines and other persistent organic pollutants) have been documented in polar bear tissues or tissues of their prey, particularly adipose tissue (e.g., Born et al. 1991; Norstrom et al. 1988, 1998; Norstrom and Muir 1994; Bernhoft et al. 1996; Letcher et al. 1995; Henriksen et al. 2001; Kucklick et al. 2002; Oskam et al. 2004; Wolkers et al. 2004; Smithwick et al. 2005; Muir et al. 2006). Effects of various compounds in the tissues of polar bears or of the seals they feed on remains largely unknown. Contaminant levels in some subpopulations correlate with impaired endocrine function (Skaare et al. 2001; Oskam et al. 2004), immune function (e.g., Bernhoft et al. 2000; Skaare et al. 2002), and potentially bone mineral composition (Sonne et al. 2004). Lie et al. (2005) demonstrated that OC exposure significantly influences specific lymphocyte proliferation responses and part of the cell-mediated immunity, which also is associated with impaired ability to produce antibodies (Lie et al. 2004).

Home Ranges, Movements, and Dispersal

Polar bears have exceptionally large home ranges compared to other terrestrial mammals (Ferguson et al. 1999; Maurizten et al. 2001), and the only practical means by which to track their movements is via satellite telemetry (see Messier et al. 2001). Radios are generally fitted using collars only on adult females given practical difficulties in securely attaching transmitters to males (necks of males are often of wider circumference than their heads); hence, movement patterns of male polar bears are not well known. Female polar bears possess large annual home ranges, varying from 940 km^2 to 540,700 km^2 ($\bar{x}$ = 125,500 km^2, SD = 113,795, n = 93; Ferguson et al. 1999). Home ranges of polar bears are influenced by the distribution and predictability of prey species and the distribution of habitat types (Ferguson et al. 1999; Messier et al. 2001) Individual space use strategies can vary from very small home ranges to home ranges that are almost as large as the population range. The ratio of land to sea within a given home range and seasonal variation in ice cover have been shown to explain up to 66% of the variation in home range size (Ferguson et al. 1999), suggesting that the land-sea edge effect may be experiences as preferred habitats by polar bears. Bears using land during the ice-free season have larger home ranges than those with year-round access to ice, as do bears that possess home ranges with greater seasonal variation in type of ice cover (Ferguson et al. 1999).

As expected from the size of home ranges, rates of movement are very high when compared to other terrestrial mammals. Most estimates of average travel speeds on sea ice fall within the range of 0.5–2.1 km/h (Larsen et al. 1983; Durner and Amstrup 1995; Born et al. 1997; Amstrup et al. 2000; Ferguson et al. 2001). The highest activity is from May through June and July, depending on conditions of sea ice and coinciding with availability of newborn seal pups (Pasitschniak-Arts and Messier 1999; Amstrup 2003). Mauritzen et al. (2003) showed that movement rates of polar bears increased with decreasing thickness of sea ice. In the High Arctic, activity is lowest during winter, perhaps due to inclement weather, limited accessibility to seals, and energy conservation during the coldest months (Messier et al. 1992, 1994).

Movements of pregnant females cease after they enter maternity dens in late autumn. Non-pregnant adult females and males will also use snow shelters for 0.5–4 months of the winter (Harington 1968) and fast in a manner that is physiologically similar to torpor during periods of food shortages (Watts and Hansen 1987). However, use of shelter dens varies with conditions of sea ice and latitude and is more common in the High Arctic (Ferguson et al. 2000b). In the southern Arctic, where sea ice melts, bears may be forced to spend up to several months on land while waiting for freeze-up. This phenomenon is most marked at the southern range of the polar bear in Canada, especially Hudson Bay and James Bay (Stirling et al. 1977; Derocher and Stirling 1990; Taylor et al. 2001, Regehr et al. 2006, 2007a, Obbard et al. 2007), eastern Baffin Island (Stirling et al. 1980; Ferguson et al. 1997; Taylor et al. 2005), Foxe Basin and Davis Strait (M. Taylor personal observation 1986-2007). Once forced on shore for summer, movements are considerably less than on sea ice and bears spend most of their time resting or, if female and pregnant, investigating areas of potential den sites (Ferguson et al. 1997, 1998; Lunn et al. 2004).

Dispersal in polar bears is poorly understood perhaps because sub-adult bears have not been monitored using radio-collars. Subadults have historically not been radio collared because they outgrow the fitted collars. Taylor et al. (2002) showed significant differences between the mean mark-recapture distances recorded from captured cubs to recaptured/harvested sub-adults, and between captured sub-adults and recaptured/harvested adults; but no significant difference between the mean mark-recapture distance recorded for captured cubs to recaptured/harvested adults. This apparent paradox suggests that sub-adults may disperse, but usually return to their maternal home range. Dispersal events have been suggested using genetic analyses (Crompton 2004; Saunders 2005). Results from bears in the Gulf of Boothia and M’Clintock Channel (Saunders 2005), and Western Hudson Bay, Southern Hudson Bay, Foxe Basin, and Davis Strait (Crompton 2004) suggest that dispersing bears occasionally traverse identified subpopulation boundaries. The limited dispersal across subpopulation boundaries, initially identified based on movements of marked and radio-collared adults (Taylor and Lee 1995; Taylor et al. 2001, Bethke et al. 1996), is sufficient to explain the lack of sharp genetic differences among subpopulations.

Foraging Behavior

In addition to being physiologically adapted to environmental variability and to surviving long periods without food, polar bears exhibit behavioral adaptations that allow them to survive in extreme or variable environments. Participants of recent ATK studies in Gjoa Haven, Cambridge Bay and Taloyoak (Atatahak and Banci 2001; Keith et al. 2005) communicated that polar bears readily adapt their movements to environmental conditions and availability of prey species, but can be sensitive to human activity. Polar bears are known to use non-natural sources of food (e.g., garbage) and may habituate to the presence of humans, even in the presence of disruptive activities (e.g., hazing or tourism; Dyck and Baydack 2004) if food rewards can still be obtained. The curiosity of polar bears makes them particularly vulnerable to human-caused mortality in defense of life or property (Dyck 2004). Polar bears are also attracted to and may consume foreign substances (e.g., petroleum products or ethylene glycol [antifreeze]) that can be harmful or cause death (Stirling 1988b; Amstrup et al. 1989; Derocher and Stirling 1991). Inuit observations of polar bears eating plastic bags and engine oil apparently increased through the 1990s (McDonald et al. 1997), and Inuit observers of polar bears in the Baffin Bay area report an expansion in the types of foods eaten by bears in recent years (Dowsley 2005), including eggs of sea birds and an Inuit meat caches. As described above, the diet of polar bears can extend to several species of mammals and birds, Inuit meat caches, and vegetation including berries (Dowsley and Wenzel 2008). Taken all together opportunistic predation on alternative species, open water predation, carrion feeding, and scavenging from human refuse and meat caches and intra-specific predation is still a minor source of polar bears annual energy intake. Polar bears are essentially an obligate predator of seals using sea ice as a hunting platform.

Human-Caused Mortality

Currently, polar bear harvest activities occur mainly through regulated hunting. Over-hunting is currently and has historically been a concern for some demographic units, particularly where there is outdated information on abundance or a lack of enforceable quotas. The 1974 International Agreement for the Conservation of Polar Bears and their Habitat was developed in response to concern about depletion occurring from over hunting by sportsmen and trappers in Alaska and Svalbard. Polar bear harvests in Canada reached unsustainable levels when snow machines became available in the mid-1960's and quotas were imposed. In recent times, some Canadian and Greenland polar bear subpopulations have been over-hunted, with unfortunate examples coming from M'Clintock Channel (Taylor et al. 2006) and Viscount Melville Sound (Taylor et al. 2002) and Kane Basin (Taylor et al. 2008b). Today, substantially reduced mean rates of annual kill (34.0 bears [1979–1999] reduced to 2.1 bears [2001–2006] for M'Clintock Channel; 19.6 bears [1985–1990] reduced to 4.2 bears [2001–2006] for Viscount Melville Sound) are projected by simulations to have reversed trends in these subpopulations (Taylor et al. 2002, 2006), although numbers will remain reduced for at least 20 years due to the low population growth rate of this species.

Currently, the most important problems with over-hunting are for the subpopulations of Kane Basin, Baffin Bay, Western Hudson Bay, and the Southern Beaufort Sea. Both the governments of Nunavut and Greenland have substantially increased their kill in Baffin Bay and Kane Basin in recent years (the 2005-2006 harvest of polar bears in Baffin Bay was 98 for Nunavut and 135 for Greenland (Polar Bear Technical Committee 2007)). However, the Baffin Bay subpopulation was projected by Taylor et al. (2005) to be able to sustain a maximum annual harvest of about 120 bears in 1997. Effective January 1, 2006, Greenland instituted its first quota for polar bear hunting which should reduce the kill of polar bears in Kane Basin and Baffin Bay (West Greenland harvest is not to exceed 100 bears/year (Polar Bear Technical Committee 2006). Nunavut, Canada is also reviewing its harvest practices in Baffin Bay. The current combined Nunavut/Greenland regulated harvest of polar bears in Kane Basin and Baffin Bay appears to be unsustainable and is reducing the population.

Current estimates of birth and death rates for the Western Hudson Bay and Southern Beaufort Sea populations indicate that these populations are no longer capable of sustaining a harvest and would decline even if all harvest activities were stopped. The decline of birth and survival rates in these two populations is believed to be due to ice reductions caused by climate change. The continued harvest of polar bears in these areas will only accelerate the decline of these populations unless conditions improve there.

Development and Research Impacts

Since the mid-1960s, exploration for energy and mineral reserves has led to an increased amount of industrial activity in the Arctic. Concerns about disturbance of bears at denning areas due to noise or construction have been voiced in recent interviews of ATK (Atatahak and Banci 2001; Keith et al. 2005), and new activity in the Arctic has the potential to increase killing of bears in defense of life or property. However, the primary threat to polar bears from industrial development may come from the potential for environmental contamination, especially large-scale oil spills. Oil is extremely toxic and may be lethal to bears in even small amounts (Øritsland et al. 1981). Although recent oil-spill simulations (Durner et al. 2001) suggest that relatively few bears in the Southern Beaufort Sea would encounter oil if a major spill occurred from existing operations, the magnitude of risk can be expected to increase in proportion to oil and gas exploration and development activities that occur.

Inuit interviewed for ATK have recently expressed concerns that studies for scientific research, whereby bears are immobilized using drugs and helicopters and snowmobiles are used to capture bears, may cause displacement of bears or result in long-term, adverse physiological effects (McDonald et al. 1997; Atatahak and Banci 2001; Dowsley and Taylor 2006; Dowsley 2005). However, Messier (2000), after analyzing 3,237 research handlings of polar bears for the period 1989–1997, concluded that long-term effects on polar bears of tagging and radio-collaring are largely negligible from the perspective of population dynamics. Nonetheless, polar bears are sometimes killed by accident during the course of scientific research. Messier (2000) reported that mortalities occurred at an average rate of 1 per 1000 bears handled for management and population studies. Risk of mortality was higher for more complex handling protocols associated with studies of physiology (28 bears per 1000 bears handled).

Current Population Status based on Population Demography

A demographic perspective on the status of polar bears is provided by Table 1 (modified from Aars et al. 2006 and McLoughlin et al. 2008). Polar bears are removed from their subpopulations mainly as harvest removals, bear control removals, and natural mortality (Aars et al. 2006). Removals due to harvest and control activities can be regulated and controlled to a certain degree, but natural mortality is a function of ecosystem risks and environmental conditions. Table 1 examines status in two ways: current trend and anticipated population growth rate (PGR) with no removals other than natural mortality. Subpopulations that will decline (PGR < 1.0) with no removals are not viable unless the underlying demographic rates (Tables 2 and 3) increase due to improved environmental conditions or reduced density effects. Sub populations that will increase (PGR > 1.0) with no removals are viable if removals managed to remain within sustainable limits. If removals cannot be managed to remain within sustainable limits or the subpopulation is not viable; it is legitimate (from a demographic perspective) to consider the subpopulation to be threatened with extinction.

Estimates of subpopulation numbers, survival rates, and recruitment rates (Tables 1,2,3) are not exact values. Estimates of demographic rates have uncertainty based on sampling variance, environmental variability, and individual variability. When the variance of estimates is known this uncertainty can be used to calculate the proportion of subpopulation simulations that in crease and the proportion that decline. This type of analysis is called population viability analysis (PVA). Demographic PVA assumes that the best indication of a subpopulation's future demographic performance is the current (or last observed) estimates of survival, recruitment, and removal rates. When there are no databased estimates for subpopulation numbers or demographic rates, information from other populations can be extrapolated from other populations (meta-analysis). Demographic meta-analysis assumes that the density or demographic information is similar between populations. Ecological meta-analysis assumes that environmental effects observed for one subpopulation can be generalized to other populations. The status determinations listed in Table 1 do not employ meta-analysis but do assume constancy of demographic rates and removals for the period considered (36 years).

The generation time for polar bears was listed as 15 years by the Polar Bear Specialists Group (Aars et al. 2006). The age if first reproduction in most polar bear populations was taken as 5 and the maximum age of polar bears was taken as 25. Considering that about half of the reproductive age polar bears reproduce in a given year due to the three-year reproduction cycle, the 20 years (25-5) of adulthood was divided by two to give the average reproductive lifespan as 10 + 5 = 15 years. This method of calculating generation length is incorrect (McLoughlin et al. draft COSEWIC polar bear status report). Rather reproductive output at age must be weighted by the number present at that age (McLoughlin et al. 2008). The correct protocol gives a mean generation time of 12 not 15 years. Table 1 gives PVA results for three generations or 36 (not 45) years to be consistent with IUCN Redbook and COSEWIC definitions of generation time.

Of the 19 polar bear populations thought to exist world wide (Figure 1, Table 1) recent studies have indicated only 2 (Western Hudson Bay (WH) and the Southern Beaufort Sea (SB) that have declined due to climate change effects (Ferguson et al. 2005; Regehr et al. 2006, 2007a,b; Rode et al. 2007; Hunter et al. 2007; but see Dyck et al. 2007 for a counter-view on WH status). Recent studies on the adjacent populations of Southern Hudson Bay (SH) and the Northern Beaufort Sea (NB) suggest that although the new SH and NB estimates are lower than previously published estimates, these populations have remained at about constant numbers. The field sampling of the Davis Strait population (one of the most southern populations, Figure 1 and 2) was completed in fall 2007, but an analysis for current population growth rate in DS has not been completed. A preliminary population estimate of 2100 (E. Peacock personal communication 2007, Table 1) suggests a significant (but unquantifiable)increase from the previous estimate of 900 (Stirling and Killian 1980, Stirling et al. 1980) from the mid 1970s, which is consistent with information on long term trends on local densities from hunters in Labrador, Quebec, and Nunavut.

A 2004 aerial survey conducted in the Barents Sea indicated about 3000 polar bears were present in that population (Aars et al. 2006). The Barents Sea (BS) population is un-hunted so human removals are for defense purposes only. However, rates of birth and death are not known for this population so the status of the Barents Sea polar bears (like the status of the Davis Strait polar bears) is abundant, but current trend unknown.

For the 6 most recent (2004 to 2008) polar bear studies, 2 have identified a decline associated with climate change (WH, SB), 2 have identified no change over the past 15-20 years (SH, NB), one has identified an increase over the past 20 years (DS) but not current trend, and one identified a population that is abundant (BS), but could not estimate trend.

Of the 13 remaining populations 8 have been inventoried relatively recently (the year in bold is the time reference for the estimate): Foxe Basin **1993** (Taylor et al. 2007) Viscount Melville Sound **1992** (Taylor et al. 2002), Lancaster Sound **1997** (Taylor et al. 2008a), Norwegian Bay **1997** (Taylor et al. 2008a), Kane Basin **1997** (Taylor et al. 2008b) Baffin Bay **1997** (Taylor et al. 2005), McClintock Channel **2000** (Taylor et al. 2006), and Gulf of Boothia **2000** (Taylor et al. 2008c). The estimates for birth and survival rates for these polar bear populations, except Foxe Basin where vital rates were not estimated, demonstrate that productivity was sufficient for the population to increase at current densities with no harvest, or to be maintained indefinitely at estimated numbers by an appropriate sustainable harvest rate. The bio-marking (tetracycline) method used to estimate numbers in Foxe Basin did not allow estimates or recruitment and survival. Climate warming with consequent reductions in ice has been occurring from the 1970's to the present (Comiso 2002; Rigor and Wallace 2004; Belchansky et al. 2005; Holland et al. 2006; Richter-Menge et al., 2006; DeWeaver 2007; Durner et al. 2007; Meehl et al. 2007; Ogi and Wallace 2007; Serreze et al. 2007; Stroeve et al. 2007). Most polar bear population inventory studies have been carried out during the later part of this 40-year warming period. It is universally accepted that polar bear numbers have generally increased during this same period as a result of the 1974 International Agreement for the Conservation of Polar Bear (Brower et al. 2002; Fikkan et al. 1993, Prestrud and Stirling 1994) due to improved harvest management and better management of human-bear conflicts (defense kills).

Estimates for the five remaining populations: the Chukchi Sea, Kara Sea, Laptev Sea, East Greenland, and Arctic Basin populations have been variously suggested based on reconnaissance level information, extrapolation of densities from areas where population estimates were available, and the apparent sustainability of the long term harvest. These estimates were: Chukchi Sea >**2000** (Lunn et al. 2004) Kara Sea **800-1200** (Lunn et al. 2002), Laptev Sea **no estimate** (Aars et al. 2006, Lunn et al. 2002), East Greenland **2000** (Lunn et al. 2002), and Arctic Basin **inconsequential/transient** (Aars et al. 2006, Lunn et al. 2002). Estimates for population numbers in the Chukchi Sea, Kara Sea, Laptev Sea, East Greenland, and Arctic Basin were subjective so any suggestion of a trend in numbers is also subjective.

The recent Polar Bear Specialist Group status report (Aars et al. 2006) identified 5 of the world's 19 populations as declining. Two of these populations, the Western Hudson Bay (WH) and Southern Beaufort Sea (SB) are in decline due to reduced ice conditions caused by climate warming. The decline in WH and SB is accelerated by continuing legal harvest and control activities. However the other 3 populations listed as declining by the 2005 PBSG (i.e., Baffin Bay, Kane Basin, and Norwegian Bay) are identified as declining solely due to over-harvest (Table 1), not climate change effects. Baffin Bay, Kane Basin, and Norwegian Bay are viable, but over-hunted populations (Table 1).

The Kane Basin population is shared between Greenland and Canada, and has been chronically over-harvested by Greenland hunters since well before the International Agreement was signed. Greenland enacted a quota system on January 1, 2006 and the west Greenland harvest is not to exceed 100 bears/year (Polar Bear Technical Committee 2006). However, because Kane Basin, Baffin Bay and Davis Strait are treated as a single unit for management purposes by Greenland, it is unclear whether reductions in the harvest of bears in Kane Basin will result from the establishment of this quota. The mean kill of polar bears in Kane Basin has been 10 bears/year for hunters of Greenland but less than 1 per year for hunters of Nunavut (Polar Bear Technical Committee 2006). Co-management discussions regarding the hunting of polar bears have been ongoing between Greenland and Canada for several years.

The Baffin Bay (BB) subpopulation of polar bears is shared with Greenland, which until January, 2006, did not limit the number of bears killed in a year. Based on mark-recapture sampling, Taylor et al. (2005)

estimated the Greenland annual removal at 18–35 bears for the period 1993–1997. However, Born (2002) reported that the estimated Greenland average annual catch of polar bears from Baffin Bay was 73 bears/year over the period 1993–1998. Greenland documents that the average kill by Greenland hunters in Baffin Bay for the period 2001–2006 was 135 bears/year (range: 97–206 bears/year; Polar Bear Technical Committee 2007).

The 2004 estimate of <1,600 Baffin Bay bears is based on population simulations that employed the pooled Canadian and Greenland harvest records since 1998 (Table 1; Polar Bear Technical Committee 2006, 2007). Greenland adopted a quota system effective January 1, 2006, which should see the elimination of extremely high harvests like that of 2002/2003 (206 polar bears). However, assuming that 80-85 bears taken per year in Baffin Bay will comprise the 100-bear West Greenland quota (historical Greenlander harvest of bears in Kane Basin and Davis Strait has been 10 and 5-10 bears, respectively (Polar Bear Technical Committee 2006)), the recent level of current Nunavut-Greenland harvest could be as high as 185 bears/year. Simulations suggest that this level of hunting will continue to deplete the subpopulation (Taylor et al. 2005, Table 1).

The risk of decline in the Norwegian Bay (NW) population is increased by a relatively low rate of reproduction and low numbers. Norwegian Bay is currently dominated by heavy multi-year ice, and is one of the areas where polar bears could benefit from climate warming due to more active and more annual ice (i.e., expected increase in both abundance of and accessibility to seals). The harvest quota for the Norwegian Bay subpopulation was reduced to 4 bears (3M:1F) in 1996 and remains at this level today. The harvest of polar bears from Norwegian Bay is predominately males because the harvest is mostly guided sport hunts (Taylor et al. 2007). The predominately male harvest is expected to cause the total population to decline initially due to a reduction in males, but increase in the long term as the under-utilization of females caused females numbers (and population productivity) to increase (Taylor et al. 2008a,d). The decline indicated by the PVA model used to assess status (Aars et al. 2006) is an artifact of the limited time frame (10 years) and the unusual effect of the male-selective sport harvest.

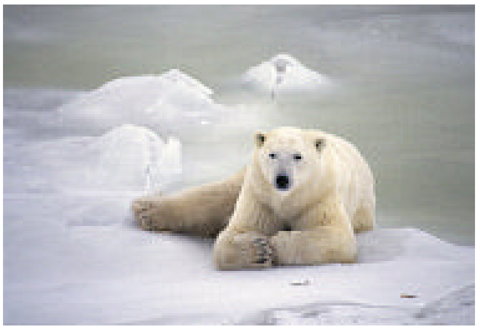
The declines indicated for KB, BB, and NW have nothing to do with climate change effects.

Of 6 polar bear populations recently evaluated during the climate warming period, two populations appear to have been reduced (WH, SB), 2 populations appear to have remained constant (SH, NB), and one population appears to have increased (DS), and one was abundant but the information was not sufficient to estimate trend (BS). Seven other populations (VM, LS, NW. BB, KB, MC, GB) surveyed during the period of climate warming had vital rates sufficient to sustain substantial rates of harvest at the time they were studied. Information from a Foxe Basin (FB) population survey was sufficient to document that the population had remained abundant although it had been harvested at a relatively high rate, although the survival and recruitment estimates necessary to determine trend were not available. The biological information on the remaining four populations (CS, LS, KS, EG) and the few bears that may inhabit the Arctic Basin is insufficient to suggest anything about current numbers or trend.

Considered together, these demographic data do not suggest that polar bears as a species are headed for extinction in the next three generations (45 years) or the foreseeable future. The demographic data do support increased monitoring, and augmenting periodic population surveys with ecological and behavioral studies.

Polar Bear Status Determination Based on Climate Model Projections

In August 2005, the IUCN/SSC Polar Bear Specialists Group resolved that the risk from climate change was sufficient that polar bear stocks might be reduced by as much as 30% over the next three generations (45 years in Aars et al. 2006). The IUCN/SSC species status designation rules identify a species that is reduced by >30% over 3 generations as "threatened". However it appears that the PBSG erred in its calculation of generation time (see above and McLaughlin et al. 2008). The generation time of polar bears is actually 12 years not 15 years, which reduces the time required for three generations from 45 to 36 years. The PBSG resolution to list polar bears as "threatened " under the IUCN/SSC "Redbook" system was unanimously supported. However, a reduction in range and numbers due to reduced habitat over a 45 (or 36) year period is not the same as extinction in that same time period, and does not automatically imply that the decline will continue until polar bears are eliminated as a as a species (Endangered Species Act definition of "threatened"). Although many people may not consider a 30% decline of polar bear numbers to be acceptable given the terms of the International Agreement, a reduction in range and reduced numbers is not extinction; and does not necessarily imply extinction. To qualify for listing as a "threatened species" under the U.S. Endangered Species Act (49 FR 38908, Oct. 1, 1984) the following definitions/criteria apply:



(e) *Endangered species* means a species that is in danger of extinction throughout all or a significant portion of its range.

(m) *Threatened species* means any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

The proposed rule or finding that polar bears should be listed under the Endangered Species Act as threatened (USFWS 2007) depends on the argument that continued climate warming with its projected effects on sea ice constitutes "present or threatened destruction, modification, or curtailment of its (polar bear) habitat or range" sufficient to cause extinction if not stopped or reversed.

The prognosis that global climate will continue to warm with associated reductions in sea ice are entirely from the Inter-governmental Panel on Climate Change (IPCC) climate model projections. Based on economic assumptions that atmospheric greenhouse gasses will continue to increase from anthropogenic sources, the In IPCC climate change models project an increase in global temperature and a consequent decline in sea ice over the next millennium. These IPCC projections of global climate warming and seasonal reductions to sea ice are qualitatively consistent irrespective of the economic alternatives (assumptions) about expected future anthropogenic greenhouse gas emissions (DeWeaver 2007).

The rationale for up-listing polar bears to "threatened" status is that the same effects observed in the WH and SB populations may already be occurring, or will eventually occur in all polar bear populations; and therefore all polar bear populations will decline to extinction unless climate warming is arrested. The IPCC climate modelers assert that climate warming is caused by anthropogenic greenhouse gasses, so the only way to mitigate or reverse the threat of climate warming to polar bears would be to return global greenhouse gasses to levels that will allow the earth to cool and the ice to return to former levels. However, the IPCC also asserts that global CO2 emissions will increase under the range of economic scenarios they consider practical and realistic. Logically, if one accepts the IPCC assertions, one concludes that the status and ultimately the demise of polar bears will not be influenced by its status under the Endangered Species Act. According to the

IPCC, greenhouse gasses will increase, the climate will warm, and the sea ice will be diminished. Derocher et al. (2004) concluded that "it is unlikely that polar bears will survive as a species if the sea ice disappears completely as has been predicted by some." Amstrup et al. (2007) states: "*Our modeling suggests that realization of the sea ice future which is currently projected, would mean loss of ≈ 2/3 of the world's current polar bear population by mid-century*". Regehr et al. (2007b) warns: "*Because western Hudson Bay is near the southern limit of the species' range, our findings may foreshadow the demographic responses and management challenges that more northerly polar bear populations will experience if climatic warming in the Arctic continues as projected.*" Ian Stirling was recently quoted in McLean's Magazine as saying "*The fact that things may be okay in some populations right at the moment is a little beside the point. They're trying to look at, (what would happen) if we continue on the trajectory we're on, where might we be in 45 years?*" Polar bears today are well managed and not in any immediate danger of extinction (Table 1). The concern for the continued existence of polar bears is not based on population trends today, the concern derives from assumptions about what climate model projections suggest will occur 50 and 100 years from now.

A technical evaluation of the IPCC GCMs is beyond the scope of this paper because it is beyond the expertise of the authors. However, we wish to draw attention to two apparent discrepancies in correspondence between model predictions and nature:

1) The first references the September Arctic Sea Ice (Figure 2 in: Siegel 2008) reproduced as our Figure 3). It is unclear why the IPCC models have not been particularly successful at predicting (they over-estimate) sea ice coverage from about 1990 to the present. One interpretation of the deviation between actual and predicted values of arctic ice coverage is that the IPCC models are "conservative" with respect to their predictions about the effect of climate warming on sea ice. Another interpretation is that some unknown and not included factor has been responsible for the decline in ice, and that is why the greenhouse gas driven models don't predict arctic sea ice extent very well. One thing is certain, extrapolating predictions of ice extent forward in time for 50 and 100 years using models that do not forecast ice very accurately up to the present may not provide accurate forecasts(see also .

2) Paradoxically sea ice has decreased in the northern hemisphere and simultaneously increased in the southern hemisphere (Zwally et al. 2002; Cavalieri et al. 2003, Vyas et al. 2003; Liu et al. 2004; Taylor 2006, Krinner et al. 2007, Zhang 2007). Explanations for this phenomena vary, but at minimum the apparent inconsistency underscores the complexity of global climate dynamics

Are the IPCC climate models capable of accurately predicting global climate and the extent of sea ice 50 and 100 years into the future? Accepting a polar bear status designation of "threatened" under the Endangered Species Act requires that the IPCC climate model projects that embody the Greenhouse Gas -Climate Warming hypothesis are legally (Endangered Species Act) accepted as scientifically legitimate and accurate. Siegel (2008) makes the implications of that decision clear in her testimony to the House of Representatives Select Committee on Energy Independence and Global Warming.

If current understandings of global climate turn out to be incomplete, and the climate turns colder with a consequent increase in sea ice or does not continue to warm as projected … it is clear that polar bears should not be classified as "threatened" or "endangered". If the climate continues to warm as the IPCC models suggest, the range of polar bears would diminish and polar bear numbers would decline. How much the range would diminish and how great the decline might be is conjecture.

Projected Loss of Arctic Sea Ice and Anticipated Impacts on Polar Bears

Amstrup et al. (2007) attempts to quantify the anticipated impacts (assuming the climate models are correct) by looking at the population effects of habitat change as a simple linear function of habitat availability. The approach and some of the initial assumptions in Amstrup et al. (2007) have been questioned (Armstrong et al. 2008). Polar bears in most populations are harvested and could not be at ecological carrying capacity (K). No harvested population is at carrying capacity, because, at carrying capacity, the population growth rate is 1.0 and there is no sustainable harvest. If a harvest is taken from a population at carrying capacity (N = K), the population declines to some number less than K and birth rate-death rate increase because of the relaxation of density effects. There is no evidence that polar bears are at carrying capacity for any population, and there is no evidence to support any mechanism/s of density dependent population regulation for polar bears. In any event, Amstrup et al. (2007) is not really assuming that polar bears are at ecological carrying capacity, they only assume that within ecoregions, population numbers are proportional to the available habitat … which is defined as >50% ice coverage over continental shelf waters.

Suggesting that polar bear numbers are directly proportional to the amount of available (> 50% ice coverage) ice is only an assumption, not a scientific result (Dyck et al. 2007). Stirling and Parkinson (2006) use different criteria for “available” habitat. Amstrup et al. (2007) are aware that polar bears are present at higher densities in prey-rich areas and at lower densities where prey species (especially ringed seals) are less abundant (they cite: Kingsley et al. 1985; Stirling and Øritsland 1995). They are also aware that some populations (VM, MC, and KB) are currently depleted or recovering due to over-harvest. There are no data-based population estimates for the Chukchi Sea, Kara Sea, Laptev Sea, and East Greenland populations. The Amstrup et al. (2007) population estimate for the divergent area appears to have assumed the number of polar bears in the Kara Sea subpopulation is zero, which appears to have been carried over from the status table in Aars et al (2006). No estimate of the number of polar bears in the Kara Sea was provided in the status table in Aars et al.(2006), but no estimate is not equivalent to an estimate of zero. Population and ecoregion density at “carrying capacity” was estimated as simply the sum of the subpopulations in a given ecoregion from Aars et al. (2006) divided by the area of available “habitat” in that ecoregion.

The assumption of a linear relationship of polar bear numbers to > 50% sea ice can be examined by considering the numerical response of recently surveyed populations to reductions in sea ice. Based on recent population surveys in the SB (decline), NB (stationary), WH (decline), SH (stationary), and DS (increase); the relationship between ice and population numbers appears to be more complex. Why has the number of polar bears in some populations remained constant or increased when sea ice there has declined? One explanation is that polar bears have a life history strategy that is adapted to fluctuations in environmental conditions, so that demographic effects of sea ice fluctuations have been mitigated or delayed. Polar bears exhibit a high degree of behavioral plasticity (Stirling and Derocher 1990) which assists them in adjusting to changing conditions. Stirling and Parkinson (2006) suggest that DS is enriched by increased numbers of harp seals which would mitigate the effects of a decline in ice, and perhaps it is. Since the harp seal hunt was curtailed in the mid 1970’s harp seals have become generally more abundant throughout the arctic archipelago in summer and fall. Another possibility is that some populations may have been declining in productivity due to reduced ice, but have also been under-harvested. The net effect of these opposing demographic forces could have been population growth (e.g., DS) or population stability (e.g., SH and NB). These many problems aside, it is instructive to see what impacts could be expected if polar bear numbers were proportional to the areas of > 50% ice over arctic continental shelf waters.

Climate change is not expected to affect all polar bear populations equally or simultaneously (Derocher et al. 2004, Amstrup et al. 2007). Assuming the IPCC Climate Change models are correct with respect to predicted declines in ice, and assuming there is a linear relationship between population number and available (>50% ice coverage) habitat (as per Amstrup et al. 2007); an ecoegional determination of projected ice declines can be used to estimate the numeric effect on population numbers. Table 4 in Amstrup et al. (2007) provides the percent decline in available ice for each of their four ecoregions, and Table 5 in Amstrup et al. (2007) provides best estimates of population numbers time referenced to the IUCN PBSG meeting in 2004 (Aars et al. 2006). Amstrup et al. (2007) looks at ice declines based on the most optimistic, most pessimistic, and mean values from the suite of ten IPCC AR-4 GCMs chosen based on their fit to past ice coverage. The projected declines in > 50% ice coverage were similar, so we used only the mean decline (Table 4, Figure 5) to show projected ecoregional declines in > 50% ice coverage over the same 100 year period. We then used the same linear relationship proposed by Amstrup et al. to extrapolate the decline in polar bear habitat to the populations in each ecoregion (Table 4, Figure 6).

Over 100 years, total polar bear numbers were projected to decline about 30% from 24,500 to 17,180. In 45 years numbers declined about 17% from 24,500 to 20,405. For comparison, the National Wildlife Federation (the largest conservation organization in the United States) supports ESA delisting Yellowstone grizzly bears with an estimated population of 600. The projected decline of polar bears and polar bear habitat is serious and should be taken seriously, however these results do not suggest polar bears are in danger of extinction in 45 years or even 100 years. One hundred years is well beyond the “foreseeable future” if the time machine is a contemporary climate model (Serreze et al. 2007, DeWeaver 2007).

Amstrup et al. (2007) acknowledges that his measure of annual ice coverage change (km-months) may be not track key environmental variables that are seasonal (e.g., consecutive days of < 50% ice coverage). The IPCC GCMs project that summer sea ice losses are about double the losses predicted for other seasons. Polar bears have fat storage mechanisms and a resting metabolism that allows them to increase their energy stores (fat) during favorable hunting periods, and to use that stored energy efficiently during periods of fasting (Watts and Hansen 1987, Ramsay and Stirling 1988, Ramsay and Hobson 1991). However, the decline in demographic performance for some polar bear populations (Hunter et al. 2007, Regehr et al. 2006, 2007a, b; Rode et al 2007) demonstrates that there are limits to the degree to physiological adaptations can mitigate an extended open-water season.

Additional analyses could improve our understanding of the potential impacts of the IPCC GCM projections of ice declines. However, the majority (60%) of the IPCC models project ice cover in all seasons for the next 40-50 years throughout much of the North American continental shelf where most polar bears reside (Alley et al. 2007, Serreze et al. 2007). The IPCC climate model forecasts for ice reductions in fall, winter, and spring are substantially less than for the summer open water season (Serreze et al. 2007). Most of the ice coverage maps that have been developed for publication in the popular press have been for the month of minimum ice (September) which also is the month when ice coverage is forecast to decline the most. Polar bears have historically maintained viable and productive populations in areas that have an ice-free season (e.g., Western Hudson Bay, Southern Hudson Bay, Davis Strait, Baffin Bay, and Foxe Basin), and (with the exception of WH) these populations are believed to have persisted at fairly constant numbers or increased through the most recent period of climate warming (Aars et al. 2006, Obbard et al. 2007, Taylor et al. 2007, E. Peacock personal communication, 2007, Table 1). Considering that polar bear habitat (> 50% ice coverage) is forecast to decline only 18% over the next 45 years and only 32% over the next 100 years (Table 4), and considering that both annual sea ice decline and maximum days of open-water will be population specific; it is not rational to suggest that polar bears are in danger of extinction in a 45 or 100 year time frame. More detailed analyses will improve our understanding of which populations will be affected first and which will be affected the most, however the qualitative conclusion that polar bears as a species are not at risk of extinction is not in doubt.

Amstrup et al. (2007) also develops a Bayesian Network (sometimes called a "Belief Network") to systematically explore the implications of a number of beliefs or assumptions about polar bear ecology under a climate change scenario. Although this paper is essentially a tautology because it assumes from the start that ice will decline and that sustaining polar bears at current numbers depends on sea ice continuing at approximately current levels; the paper does state formally the rationale behind the argument for a "threatened" listing. If you believe the initial assumptions, then the conclusions make sense. Amstrup et al.'s (2007) Belief Network provides an explicit logical structure that links Amstrup's beliefs (Dr. Amstrup provided the only expert opinion for the Bayesian Network) about the negative impacts to polar bears that will occur if sea ice was reduced to IPCC GCM's projection of sea ice reduction. The IPCC models considered all predict that arctic sea ice will be reduced, so the outcome of the exercise is never in doubt. The Belief Network that was developed simply allows the calculation of the joint probabilities of various qualitative outcomes. These outcomes are not data-derived, rather they are Amstrup's beliefs about what reduction in sea ice might mean to polar bears. In fairness, Amstrup's beliefs are based on both data he has collected, data reported by others in the scientific literature, and extensive field experience (mostly in the Beaufort Sea). However, suggesting that this construct can forecast the status of polar bear population up to 100 years in the future is not credible as "science". Repeating the same exercise with an initial assumption that climate will cool or simply fluctuate would result in a totally different perspective on the status of polar bears. Repeating the same exercise with an "expert" opinion that polar bears will adapt to climate change, especially those polar bears that inhabit the continental shelf of Canada's Arctic Archipelago, would also result in a totally different perspective. There can be a diversity of opinion on status when the future is uncertain.

The Amstrup et al. (2007) Bayesian Network approach is useful, but should not be considered as equivalent to scientific studies to support management decisions or status determinations. Only one person's view was included in the Amstrup et al. (2007) implementation the Bayesian Network (i.e., Dr. Amstrup). If the selection of experts was based on a group with similar attitudes the status determinations results from such an "expert" group would be about the same as those from Dr. Amstrup alone. A scientific result should not be dependent on the choice of investigators (Armstrong et al. 2008). The Bayesian Network approach was much more pessimistic than the "carrying capacity" data-based approach included in the same paper (Amstrup et al. 2007), which may provide some insight into the difficulties of interpreting this methodology.

Demographic versus GCM Perspectives on Polar Bear Persistence

Taken without reference to climate model projections, the existing demographic data do not support the perspective that polar bears are headed for extinction in the foreseeable future. Demographic studies on polar bear populations that seek onshore retreats during the open-water seasons demonstrate that summer sea ice is not required for a population to sustain a harvest or to persist indefinitely. Most polar bear populations surveyed during the current climate warming period have been shown to be viable and productive, and would persist indefinitely if the harvest was managed to remain within sustainable limits. However, biological data also document that if the open water season becomes too long, recruitment, cub survival, subadult survival, and population viability can be affected. If the effects are long-term and consistent, polar bear numbers can decline and subpopulations can eventually be expatriated.

To date, no population has been expatriated due to climate change effects, so the effect of decreased densities, alternative food sources, or behavioral adaptation to less ice on population persistence is not known. However, the importance of sea ice to polar bears, including polar bear population demography, is not in question. We share our colleague's opinions (DeMaster and Stirling 1981, Amstrup, 2003, Derocher et al. 2004) that neither evolutionary adaptation nor terrestrial foraging alone could be sufficient to accommodate a catastrophic loss of sea ice. However, the increase to current high numbers if polar bears in Davis Strait has occurred during the current warming period, and has occurred with declining sea ice conditions that are sometimes less that 40% coverage at winter maximum (Stirling and Parkinson 2006). Clearly the DS bears do manage to hunt successfully in unconsolidated pack ice. Harp seals have increased in the DS area, but telemetry (Taylor et al. 2001) and harvest/capture records do not support the notion that all or even a substantial fraction of the DS population makes the journey to the harp seal pupping areas each spring for hyperphagic feeding. Successful hunting (fresh seal kills) in the summer open-water season have been observed in Western Hudson Bay, Foxe Basin, Baffin Bay, and Davis Strait populations and (M. Dyck and M. Taylor personal observation) and elsewhere (Furnell and Oolooyuk 1980, Derocher et al. 2004). These natural history observations do not prove or disprove that polar bears can mitigate seasonal declines or seasonal loss of sea ice. These observations do suggest that the degree to which polar bears can adapt to more active ice and a longer open water season is at present unknown and may be area specific.

Generally, polar bears currently appear to be as abundant as, or more abundant than at present as they have ever been in modern times (Table 1). The perspective that polar bears are threatened with extinction depends entirely on two hypotheses: The first is that the climate will continue to warm as projected by the IPCC climate models. The second is that the effect of climate warming will cause reductions to sea ice sufficient that all or most populations of polar bears can no longer persist. The ability of climate models to forecast climatic conditions (including ice coverage) will become clear with time. Atmospheric CO2 and other greenhouse gasses will increase, and the effect of anthropogenic greenhouse gas emissions on the earth's climate may become clear (Soon et al. 2001, Soon 2007). The forecast reductions to arctic sea ice that forms polar bear habitat will reduce the number and may reduce the range of polar bears if these ice cover predictions are accurate. However, the forecast reductions in polar bear sea ice habitat will not be sufficient to endanger polar bears as a species for more than 100 years.

It appears that from both a demographic and an ecological perspective, polar bears are not currently endangered and are not forecast to become endangered "in the foreseeable future". The observed and forecast decline in polar bear habitat and polar bear numbers does indicate that polar bear research and management initiatives should be identified as priority conservation activities.

Anecdotal Information and "The Science"

Most demographic studies (Taylor et al. 1987; 2001; 2002; 2005; 2006; 2008a, b, c; Stirling et al. 2007; Regehr et al. 2006, 2007b) from populations that are viable have sustained long-term historical harvest on the order of 4.5% per year have been found to have natural adult mortality rates of about 4-5% per year. Cubs of the year, subadults, and senescent (age >20) adults typically have higher rates of natural mortality than prime age adults. These mortality rates suggest that one should expect something like 1500+ polar bears of all ages to die from natural causes from a world population of population of 24,000 individuals. Incidental observation of natural mortality does not mean the population from which the observation was taken, or polar bears as a species, have become non-viable. Mortalities are as natural as births.

Natural mortality can occur from a number of causes (e.g., disease, injury, intra-specific predation (cannibalism), drowning, and starvation). In the pre-climate change era, these natural mortalities were observed and recorded without much fanfare. Currently it seems that any observation of natural mortality, or even the sighting of a skinny bear, seems to be held up as evidence (or consistent with the notion) that polar bears are dying out because of climate change (Siegel 2008).

A case in point is provided in a recent testimony the US House of Representatives Select Committee on Energy Independence and Global Warming by K. Siegel. Her submission contained a picture (Figure 3 in: Siegel 2008) of an emaciated polar bear taken in the east Ungava Bay area. Her analysis of this picture which came from a newspaper article (Nunatsiaq News 2007-09-14) about the sighting was: “*While we cannot say for sure that this bear starved to death as a direct result of global warming, as we do not know the bears history or origin, we do know that global warming will increase the number of bears that suffer this fate*.” The newspaper article (that carried this picture mentioned that local Inuit were surprised to see such a skinny bear when most polar bears encountered in this area were in good condition, but this local knowledge was not mentioned in Siegel’s testimony. One of the authors of this report (Taylor) has recently been involved in a polar bear mark recapture survey of the entire Davis Strait area which included east Ungava Bay, and most (great majority) of the bears we encountered and captured were in good to excellent condition. The sighting of a single bear in poor condition maybe distressing, but one cannot infer anything about the cause or nutritional status of the population from such a sighting. The emaciated bear in Siegel’s Figure 3 had large scar on the muzzle from some injury. Was the injury related to the bear’s condition? Is the bear simply old and near the end of its life? None of these considerations are mentioned.

The cover page of Siegel’s same testimony (Siegel 2008) has a photo of polar bear in good condition, but there is no caption stating: “*While we cannot say for sure that all polar bears in this area are in excellent condition and have never experienced any climate change effects; the sighting of this bear (which is in fine condition) is entirely consistent with that perception. If global warming turns out to be a myth or to be simply misguided, more bears will be in excellent condition as climate cycles back to colder temperatures*.”

Asserting or implying that isolated observations constitute “the science” on some topic shows a poor understanding what science actually is. Natural mortality on polar bears from starvation, intra-specific attacks, grizzly bear attacks, failed walrus predation attempts, drowning, and physical injuries are not uncommon (Taylor personal observations). In 2007 an adult male in good condition was observed eating a freshly killed cub of the year that was in good condition. An adult female, presumably the cub’s mother and also in good condition, was watching from a nearby hill top. This does not mean that all the bears in DS are in good condition. Nor does it mean that polar bears in DS are starving to death and have been forced to eat each other to survive. It is an anecdotal observation of an isolated incident, nothing more. Our Inuit colleagues have shared similar observations of intra-specific aggression over the years. These events are understood to be part of the natural history of polar bears, not some desperate cannibalistic act that occurred to mitigate the effects of climate change. Witnessing natural mortality, then hypothesizing about possible causal relationships is not “science”, even if the person giving his/her thoughts is a technical expert. Incidental observations or the lack of them are interesting, but not as informative as statistical analysis of data collected systematically in a manner consistent with the analysis model.

As far as we know, none of the IPCC GCM projections suggest that the sea ice will disappear. Each winter the earth tilts the arctic away from the sun, and the northern sea freezes. Several polar bear populations have historically occurred in areas that have an extended open water season, so simply the existence of an open water season would not doom a population to extinction. Some IPCC GCM projections suggest an ice free polar basin in the distant future, but this projection is for September, the month of minimum sea ice, not the entire year. The often quoted statement from Derocher et al. (2004): “it is unlikely that polar bears will survive as a species if the ice disappears completely as has been predicted by some” has little meaning in the context of the IPCC GCM projections. None of them predicts that the ice will disappear completely in all seasons. Similarly glib quotes like “no ice, no bears” may sound profound, but they are not useful to a scientific consideration of polar bear status.

The role of a scientist in public policy formation is to remain neutral and objective. Environmentalists, industry advocates, and the interested public do not labor under these constraints. They may choose to view the decision process as adversarial, and present only the information that supports their view. An example may be found in Siegel’s recent testimony where she considers the results of Amstrup et al.’s (2007) polar bear status paper. As indicated above, the ecoregion habitat analysis portion of Amstrup et al.’s paper provides good reasons to be optimistic about the long-term persistence of polar bears. However, the Bayesian Network described in the same paper suggests that one expert (Amstrup) believes that 2/3 of all polar bears will be lost by 2050 if the IPCC GCM predictions hold true. Siegel reports only the negative results of the Bayesian Network in her testimony.

Alternatives and Options

Historically, polar bears were managed throughout the circumpolar basin as though their environment was static (Lunn et al. 2002, Aars et al 2006). Although there was general appreciation for the annual variability of arctic ecosystems and a growing appreciation for decadal cycles that affected habitat quality and some demographic rates (Stirling 2002), the general technical consensus was that the variability and the cycles were around some long-term mean or baseline that was constant. The general climate warming and subsequent deterioration of sea ice over the last 2-3 decades has made it apparent that environmental change can be both unidirectional and long-term (Maslanik et al., 1996; Serreze et al., 2000, 2007; Parkinson and Cavalieri, 2002; Richter-Menge, 2006; Shimada et al. 2006; DeWeaver 2007; Meehl et al. 2007; Stroeve et al. 2007). This new information coupled with the IPCC GCM projections that climate warming will continue in the long term has caused concern for the status of polar bears. The available scientific information available to evaluate climate change model predictions may or may not be sufficient to conclude that the models are reliable and accurate. If they are not deemed to be reliable and final, I submit that the argument to list polar bears as a threatened species no longer has a valid premise. That does not mean that polar bear researchers should return to their “baseline” thinking, only that status determinations of polar bears should be based on current demographic data until the mechanisms of long-term trends are better understood.

If the IPCC GCM projections are accepted, the question of status becomes a question of anticipated impacts. The projected amount of habitat loss and subsequent population reduction does not suggest that polar bears are endangered as a species for more than 100 years. However, some of the assumptions required to develop this ecoregion perspective are questionable. A better approach to the question of status is possible with the existing data.

The decline of polar bears in the WH and the SB population (Table 1) appears to have occurred as a gradual reduction in litter production rate, litter size, cub survival, and subadult survival; which caused the removal rate (harvest and defense removals) to eventually become unsustainable (Stirling et al. 1989, Derocher and Stirling 1996, Stirling and Parkinson 2006, Regehr et al. 2006, 2007a,b,c; Rode et al. 2007; Hunter et al. 2007). The biology of the decline does not suggest linear relationship between available habitat and the number of bears. Rather it suggests a gradual reduction in demographic rates that eventually results in a population decline that depends both on the harvest (removals) and the underlying vital rates. An alternative perspective for populations that summer onshore (or could summer onshore) is to evaluate when the number of consecutive open water (ice coverage < 50%) days reaches a threshold where un-harvested population growth rate becomes less that 1.0 (population is no longer viable). For open ocean populations (where polar bears summer on pack ice), the threshold value could be the number of consecutive days of < 50% ice cover over continental shelf or some other appropriate measure. Threshold values for both scenarios could be calculated from existing data for both WH and SB populations.

The next step would be to use the IPCC GCMs to predict the anticipated declines in ice for each population, and thus identify the year when the threshold (consecutive days of open water) is reached for each population. Each population might reach the threshold at a different time, some populations might group within Ecoregions, and some populations might never reach the threshold. This approach would allow a perspective on population status that was independent of current or historical population or vital rate estimates for the 19 individual circumpolar populations. The assumption would be that the threshold value identified for the SB (open ocean) and WH (onshore summer) retreat populations could be extrapolated to all populations.

Unlike the Southern Beaufort Sea, Northern Beaufort Sea, Western Hudson Bay, and Southern Hudson Bay, only one reliable population estimate has been developed for the Viscount Melville, Norwegian Bay, Lancaster Sound, Kane Basin, Baffin Bay, Foxe Basin, M'Clintock Channel, and Gulf of Boothia populations. A second mark-recapture demographic survey in these areas will allow statistical evaluation of any changes in demographic rates and population numbers which will allow a direct evaluation of climate change effects. These surveys are planned as part of the Nunavut Polar Bear Memoranda of Understanding, and the rotational inventory has been discussed at national conservation meetings in Canada. An alternative to listing polar bears immediately would be to defer (not up-list) polar bears at the present time to allow time for a more thorough analyses of existing data, collection of more data, and additional time to compare model predictions with nature. The argument that drastic measures to cut greenhouse emissions are required immediately is not consistent with the IPCC assessment that greenhouse gas emissions will continue in any event, and does not take into account that the projected effects of greenhouse gas emissions on climate and sea ice appears to asymptote in about 100 years, before polar bears would be threatened with extinction from sea ice reductions. Neither the demographic nor ecological perspectives suggest any conservation benefit from a premature decision to list polar bears as a "threatened species".

The negative conservation implications from a premature up-listing include loss of scientific credibility, loss of support from aboriginal harvesters, and perhaps even reduced support for the Endangered Species Act as conservation legislation.

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Table 1. Status of subpopulations of polar bears within or shared by Canada. Source: IUCN/SSC Polar Bear Specialist Group (2006) and Canadian Federal/Provincial Polar Bear Technical Committee (2007), Committee on the Status of Endangered Wildlife in Canada Polar Bear Status Report (2008), and primary literature cited by population in text.

Subpopulation	**Previous Estimate**		**Current Estimate**		**Known Removals**[a]		**Population Viability (Current Estimate)**[b]		
	No. of bears (year of estimate)	**±2 SE**	**No. of bears (year of estimate)**	**±2 SE**	**Identified permitted harvest (bears/year)**	**5-year mean kill in bears/year (2001-2006)**	**Likelihood**[c] **of any decline**	**Finite rate of increase w/removals (λ ± 1 SE)**	**Finite rate of increase w/no removals (λ ± 1 SE)**
Baffin Bay	2074 (1998)	1544 - 2604	1546 (2004)	690 - 2402	105 + Greenland	220.6	0.999	0.747 ± 0.343	?
Davis Strait	1400 (1980)	n/a	2100 (2006)	n/a	52 + Greenland, Québec	58.6	unknown	n/a	?
Foxe Basin	2119 (1996)	1421 - 2817	2300 (2004)[d]	1780 – 2820[e]	106 + Québec	98.0	unknown	n/a	?
Gulf of Boothia	n/a	n/a	1528 (2000)	953 - 2093	74	50.6	0.079	1.048 ± 0.049	?
Kane Basin	n/a	n/a	164 (1998)	94 -234	5 + Greenland	13.8	0.999	0.954 ± 0.025	?
Lancaster Sound	1031 (1979)[f]	795 - 1267	2541 (1998)	1759 - 3323	85	77.8	0.386	1.003 ± 0.024	?
M'Clintock Channel	700 (1978)	n/a	284 (2000)	166 - 402	3	1.2	<0.001	1.021 ± 0.010	?
Northern Beaufort Sea	1200 (1986)	n/a	980 (2007)	825-1135	65	35.4	?	?	?
Norwegian Bay	n/a	n/a	190 (1998)	102 - 278	4	2.4	0.697	0.951 ± 0.179	?
Southern Beaufort Sea	1800 (1983)	1300 – 2500[e]	1526 (2007)	1211 - 1841	81	53.0	0.999	0.967 ± 0.014	?
Southern Hudson Bay	1058 (1986)	618 - 1498	681 (2007)	401 - 961	25 + Ontario + Québec	40.0	?	?	?
Viscount Melville Sound	161 (1993)	121 - 201	215 (1996)	99 - 331	7	4.4	0.074	1.054 ± 0.032	?
Western Hudson Bay	1194 (1987)	1020 - 1368	935 (2007)	794 - 1076	56 + Manitoba	46.4	0.999	0.922 ± 0.097	?
Chukchi Sea	2000 (2002)	na	**na**	**na**	Alaska + Russia	unknown	unknown	unknown	unknown
Laptev Sea	1000 (2002)	800-1200	**na**	**na**	Russia	unknown	unknown	unknown	unknown
Kara Sea	unknown	na	**na**	**na**	Russia	unknown	unknown	unknown	unknown
Barents Sea	2997	2299-4116	**na**	**na**	Norway+ Russia	unknown	unknown	unknown	unknown
East Greenland	2000 (2002)	na	**na**	**na**	Greenland	70	unknown	unknown	unknown
Arctic Basin	transient	na	**na**	**na**	na	na	na	na	na
TOTAL	**Current estimate : ~ 23,000** Approximate range 17,600 – 28,500				**>668**	**772.2**	**unknown**	**unknown**	**unknown**

Footnotes for Table 1:

[1] The identified permitted harvest includes the maximum harvest that is presently allowed by jurisdictions with an identified quota. Where bears are harvested without quota the jurisdiction(s) without a dedicated quota (named) will add kills to the identified quota. Greenland has, as of January, 2006, identified a quota of 100 bears for "West Greenland", but how kills will be apportioned among the subpopulations of Baffin Bay, Kane Basin, and Davis Strait is unknown. Historic harvest of these subpopulations by Greenland (PBTC 2007) suggests that a breakdown of 80-85, 10-20, and <5 bears, respectively, would be reasonable.

[2] Simulation results are stochastic birth-pulse life table population projections. Models for subpopulations were developed from information contained in tables 2–4 using the simulation model RISKMAN. Models were only conducted for subpopulations where data were of sufficient quality to project the population with reasonable confidence, or simulation results were qualified. Values > 1 indicate a growing population; values < 1.0 indicate a declining population.

[3] A biologically viable population is one that can sustain itself or increase with no anthropogenic removals (i.e., $\lambda \geq 1.0$).

[4] Derived from ATK and the expectation that the population increased under past rates of harvest.

[5] Underestimate because the 1979 study area (Schweinsburg et al. 1982) differs substantially from that used to determine the 1998 estimate (Taylor et al. 2008b). The study area of Taylor et al. (2008b) is much larger and extends further to the west, north, and south of Lancaster Sound, although Taylor et al. (2008b) exclude portions of northern Baffin Bay included in the assessment of Schweinsburg et al. (1982).

[6] Survival rates of yearlings from Stirling et al (2007) appeared to be under-estimated, so a meta-analysis approach was used. Yearling survival rate estimates were taken from the adjacent Southern Beaufort Sea (Regehr et al. 2006,2007b; Table 4. Errors in survival rate estimates may be due to unmodelled heterogeneity in the data. Stirling et al. (2007) conclude that the population has been about constant in numbers, and that earlier estimates of abundance were biased low.

[7] Abundance estimates for Southern Hudson Bay in Obbard et al. (2007) are suggested to by Obbard et al. (2007) to underestimate the true abundance by 70-110 bears because the entire subpopulation was not sampled.

[8] Highly variable and apparently unrealistic survival rate estimates preclude a confident simulation. Trajectories based on population simulations may be biased low if the survival rates presented in Obbard et al. (2007) have been under-estimated. Using the same data used to estimate survival rates Obbard et al. (2007) conclude that the population has been constant in number since the mid-1980s, but may decline in the future because of observed reductions in body condition likely associated with climate change.

[9] Population simulations for Western Hudson Bay conducted using the high (top row) and low (bottom row) survival rates for ages 2–4 and ≥20 as presented in Table 5 and Regehr et al. (2007a).

[10] Estimated minimum and maximum range only.

[11] Population numbers were estimated by extrapolating the subpopulation density of the adjacent Laptev Sea e to the Kara Sea which has approximately the same continental shelf sea ice habitat area. No other population estimate is available for this subpopulation.

Table 2. The mean (standard error in parentheses) of post-den-emergence litter size and age-specific probabilities of litter production (LPR) for lone adult females or females with dispersing (2-year-old) cubs is reported for subpopulations with sufficient data to calculate these estimates. LPR is referenced to single adult females and females with 2-year-old cubs because of the 3-year reproductive cycle of polar females with cubs-of-the-year or yearlings are not available to mate (i.e., 3-year reproductive cycle).

Subpopulation (data source)	Cub (age 0) litter size	Age 4 LPR	Age 5 LPR	Age 6 LPR	Age 7+ LPR
Baffin Bay (Taylor et al. 2005)	1.587 (0.073)	0.096 (0.120)	0.881 (0.398)	1.000 (0.167)	1.000 (0.167)
Gulf of Boothia (Taylor et al. 2008c)	1.648 (0.098)	0.000 (0)	0.194 (0.178)	0.467 (0.168)	0.965 (0.300)
Kane Basin (Taylor et al. 2008a)	1.667 (0.083)	0.000 (0)	0.000 (0)	0.357 (0.731)	0.978 (0.085)
Lancaster Sound (Taylor et al. 2008b)	1.688 (0.012)	0.000 (0)	0.107 (0.050)	0.312 (0.210)	0.954 (0.083)
M'Clintock Channel (Taylor et al. 2006)	1.680 (0.147)	0.000 (0)	0.111 (0.101)	0.191 (0.289)	0.928 (0.334)
Northern Beaufort Sea (PBTC 2007)	1.756 (0.166)	0.118 (0.183)	0.283 (0.515)	0.883 (0.622)	0.883 (0.622)
Norwegian Bay (Taylor et al. 2008b)	1.714 (0.081)	0.000 (0)	0.000 (0)	0.000 (0)	0.689 (0.534)
Southern Beaufort Sea (Regehr et al. 2006)[1]	1.750 (0.170)	0.000 (0)	0.470 (0.090)	0.470 (0.090)	0.470 (0.090)
Southern Hudson Bay (PBTC 2007)[2]	1.575 (0.116)	0.087 (0.202)	0.966 (0.821)	0.967 (0.022)	0.967 (0.022)
Viscount Melville (Taylor et al. 2002)	1.640 (0.125)	0.000 (0)	0.623 (0.414)	0.872 (0.712)	0.872 (0.712)
Western Hudson Bay (IUCN/SSC 2006 and PBTC 2007)[3]	1.540 (0.110)	0.000 (0)	0.257 (0.442)	0.790 (0.180)	0.790 (0.180)

[1] No mean LPR for an age category is presented in Regehr et al. (2007b). Selected values provided by E. Regehr (USGS, Alaska Science Centre, Anchorage, AK) for the 2007 meeting of the PBTC.

[2] Also presented in IUCN/SSC Polar Bear Specialist Group (2006)

[3] Data presented in Table 3 of IUCN/SSC Polar Bear Specialist Group (2006), updated online version only.

Table 3. The mean (SE in parentheses) of total (i.e. includes all anthropogenic mortality) annual survival rates for age and sex classes of subpopulations is reported where the data are sufficient to calculate these estimates.

Subpopulation **(data source)**	**Males**					**Females**				
	Total Survival					**Total Survival**				
	0	**1**	**2-4**	**5-20**	**>20**	**0**	**1**	**2-4**	**5-20**	**>20**
Baffin Bay (Taylor et al. 2005)	0.538 (0.094)	0.879 (0.049)	0.879 (0.049)	0.923 (0.024)	0.874 (0.062)	0.600 (0.096)	0.901 (0.045)	0.901 (0.045)	0.940 (0.021)	0.913 (0.047)
Gulf of Boothia (Taylor et al. 2008c)	0.817 (0.201)	0.875 (0.085)	0.875 (0.085)	0.935 (0.040)	0.935 (0.040)	0.817 (0.201)	0.875 (0.085)	0.875 (0.085)	0.935 (0.040)	0.935 (0.040)
Kane Basin (Taylor et al. 2008a)	0.308 (0.172)	0.617 (0.180)	0.617 (0.180)	0.957 (0.046)	0.957 (0.046)	0.374 (0.180)	0.686 (0.157)	0.686 (0.157)	0.967 (0.043)	0.967 (0.043)
Lancaster Sound[1] (Taylor et al. 2008b)	0.633 (0.123)	0.790 (0.073)	0.790 (0.073)	0.892 (0.030)	0.653 (0.085)	0.749 (0.105)	0.879 (0.050)	0.879 (0.050)	0.936 (0.019)	0.758 (0.054)
M'Clintock Channel (Taylor et al. 2006a)	0.620 (0.15)	0.900 (0.04)	0.900 (0.04)	0.880 (0.04)	0.880 (0.04)	0.620 (0.15)	0.900 (0.04)	0.900 (0.04)	0.900 (0.04)	0.900 (0.04)
Northern Beaufort Sea (Stirling et al. 2007)[2]	0.487 (0.173)	0.248 (0.124)	0.826 (0.073)	0.818 (0.071)	0.581 (0.104)	0.605 (0.170)	0.348 (0.147)	0.895 (0.046)	0.89 (0.044)	0.713 (0.079)
Norwegian Bay[1] (Taylor et al. 2008b)	0.633 (0.123)	0.790 (0.073)	0.790 (0.073)	0.892 (0.030)	0.653 (0.085)	0.749 (0.105)	0.879 (0.050)	0.879 (0.050)	0.936 (0.019)	0.758 (0.054)
Southern Beaufort Sea (Regehr et al. 2006)	0.430 (0.110)	0.920 (0.040)	0.920 (0.040)	0.920 (0.040)	0.920 (0.040)	0.430 (0.110)	0.920 (0.040)	0.920 (0.040)	0.920 (0.040)	0.920 (0.040)
Southern Hudson Bay (Obbard et al. 2007)[3]	0.492 (0.143)	0.485 (0.143)	0.812 (0.076)	0.811 (0.076)	0.293 (0.143)	0.645 (0.135)	0.640 (0.136)	0.893 (0.052)	0.892 (0.052)	0.444 (0.148)
Viscount Melville (Taylor et al. 2002)	0.448 (0.216)	0.774 (0.081)	0.774 (0.081)	0.774 (0.081)	0.774 (0.081)	0.693 (0.183)	0.905 (0.026)	0.905 (0.026)	0.905 (0.026)	0.905 (0.026)
Western Hudson Bay[4,5] (Regehr et al. 2007a)	0.620 (0.020)	0.620 (0.020)	0.810 (0.015) 0.720 (0.020	0.900 (0.005)	0.750 (0.020) 0.650 (0.031)	0.700 (0.020)	0.700 (0.020)	0.860 (0.015) 0.780 (0.020)	0.930 (0.005)	0.810 (0.015) 0.720 (0.031)

[1] Survival rates pooled for Lancaster Sound and Norwegian Bay (see Taylor et al. 2008b).

[2] 2003–2005 means are reported. Estimated SE is the difference between the estimate and upper CL, divided by 1.96. Some survival rate estimates are inconsistent with known biology of polar bears (e.g., yearling survival rates) to conduct meaningful population simulations.

[3] 2004 means are reported. Estimated SE is the confidence interval, divided by 3.92.

[4] Survival rates listed in the age 5-20 category apply to age 5-19; rates listed in the >20 category apply to the ages ≥20.

[5] Regehr et al. (2007a) present total apparent survival rates for Western Hudson Bay polar bears as 95% CI. Estimated SE is the difference between the estimate and upper CL, divided by 1.96. Survival rates presented for 2-4 and 20+ adults are those that are not reduced from capture events around Churchill (see Regehr et al. [2007a]). Survival rates for 2-4 and ≥20 age categories in Western Hudson Bay may be as low as 0.72 and 0.65 for males and 0.78 and 0.72 for females, respectively. The true survival rates for subadult and senescent bears in Western Hudson Bay likely lie somewhere between the rates in the table and those stated in the previous sentence (E. Regehr, personal communication, USGS, Alaska Science Centre, Anchorage, AK).

Table 4. The mean (SE in parentheses) of natural (i.e., unharvested) annual survival rates for age and sex classes of subpopulations polar bears is reported where there is sufficient data to calculate natural survival rates.

Subpopulation **(data source)**	**Males**					**Females**				
	Natural Survival					**Natural Survival**				
	0	**1**	**2-4**	**5-20**	**>20**	**0**	**1**	**2-4**	**5-20**	**>20**
Baffin Bay (Taylor et al. 2005)	0.570 (0.094)	0.938 (0.045)	0.938 (0.045)	0.947 (0.022)	0.887 (0.060)	0.620 (0.095)	0.938 (0.042)	0.938 (0.042)	0.953 (0.020)	0.919 (0.050)
Gulf of Boothia (Taylor et al. 2008c)	0.817 (0.201)	0.907 (0.084)	0.907 (0.084)	0.959 (0.039)	0.959 (0.039)	0.817 (0.201)	0.907 (0.084)	0.907 (0.084)	0.959 (0.039)	0.959 (0.039)
Kane Basin (Taylor et al. 2008a)	0.345 (0.200)	0.663 (0.197)	0.663 (0.197)	0.997 (0.026)	0.997 (0.026)	0.410 (0.200)	0.756 (0.159)	0.756 (0.159)	0.997 (0.026)	0.997 (0.026)
Lancaster Sound[1] (Taylor et al. 2008b)	0.634 (0.123)	0.838 (0.075)	0.838 (0.075)	0.974 (0.030)	0.715 (0.095)	0.750 (0.104)	0.898 (0.005)	0.898 (0.005)	0.946 (0.018)	0.771 (0.054)
Northern Beaufort Sea (Stirling et al. 2007)[2]	0.489 (0.173)	**0.928** **(0.080)**	0..906 (0.073)	0.940 (0.071)	0.859 (0.104)	0.607 (0.170)	**0.931** **(0.080)**	0.956 (0.046)	0.929 (0.044)	0.730 (0.079)
M'Clintock Channel (Taylor et al. 2006a)	0.619 (0.151)	0.983 (0.034)	0.983 (0.034)	0.977 (0.033)	0.977 (0.033)	0.619 (0.151)	0.983 (0.034)	0.983 (0.034)	0.921 (0.046)	0.921 (0.046)
Norwegian Bay[1] (Taylor et al. 2008b)	0.634 (0.123)	0.838 (0.075)	0.838 (0.075)	0.974 (0.030)	0.715 (0.095)	0.750 (0.104)	0.898 (0.005)	0.898 (0.005)	0.946 (0.018)	0.771 (0.054)
Southern Beaufort Sea[3] (Regehr et al. 2006, 2007b)	0.430 (0.11)	0.930 (0.040)	0.930 (0.040)	0.930 (0.040)	0.930 (0.040)	0.430 (0.11)	0.930 (0.040)	0.930 (0.040)	0.930 (0.040)	0.930 (0.040)
Southern Hudson Bay[4] (Obbard et al. 2007)	0.492 (0.143)	0.517 (0.143)	0.929 (0.076)	0.892 (0.076)	0.556 (0.143)	0.645 (0.135)	0.645 (0.136)	0.973 (0.052)	0.951 (0.052)	0.523 (0.148)
Viscount Melville (Taylor et al. 2002)	0.448 (0.216)	0.924 (0.109)	0.924 (0.109)	0.924 (0.109)	0.924 (0.109)	0.693 (0.183)	0.957 (0.028)	0.957 (0.028)	0.957 (0.028)	0.957 (0.028)
Western Hudson Bay[5] (Regehr et al. 2007a)	0.710	0.710	0.940 0.780	0.940	0.820 0.680	0.730	0.920	0.920 0.820	0.930	0.820 0.720

[1] Survival estimates pooled for Lancaster Sound and Norwegian Bay (Taylor et al. 2008a).

[2] Natural survival estimates for the Northern Beaufort Sea were estimated by adding harvest mortality to total survival. The yearling survival rate from the adjacent Southern Beaufort Sea was used (substituted) because the Northern Beaufort estimate of total survival for yearlings (Stirling et al 2007) appears to be under-estimated. The SE for Southern Beaufort yearling survival was doubled to reflect the increased uncertainty of a meta-analysis approach.

[3] Based on survival rates provided by E. Regehr (USGS, Alaska Science Centre, Anchorage, AK).

[4] Obtained from the last year (2004) survival estimates in Obbard et al. (2007) and using all captures pooled to 2000 to estimate the standing age distribution and relative proportions of sex/age groups identified in Obbard et al.'s (2007) analysis. These proportions were multiplied by the population estimate (N = 681) to get the current number of individuals in each strata. Using the harvest sex and age distribution, the proportions of the known kill (36.2 bears from 2002–2007) were apportioned according to the same sex/age strata identified by the Obbard et al. (2007) survival estimates. The contribution to total mortality provided by harvest mortality was then obtained by dividing the number of individuals in the appropriate harvest strata by the number of individuals in the appropriate population strata. Natural survival was calculated by then adding harvest mortality to total survival by strata (i.e. raising total survival rates by the apportioned known mortality rates).

[5] Natural survival rates provided in Regehr et al. (2007) include two estimates for the 2-4 and 20+ age categories. The top estimate is for the mark-recapture model that excludes a capture effect on mortality of handling bears in Churchill; the bottom the rates are reduced to reflect heterogeneity in the data associated with captures around Churchill by the Manitoba Department of Conservation. Regehr et al. (2007) present no error estimates with these rates; for simulations (Table 1) the errors associated with total survival rates were used.

Table 5. Amstrup et al. (2007) identifies four "ecoregions" (Archipelago, Seasonal, Divergent, and Convergent) that can be expected to have different rates of climate warming induced ice loss based on simulations from a suite of 10 IPCC GCMs. The projected rates of loss of polar bear habitat (>50% ice coverage over continental shelf areas) were taken from tables 4 and 6 in Amstrup et al. (2007) for the mean of the 10 IPCC GCMs they selected. Amstrup et al. (2003) suggests a linear relationship between arctic polar bear habitat and total polar bear numbers (Aars et al, 2006), and this relationship was used to extrapolate the expected number of bears remaining in each ecoregion over time.

Year	**Archipelago**	**Seasonal**	**Divergent**	**Convergent**	**All**
	Proportion Reduction of > 50% Coverage Sea Ice from 2004				
2004	1.0	1.0	1.0	1.0	1.0
2049	.88	.85	.79	.85	.82
2079	.80	.74	.68	.75	.71
2104	.78	.72	.64	.72	.68
	Estimated Number of Individuals in Each Ecoregion				
2004	5000	7800	9500	2200	24500
2049	4400	6630	7505	1870	20405
2079	4000	5772	6460	1650	17882
2104	3900	5616	6080	1584	17180

Figure 1. Circumpolar distribution of the polar bear. Abbreviations of delineated subpopulations include Viscount Melville Sound (VM), Norwegian Bay (NW), Kane Basin (KB), Lancaster Sound (LS), Baffin Bay (BB), Davis Strait (DS) Southern Hudson Bay (SH), Western Hudson Bay (WH), Foxe Basin (FB), Gulf of Boothia (GB), M'Clintock Channel (MC), Southern Beaufort Sea (SB), and Northern Beaufort Sea (NB). Source: IUCN/SSC Polar Bear Specialist Group (2006).

Figure 2. Canadian subpopulations of polar bears. Abbreviations of delineated subpopulations include Viscount Melville Sound (VM), Norwegian Bay (NW), Kane Basin (KB), Lancaster Sound (LS), Baffin Bay (BB), Davis Strait (DS) Southern Hudson Bay (SH), Western Hudson Bay (WH), Foxe Basin (FB), Gulf of Boothia (GB), M'Clintock Channel (MC), Southern Beaufort Sea (SB), and Northern Beaufort Sea (NB). Source: Taylor et al. (2001).

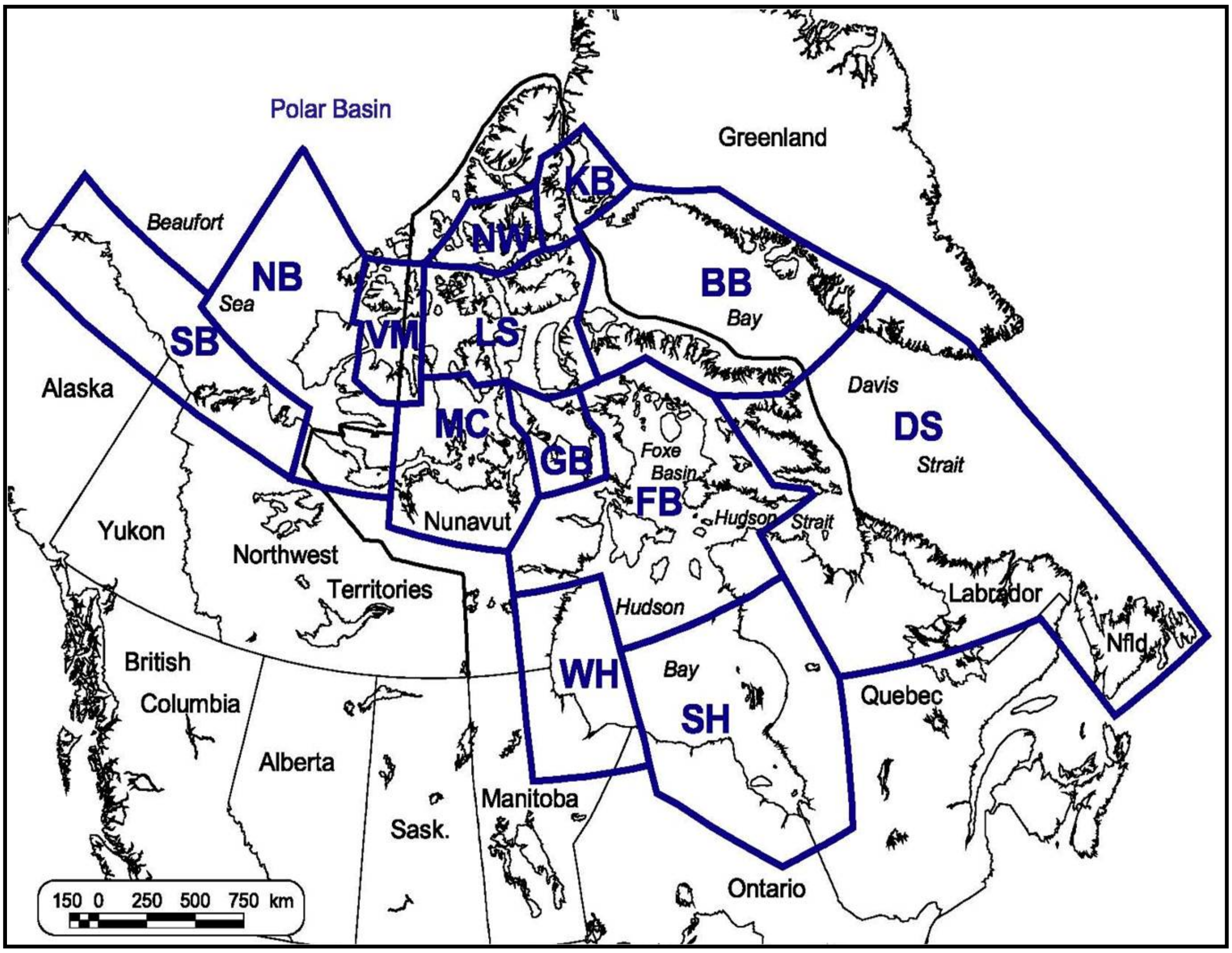


Figure 3. Arctic September sea ice extent (X 10^6 km^2) from actual observations (thick red line) are compared to 13 IPCC AR4 climate model projections. The mean (solid black line) and standard deviation (dotted black line) for the 13 projections indicates that actual sea ice extent has been about one standard deviation less than predicted since about 1985. Source: DeWeaver (2007); Stroeve et al. (2007); Siegel (2008).

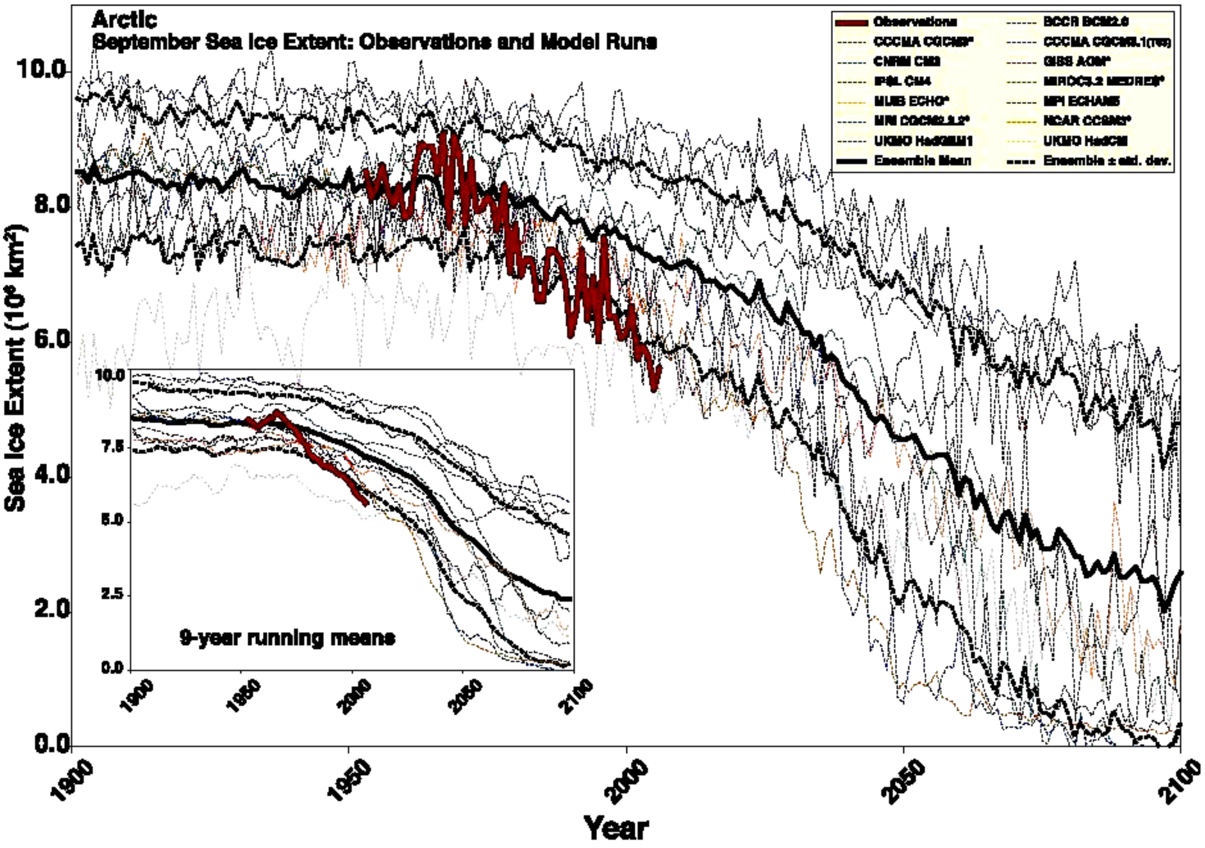


Figure 4. Four Ecoregions (Divergent, Convergent, Seasonal, and Archipelago) were defined by Amstrup et al. (2007) by grouping recognized polar bear subpopulations (Aars et al. 2005) which share seasonal patterns of ice motion and distribution. The Divergent Ice Ecoregion (purple) includes the Southern Beaufort Sea (SBS), Chukchi Sea (CS), Laptev Sea (LVS), Kara Sea (KS), and the Barents Sea (BS). The Convergent Ice Ecoregion (blue) includes the East Greenland (EG), Queen Elizabeth (QE), Northern Beaufort Sea (NBS). The Seasonal Ice Ecoregion (Green) includes the Southern Hudson Bay (SH), Western Hudson Bay (WH), Foxe Basin (FB), Davis Strait (DS), and Baffin Bay (BB). The Archipelago Ecoregion (yellow) includes the Gulf of Boothia (GB), M'Clintock Channel (MC), Lancaster Sound (LS, orange), Viscount-Melville Sound (VM), Norwegian Bay (NW), and Kane Basin (KB). Source Amstrup et al. (2007).

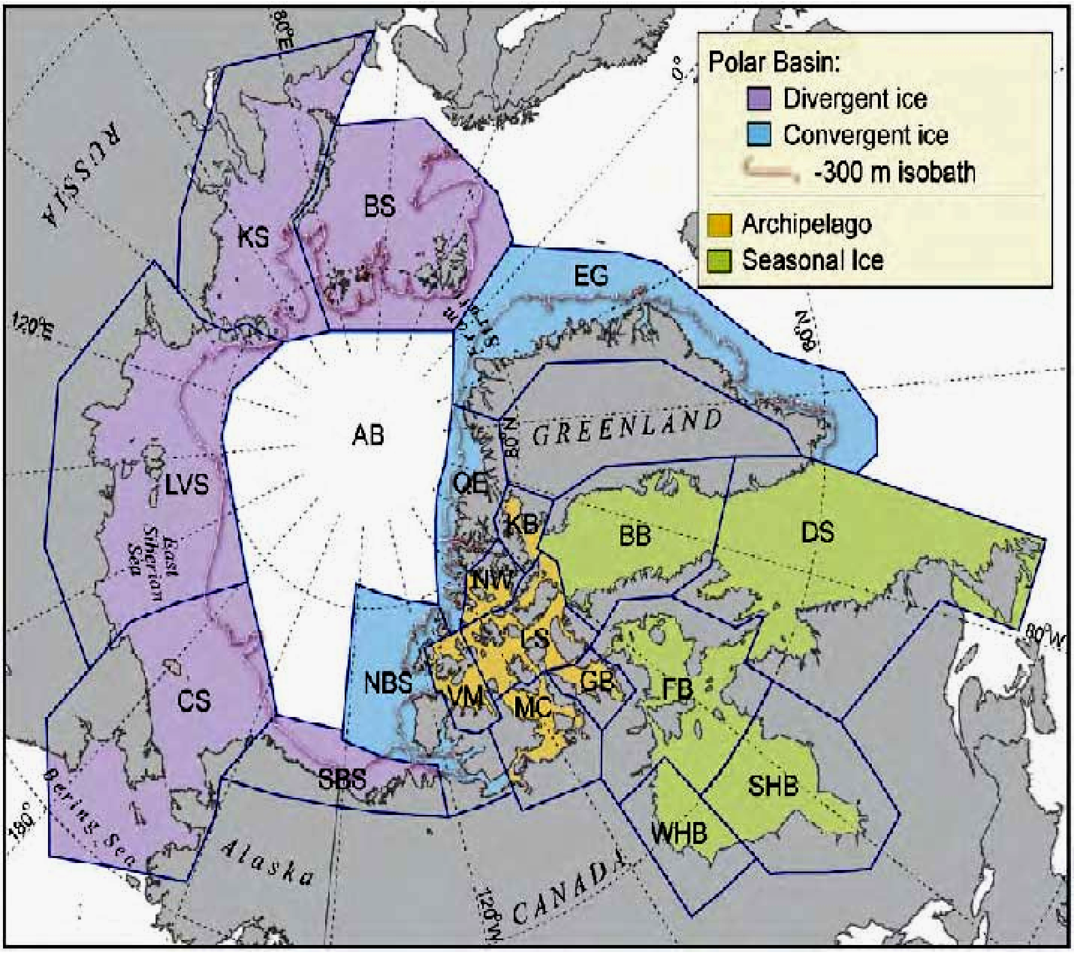


Figure 5. The mean projected reduction in >50% ice coverage over time from the 10 best IPCC GCMs (from Table 4 in Amstrup et al. 2007) is shown for the four Ecoregions (Divergent, Convergent, Seasonal, and Archipelago) that were defined by Amstrup et al. (2007, Figure 3) by grouping recognized polar bear subpopulations (Aars et al. 2005) which share seasonal patterns of ice motion and distribution. Overall arctic sea ice is projected to decline by about 30% over the next 100 years.

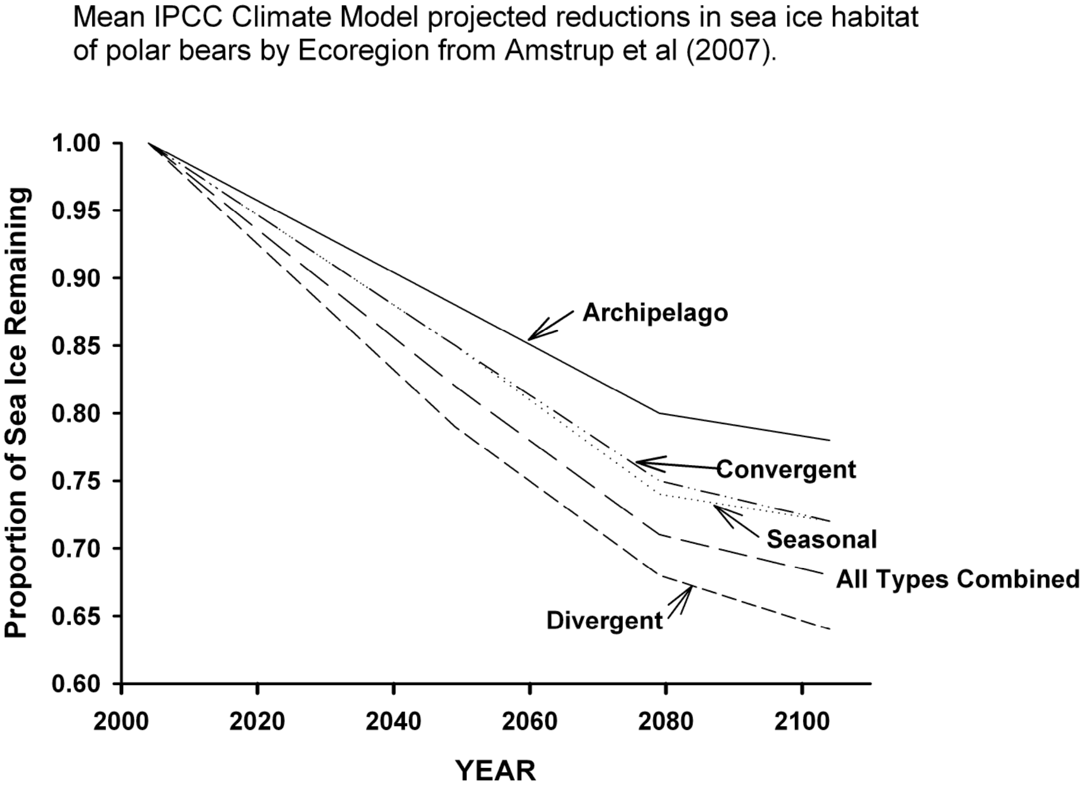
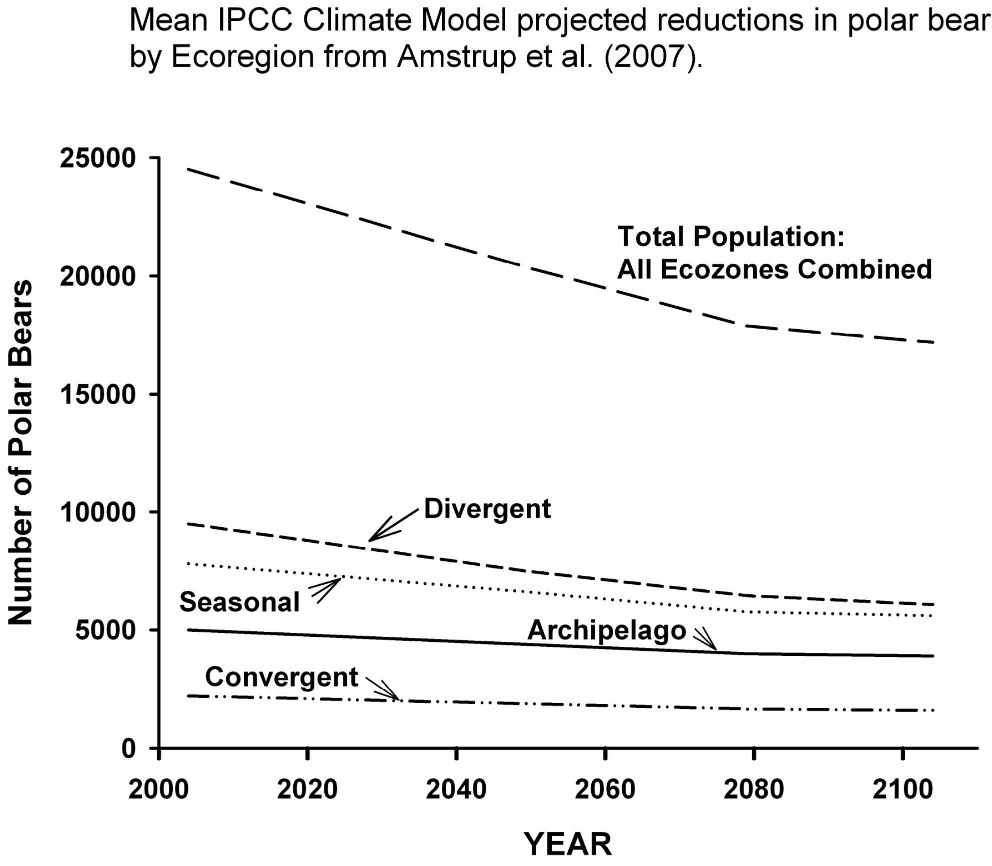


Figure 6. The mean projected reduction in polar bears over time based on the assumption that numbers are proportional to >50% ice coverage in continental shelf waters (from table 6 in Amstrup et al. 2007), is shown for the four Ecoregions (Divergent, Convergent, Seasonal, and Archipelago) that were defined by Amstrup et al. (2007, their Figure 3). The starting numbers of animals for each subpopulation was from Aars et al. (2005) as cited by Amstrup et al. (2007). Under these assumptions, polar bears would be expected to decline by about 30% over the next 100 years, mainly in the divergent and seasonal Ecoregions.



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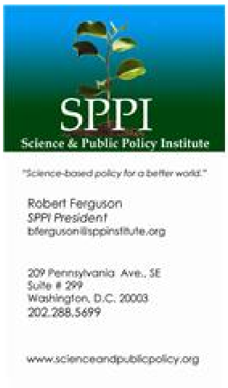
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Dr. Taylor has worked on polar bears for the past 30 years, and was the polar bear biologist for the Northwest Territories and Nunavut Territory, Canada for over 20 years. Dr. Taylor has been a continuing member of the IUCN/SSC Polar Bear Specialists Group and Canada's Federal Provincial Polar Bear Technical Committee. Dr. Taylor has published over 50 scientific papers on polar bear related topics, has worked in the field on most of the world's polar bear populations. Most recently (2007) Dr. Taylor assisted with field sampling (mark-recapture) the Davis Strait population (one of the most southern of all polar bear populations) and is a co-author on Canada's COSEWIC polar bear draft status report.

Dr. Taylor recently retired from government service and is currently based at Lakehead University in Thunder Bay, Canada.