RANGE-WIDE STATUS REVIEW
OF THE
POLAR BEAR
(*Ursus maritimus*)

Prepared and Edited

By

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STATUS REVIEW OF THE
POLAR BEAR (*Ursus maritimus)*

I. Introduction to Polar Bear Status Review

On February 16, 2005, the Center for Biological Diversity (CBD) filed a petition with the U.S. Fish and Wildlife Service (Service) to list the polar bear (*Ursus maritimus*) as threatened throughout its range, pursuant to the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq*.) (Act). On July 5, 2005, Natural Resources Defense Council and Greenpeace, Inc. joined CBD as petitioners.

Section 4(b)(3)(A) of the Act requires that we make a finding on whether a petition to list a species presents substantial scientific or commercial information indicating that the petitioned action may be warranted. To the maximum extent practicable, this finding is to be made within 90 days of receipt of the petition, and the finding is to be published promptly in the *Federal Register*. On February 9, 2006, the Service published a positive 90-day finding in the *Federal Register* (meaning that we determined that the petition did present substantial scientific or commercial information that listing the polar bear under the Act may be warranted), and promptly initiated a status review of the species as required under the Act (USFWS 2006a).

The purpose of the status review/assessment is to obtain, synthesize, and evaluate the best available scientific and commercial data on the status of the polar bear and threats thereto. Information in the status assessment is to form the basis for the next finding the Act requires the Service to make, the 12-month finding that the petitioned action is either: (1) warranted; (2) not warranted; or (3) warranted but precluded.

To ensure that the status review would be complete and based on the best available scientific and commercial information, we solicited information from the public on the status of the polar bear in two separate public comment periods announced in the *Federal Register* (USFWS 2006a, 2006b). In accordance with Office of Management and Budget and Service policy and guidelines for peer review, we also provided a draft of this status assessment to experts in the field of polar bear biology, climatology, toxicology, and/or, traditional ecological knowledge. We appreciate the comments we received from the peer reviewers and have incorporated them where appropriate.

This document constitutes the Service's "Range-Wide Polar Bear (*Ursus maritimus*) Status Review". It is intended to be a detailed and comprehensive assessment of the status of knowledge of the species and threats thereto.

II. Population Ecology and Characteristics of Taxon

A. Taxonomy

Throughout the Arctic polar bears are known by a variety of common names, among them are, nanook, nanuq, ice bear, sea bear, isbjørn, white bear, and eisbär. Phipps (1774) first proposed and described polar bear as a species distinct from other bears and provided a scientific name *Ursus maritimus*. A number of alternative namings followed: Pallas (1776) *Ursus marinus*: Shaw (1792) *Ursus polaris*: Knotterus-Meyer (1908) *Thallassarctos eogroenlandicus, Thalassarctos labrodorensis;* and, *Thalassacrostos jenaensis.* Erdbrink (1953) and Thenius (1953) used *Ursus (Thalarctos) maritimus*, since interbreeding between grizzly bears (*Ursus arctos*) and polar bears had been observed in zoos. Kurt'en (1964) examined the fossil evidence and suggested that polar bears originated from grizzly bears in Siberia during glacial ice advances of the mid-Pleistocene period. Kurt'en (1964) and Manning (1971) agreed that different populations of polar bears represent a single species based on morphometric data. Kurt'en (1964) described the last Pleistocene occurrence of a subspecies, *Ursus maritimus tyrannus*, which was much larger than recent fossils. Harington (1966), Manning (1971), and Wilson (1976) subsequently promoted the use of the name *Ursus maritimus*, that has been used since. Recent genetic research has confirmed that polar bears evolved from grizzly bears (Shields and Kocher 1991, Cronin et al. 1991, and Talbot and Shields 1996a). The polar bear is usually considered a marine mammal since its primary habitat is the sea ice (Amstrup 2003), and it was included in those species covered under the Marine Mammal Protection Act of 1972 (MMPA, 16 U.S.C. § 1361 *et seq*.).

B. General description

Polar bears are characterized by large body size and a stocky form. Polar bears have a longer neck and proportionally smaller head than other members of the bear family although missing the distinct shoulder hump common to grizzly bears. Fur color varies between white, yellow, grey, or almost brown, and is affected by oxidation, i.e. exposure to the air, light conditions, and soiling or staining due to contact with fats obtained from prey items. The nose, lips, and skin of polar bears are black (DeMaster and Stirling 1981, Amstrup 2003).

Polar bears are the largest of the living bear species (DeMaster and Stirling 1981). Polar bears exhibit sexual dimorphism with female body length and skull size being considerably smaller and body mass considerably less than that of males (Derocher et al. 2005). Adult males have been recorded weighing 654 kg (1440 pounds) (Kolenosky et al. 1992), with some individuals too large for the weighing equipment, estimated at 800 kg (1760 pounds) (DeMaster and Stirling 1981). Adult females weigh 181 to 317 kg (400-700 pounds). Adult males range in nose to tail length from 230 to 285 cm (7.5 - 9.3 feet) and adult females range in length from 180 to 2.40 cm (6-8 feet) (Amstrup 2003, Stirling 1988).

C. Ecological Adaptations

There is some uncertainty concerning when polar bears evolved from grizzly bears (*Ursus arctos*). Based on the relatively few specimens of polar bears in the fossil history Kurten (1964) estimated that polar bears may have evolved as recently as 70,000 to 100,000 years ago. Recent mtDNA information supported Kurten's supposition of a relatively late polar bear evolution from within the range of grizzly bear population (Yu, L. et al. 2004). It has been proposed that polar bears are believed to have originated from a group of grizzly bears (*Ursus arctos*) which became isolated during the glacial periods of the mid-Pleistocene approximately 200,000 - 250,000 years ago (Talbot and Shields 1996b). Age models based on molecular studies of evolutionary relationships among extant species of bears differ considerably as to the divergence time of polar bears from grizzly bears. Wayne et al. (1991) suggested this happened 70,000 – 100,000 yrs ago while Yu et al. (2004) concluded this might have happened 100,000 – 150,000 yrs ago. Only in portions of northern Canada and northern Alaska do the ranges of polar bears and grizzly bears overlap. Cross breeding of grizzly bears and polar bears in captivity has produced reproductively viable offspring (Gray 1972). The first documented case of cross breeding in the wild was reported in the spring of 2006. A sport hunter in the Canadian southern Beaufort Sea region harvested a hybrid and genetic testing by Wildlife Genetics International in May 2006 confirmed breeding between a polar bear female and grizzly bear male had occurred.

Evolutionary adaptations by polar bears to life on sea ice include: a white pelage with water repellent guard hairs and dense under-fur; a short furred snout; small ears; teeth specialized for a carnivorous rather than an omnivorous diet; and feet with hair on the bottoms (Stirling 1988). Polar bears have large, paddle-like feet (Stirling 1988) that probably assist in swimming and also help to disperse weight and avoid breaking through when walking on thin ice (Stirling 1988). Polar bear claws are shorter and more strongly curved than those of grizzly bears, and larger and heavier than those of black bears, and appear to be well adapted to traveling over blocks of ice and snow and to securely gripping prey animals (Amstrup 2003). Polar bear teeth have evolved significantly from those of their grizzly bear ancestor (Amstrup 2003). Their teeth are better suited to grab prey and eat fat from the meat and hide and less well suited for grinding grasses or other vegetation (Amstrup 2003).

Polar bears are well adapted for thermoregulation in the extreme cold conditions of the Arctic. Normal body temperature of a resting polar bear is 37°C (98.6° F), quite similar to other mammals (Best 1982, Stirling 1988). Additionally a combination of fur and hide properties, and up to 11 centimeters (4.5 in.) of blubber all serve as excellent insulators and operate to maintain body temperature and metabolic rate at near normal levels even at environmental temperatures of -37° C (-34° F) (Stirling 1988). However, polar bears are susceptible to overheating (Best 1982, Stirling 1988).

Polar bears radiate heat from their muzzle, nose, ears, footpads, and insides of the thighs, and also, apparently, from blood vessels in the shoulder region which lie only a few millimeters under the skin (Stirling 1988). Polar bears can also cool off by swimming, since water conducts heat about 20 times more efficiently than air (Stirling 1988). For young cubs, however, swimming may be dangerous if it chills their body too much (Blix and Lentfer 1979, Stirling 1988). Bears also conserve body temperature by curling into a ball when exposed to extremely cold, windy weather, or sprawl out to keep cool on warm days (Stirling 1988). Bears in warm areas like Hudson Bay also move very little in the summer in order to stay cool and conserve energy (Knudsen 1978, Derocher and Stirling 1990).

Unlike other species of bears, where both sexes may hibernate, only pregnant female polar bears hibernate through the winter (Stirling 1988, Amstrup 2000). This is specialized winter dormancy, and not a true hibernation. It is typified by a slightly depressed heart rate and temperature, during which time the bear does not feed and lives off its accumulated fat stores (Stirling 1988, Amstrup 2003).

Unlike grizzly and black bears, polar bears can also enter a hibernation-like state facultatively, as needed (Derocher et al. 2004). This allows polar bears to feed hyperphagically, both seasonally and when an unpredictable opportunity presents itself, and then slow down their metabolism to make their stored fat reserves last longer during periods of food shortage (Derocher et al. 1990, Ramsay et al. 1991, Stirling and Øritsland 1995). This, combined with an ability to digest fat with an efficiency of 98%, is probably the most important single adaptation of polar bears to the arctic environment. This is what allows bears to fast for months on shore in Hudson Bay during the summer.

D. Distribution

Polar bears evolved to utilize the Arctic sea-ice niche and are distributed throughout most ice-covered seas of the Northern Hemisphere. Their range is limited to areas where the sea is ice covered for much of the year. However, polar bears are not evenly distributed throughout areas of ice coverage. They are most abundant near shore in shallow-water areas and in other areas where currents and ocean upwellings increase productivity and serve to keep the ice cover from becoming too solidified in winter (Stirling and Smith 1975, Stirling et al. 1981, Amstrup and DeMaster1988, Stirling 1990, Stirling and Øritsland 1995, Stirling and Lunn 1997, Amstrup et al. 2000b).

Over most of their range, polar bears remain on the sea-ice year-round or visit land for only short periods. They occur throughout the East Siberian, Laptev, and Kara Seas of Russia, Fram Strait and Greenland Sea, Barents Sea of northern Europe, Baffin Bay, which separates Canada and Greenland, through most of the Canadian Arctic archipelago, and in the Chukchi and Beaufort Seas north and west of Alaska. In most areas, pregnant females come ashore in the fall to create a den in snow drifts in which to give birth. Earth dens are used by bears in Hudson Bay, until sufficient snow accumulates (Richardson et al. 2005b). Following emergence from these maternal dens female polar bears will return to the sea ice as soon as their cubs are able. In some areas, notably the Beaufort and to a limited extent the Chukchi Seas of the polar basin, females may den and give birth to their young on drifting pack ice (Amstrup and Gardner 1994).

The distribution of polar bears in most areas varies with the seasonal extent of sea-ice cover and availability of prey. In Alaska in the winter, sea-ice may extend 400 km south of the Bering Strait, and polar bears will extend their range to the southernmost proximity of the ice (Ray 1971). Sea-ice disappears from the Bering Sea and is greatly reduced in the Chukchi Sea in the summer, and polar bears occupying these areas may migrate as much as 1000 km to stay with the pack ice (Garner et al. 1990, 1994a). Throughout the polar basin, during the summer polar bears generally concentrate along the edge or into the adjacent persistent pack ice. Significant northerly and southerly movements appear to be dependent on seasonal melting and refreezing of ice (Amstrup et al. 2000b). In other areas, for example, Hudson Bay, James Bay, Davis Strait, Baffin Bay, portions of the Canadian High Arctic, and some bears in the Barents Sea when the sea-ice melts, polar bears are forced onto land for up to several months while they wait for winter and new ice (Jonkel et al. 1976, Schweinsburg 1979, Prevett and Kolenosky 1982, Schweinsburg and Lee 1982, Ferguson et al. 1997, Lunn et al. 1997, Mauritzen et al. 2001).

Distribution patterns for some populations during the open water and early fall seasons have changed in recent years. In the Beaufort Sea, greater numbers of polar bears (up to 200 individuals) were found on shore during the period from 2000 to 2005 than at any previous time (Schliebe et al. 2006a). The exact reason(s) for the change in distribution are uncertain and may involve a number of factors, although a statistically significant relationship exists between the number of bears using the coast and the distance the pack ice is from shore. Telemetry data and habitat use data from the southern Beaufort Sea indicate that polar bears are shifting their activity areas during the summer and fall (Amstrup, unpubl. data), apparently in response to ice that is retreating further from shore than it had in previous years. Gleason et al (2006) analyzed fall bowhead whale aerial survey data collected from 1979 to 2005 and observed an easterly and northerly shift in distribution of polar bears in the Alaska Beaufort Sea apparently in response to changing ice conditions. Amstrup et al. (unpublished data) also noted a significant trend of increased use of land and water habitats by polar bears during recent years.

In Baffin Bay, Davis Strait, Western Hudson Bay and other areas of Canada, Inuit hunters are reporting an increase in the numbers of bears present on land during summer and fall (Dowsley and Taylor 2005, Dowsley 2005). In many instances, the hunters believe this a result of increased population size. In an extensively studied polar bear population with a long time series of capture data in Western Hudson Bay, data analysis indicates that this population has in fact declined from 1,194 bears in 1987 to 935 bears in 2004 and the distribution pattern appears to be changing (Regehr et al., in prep., Stirling and Parkinson 2006). Also the Baffin Bay (BB) population, which is currently being over harvested by at least double the sustainable yield, is declining as a result (Stirling and Parkinson 2006). Distribution changes in response to recently recorded extreme ice retractions in areas such as the Chukchi Sea and other populations are undoubtedly occurring, yet remain unquantified by telemetry or aerial survey data. Shifts in the distribution in the Western Hudson Bay have been noted but are restricted to shifts within the same general area (Towns 2006). The home ranges and movement rates of polar bears in Western Hudson Bay were shown to have declined during the 1990s and this was postulated to be related to reduced prey intake (Parks et al., in press).

Following the IUCN classification, the Polar Bear Specialist Group (PBSG) has classified 19 polar bear populations (Figure 1) for the purposes of management. Scientists have defined these populations worldwide based on decades of intensive scientific studies of patterns in spatial segregation determined by telemetry data, survey and reconnaissance, marking and tagging studies, and traditional knowledge (Stirling and Taylor 1999, Lunn et al. 2002). There is considerable overlap in areas occupied by members of these groups, and boundaries separating the groups have been adjusted as new data were collected. With the exception of the Arctic Basin (AB) population, these boundaries are considered to be sufficiently discrete to be managed independently, based on behavioral and ecological factors. Telemetry data for the Arctic Basin population is insufficient to determine if bears occurring deep in the polar basin are residents to the area or may simply be occasional visitors from adjacent areas nearer shore (Figure 1). Furthermore, the overall correspondence between genetic data and the movement data among the polar bear populations reinforces the current population designations (Paetkau et al. 1999, Amstrup 2003).

E. Movements

Data from telemetry studies show that polar bear movements are not random, nor do they passively follow the ocean currents on the ice as previously thought (Pedersen 1945, Mauritzen et al. 2003a). Movement data come almost exclusively from adult female polar bears because male anatomy (their neck is larger than their skull) will not accommodate radio collars. The movements of seven male polar bears surgically implanted with transmitters in 1996 and 1997 were compared to movements of 104 females between 1985 and 1995 (Amstrup et al. 2001). Males and females had similar activity areas on a monthly basis, however, males traveled farther each month. Annual activity areas of females varied from year to year, however most females had an area of overlap each year (Amstrup et al. 2000b). Activity areas combined over multiyear periods could be considered as home ranges. The smaller activity areas used within the larger home ranges vary annually possibly due to sea-ice habitat quality, which also varies annually (Stirling and Smith 1975; Ferguson et al. 1997, Ferguson et al.1998, Ferguson et al. 2000a, Ferguson et al. 2000b; DeMaster et al. 1980; Amstrup et al. 2000b, Taylor et al. 2001b, Mauritzen et al. 2001, Wiig et al. 2003).

Some polar bear populations are closely associated with pack ice. For example, in the Chukchi and Beaufort Sea areas of Alaska and northwestern Canada, only 7% of the polar bear locations obtained were on land (Amstrup et al. 2000b, Amstrup, unpubl. data). The majority of the land locations were locations with bears occupying maternal dens during the winter. A similar pattern was found in East Greenland (Wiig et al. 2003). In the absence of ice during the summer season some populations of polar bears in eastern Canada, Hudson Bay, and the Barents Sea have developed a strategy of remaining on land for protracted periods of time until ice again forms and provides a platform for traveling and hunting.

The home range size and the annual movements within home ranges vary among populations. Most Canada populations are bounded and constricted by land masses of the high Arctic Archipelago, whereas populations in Russia, Alaska, and Greenland are only bounded on the southern periphery by land masses or in the case of the Chukchi or Barents seas populations, by the southerly maximal position of pack ice. In some instances the size of space use patterns by individual bears can vary greatly within geographical areas. Mauritzen et al. (2001) found that bears in the Barent's Sea have huge variations in home ranges that appear to be influenced by geographical range size despite having the same land mass boundaries and the productivity of available habitat. In other instances geographical land mass boundaries appear to have no influence on home ranges. Space use patterns can vary within geographical areas by the individual polar bear. There is a 60-fold variation in size of area utilized and it seems that this variation may be a behavioural trait which is, perhaps, learned (Mauritzen et al. 2001).

Activity areas have not been determined for many of the populations. The following information presents movement data collected from previous studies. The data do not reflect recent changes in retreating ice conditions. In the Beaufort Sea, annual activity areas for individually monitored female bears averaged 149,000 km^2 and ranged from 13,000 km^2 to 597,000 km^2 (Amstrup et al. 2000b). The mean activity area in the Chukchi Sea, characterized by highly dynamic ice conditions, was 244,463 km^2 (Garner et al. 1990). The average annual distance moved by Chukchi Sea female bears was 5,542 km. Schweinsburg and Lee (1982) reported smaller activity areas of <23,000 km^2 in the Canadian Arctic Archipelago. Spring movements averaged 14.1 km/day to the north at a time when ice was advancing 15.5 km/day in the opposite direction (Garner et al. 1990). In the Beaufort Sea, total annual movements averaged 3415 km and ranged up to 6,200 km. Movement rates of >4 km/hr were sometimes sustained for long periods, and movements of >50 km/day were observed (Amstrup et al. 2000b). Polar bears in NE Greenland pack ice had very large home ranges of 242,00 to 468,000 km^2 (Born et al. 1997) and were able to move up to 40km/day, often against the direction of movement of the pack ice (Larsen et al. 1983, Born et al. 1997, Wiig et al. 2003). Annual movement rates of the two female bears ranged from 2205 to 4053 km (Wiig et al. 2003). Ferguson et al. (1999) also reported large-scale movements for polar bears in highly dynamic sea-ice conditions of Davis Strait and Baffin Bay, and smaller movements for bears in the interior of the Canadian Arctic Archipelago. The mobility of polar bears appears to be directly related to variability in ice dynamics in specific areas (Garner et al. 1990, Garner et al. 1994a, Gloersen et al. 1992, Messier et al. 1992).

In regard to the timing of movements, Messier et al. (1992) reported that peak movement rates of polar bears in Viscount Melville Sound in the Canadian High Arctic archipelago occurred from May to July. Ferguson et al. (2001) reported movement rates varied in response to season and ice, for bears occurring between 60° N and 80° N and from 65° W to 110° W, including western Greenland, Davis Strait, Baffin Bay, and portions of the Canadian Arctic archipelago, while Messier et al. (1992) reported increasing mobility from January through July with peak acitivity occurring in May through July in a study conducted in the Viscount Melville Sound and M'Clure Strait area of the Canadian Arctic. In the Barents Sea, movement rates varied by month with higher levels in December – January although strong interactions with the direction of drifting ice lead Mauritzen et al. (2003a) to conclude that the drifting sea ice functioned as a treadmill and probably increased the energetic cost of migration. In contrast, Amstrup et al. (2000b) reported that polar bears in the Beaufort Sea were most mobile in winter and early summer. The lower level of winter movement of bears of Viscount Melville Sound (Messier et al. 1992) result from the presence of multiyear ice year-round (Gloersen et al. 1992), and foraging opportunities are restricted to particular areas which bears key in to. Also, lower rates of movement may indicate an energy conservation mode invoked when food is scarce (Amstrup et al. 2000b, Ferguson et al. 2000, Wiig et al. 2003). The ability to conserve energy by reducing energy expended is an important adaptation that allows polar bears to be successful in areas such as Hudson Bay where at the extreme southern edge of their distribution they forego feeding for long periods of time.

The high variability of summer and autumn ice presence and characteristics could affect seal hunting opportunities. This unpredictability may require longer movements and larger activity areas during seasons of freeze-up and break-up. Patterns of movement to the north and south appeared to be correlated with general patterns of ice formation and melting. (Stirling 1990, Amstrup et al. 2000b, Mauritzen et al. 2003a).

Between May and August, the ice of the southern Beaufort Sea is degrading (Gloersen et al. 1992). October is usually the month of freeze-up in the southern Beaufort Sea and may be the first time in months when ice is available over the more productive near-shore shallow water. Polar bears summering on the persistent pack ice quickly move into shallow-water areas as soon as new annual ice forms in autumn to prey on seals occupying these areas, and make easterly and westerly movements as ice solidifies through winter.

F. Feeding Habits

Polar bears are carnivorous, unlike other bear species that are typically omnivores, and are an upper level predator of the Arctic marine ecosystem. Polar bears prey heavily throughout their range on ringed seals (*Phoca hispida*) and, to a lesser extent, bearded seals (*Erignathus barbatus*) and in some locales, other seal species. Although seals are their primary prey, polar bears also have been known to kill much larger animals such as walruses (*Odobenus rosmarus*), narwhal (*Monodon monoceros*) and belugas (*Delphinapterus leucas*) (Stirling and Archibald 1977, Kiliaan et al. 1978, Smith 1980, 1985, Lowry et al. 1987, Calvert and Stirling 1990, Smith and Sjare 1990). In some areas and under some conditions prey and carrion other than seals may be quite important to polar bear sustenance. Stirling and Øritsland (1995) suggested that in areas where ringed seal populations were reduced, other prey species were being substituted. Like other ursids, polar bears will eat human garbage (Lunn and Stirling 1985), and when confined to land for long periods they will consume coastal marine and terrestrial plants and other terrestrial foods (Russell 1975, Derocher et al. 1993) but the significance of other terrestrial foods to polar bears may be limited (Lunn and Stirling 1985, Ramsay and Hobson 1991, Derocher et al. 1993). Lunn and Stirling (1985) found polar bears using the dump in Canada's Churchill area did not have increased survival or reproductive success**.** Although polar bears will use supplemental food sources if available they are not necessary for their survival.

Other studies (Iverson et al. 2006) indicate that polar bears may shift feeding preferences, presumably based on the availability of seal species. Overall, polar bears are most effective as predators of young ringed seals, possibly because young seals are naive with regard to predator avoidance. In spring, polar bears may concentrate on capturing new-born ringed seal pups (Smith and Stirling 1975, Smith 1980). Predation on pups may be extensive regionally. Hammill and Smith (1991 p. 128) estimated that polar bears annually kill up to 44% of new born seal pups in a study located between Cornwallis Island and Prince of Whales Island, in the Barrow Strait, Canada, Northwest Territories (NWT). Beyond the pupping season, polar bears mainly prey on young seals from the first two year classes (Stirling et al. 1977a, Smith 1980).

Polar bears have high digestive efficiency for protein (84%) and fat (97%) comprising an average energy utilization of 92% of the food consumed (Best 1985, Stirling 1988). Sufficient nutrition is critical and may be obtained and stored as fat when prey is abundant. On average an adult polar bear needs approximately 2 kg (4.4 lbs) of seal fat per day to survive (Stirling 1988). This nutrition must be obtained, and stored as fat, primarily during times of the year when prey is abundant and available (Stirling 1988). They prefer the fat of seals to muscle and other tissues and consume it first (Stirling 1974). Because over half of the calories in a whole seal carcass may be in the fat (Stirling and McEwan 1975), a bear that quickly consumes the fat has maximized its caloric return. Also, the digestion of fat releases water (Nelson et al. 1983) while digestion of meat/protein requires water. By eating fat, bears maximize water intake and minimize the energetic cost of associated with digesting ice and snow (Nelson 1981).

In the Beaufort Sea, polar bears have developed a habit of gathering at the butchering sites of bowhead whales (*Balaena mysticetus*) that are killed by local native people. The value of this alternate food is apparently great, as nearly every bear seen near whale carcasses in autumn is large and appears to be in good condition. (Miller et al. 2006).

G. Reproduction

Polar bears are characterized by a late age of sexual maturity, small litter sizes, and extended parental investment in raising young, factors that combine to contribute to a very low reproductive rate. Intrinsic rates of recruitment are difficult to estimate for the species. In the Southern Beaufort Sea the maximum rates of increase per annum was estimated as 6% (Angliss and Lodge 2004), and for Baffin Bay, without a harvest, the maximum rate of increase was estimated to be 5.5% per annum (Taylor et al. 2005). Reproduction in the female polar bear is similar to that in other ursids. They enter a prolonged estrus between March and June, when breeding occurs. Ovulation is thought to be induced by mating (Wimsatt 1963, Ramsay and Dunbrack 1986, Derocher and Stirling 1992). Lønø (1970) reported that breeding pairs were observed as early as 8 March and as late as 20 June. Histological evidence of testes and ovaries indicates that breeding could last into July (Lønø 1970). Rosing-Asvid (2002) found that the peak of mating season for polar bears in Greenland was between late March and end of May. Implantation is delayed until autumn, and total gestation is 195–265 days (Uspenski 1977), although during most of this time, active development of the fetus is suspended. The timing of implantation, and therefore the timing of birth, is likely dependent on body condition of the female, which depends on a variety of environmental factors. In East Greenland, the peak of the mating season was apparently somewhat earlier and shorter, from late March to May, than reported for Svalbard (Rosing-Asvid et al. 2002).

The exact timing of birth may vary across the range of polar bears. Harington (1968) reported births as early as 30 November with a median date of 2 December. Derocher et al. (1992) reported that births of Hudson Bay bears probably occur from mid-November through mid-December. Messier et al. (1994) suggested that polar bears give birth by 15 December. In the Beaufort Sea many pregnant females did not enter dens until late November or early December (Amstrup and Gardner 1994) and a later date of birth is assumed. Newborn polar bears are helpless, have hair, but are blind and weigh only 0.6 kg (Blix and Lentfer 1979). Cubs grow rapidly, and may weigh 10–12 kg by the time they emerge from the den in the spring. Young bears will stay with their mothers until weaning, which occurs most commonly in early spring when the cubs are 2.3 years of age. Female polar bears are available to breed again after their cubs are weaned. Therefore, in most areas, the minimum successful reproductive interval for polar bears is 3 years.

Age of maturation in polar bear populations appears to be largely dependent on numbers and productivity of ringed seals. For example, in the Beaufort Sea, ringed seal densities are lower than in some areas of the Canadian High Arctic or Hudson Bay. As a possible consequence, female polar bears in the Beaufort Sea usually do not breed for the first time until they are 5 years of age (Stirling et al. 1976, Lentfer and Hensel 1980). This means they give birth for the first time at age 6. In contrast, in many areas of Canada females reach maturity at age 4 and produce their first young at age 5 (Stirling et al. 1977b, 1980, 1984, Ramsay and Stirling 1982, 1988, Furnell and Schweinsburg 1984).

Derocher et al. (1992) calculated an average age of first breeding in the Hudson Bay area of 4.1 years. Cub production, assessed by estimated pregnancy rates, remained high between 5 and 20 years of age and declined thereafter (Derocher et al. 1992). Average age of first reproduction increased and pregnancy rates declined in the 1990s in Hudson Bay with corresponding declines in population size (Stirling et al. 1999, Regehr et al., in prep.).

1. Litter size and production rate

Just as with age of first reproduction, litter size and litter production rate vary by geographic area and are expected to change with population size relative to carrying capacity. Furthermore, litter size may change in response to hunting pressure, environmental factors and other population perturbations. Litters of two cubs are most common. Litters of three cubs are seen sporadically across the Arctic, and most commonly reported in the Hudson Bay region (Stirling et al. 1977b, Ramsay and Stirling 1988, Derocher and Stirling 1992). The average litter size encountered during multiple studies throughout the range of polar bears varies from 1.4 to 1.8 cubs. Evidence of a link between availability of seal prey and reproduction in polar bears has been documented for areas in the northerly parts of their range. Body weights of mothers and their cubs decreased markedly in the mid-1970s in the Beaufort Sea following a decline in ringed and bearded seal pup production (Stirling et al. 1976, 1977b, Kingsley 1979, DeMaster et al. 1980, Stirling et al. 1982, Amstrup et al. 1986). Declines in reproductive parameters varied by region and year with the severity of ice conditions and corresponding reduction in numbers and productivity of seals (Amstrup et al. 1986).

In the Beaufort Sea, females produce a litter of cubs at an annual rate of 0.25 litters per adult female (Amstrup 1995). In early years in Hudson Bay, females produced a litter of cubs at the rate of 0.45 litters per adult female (Derocher and Stirling 1992). Annual litter production rate in the Hudson Bay region declined from 0.45 litters/female in the period 1965–1979 to 0.35 litters/female during 1985–1990 (Derocher and Stirling 1992).

Polar bears may "defer" reproduction in favor of survival when foraging conditions are difficult (Derocher et al. 1992). A complete reproductive effort is energetically expensive for polar bears. When energetically stressed, female polar bears may forgo reproduction rather than risk incurring the energetic costs and consequent reduced physical fitness of a potentially unsuccessful reproductive process. The reproductive cycle lends itself to convenient early termination and may occur without extensive energetic investment on the part of the female (Ramsay and Dunbrack 1986, Derocher and Stirling 1992). Persistent deferral of reproduction could cause a declining population trend in populations with an intrinsically low rate of growth.

2. Reproductive maturity and senescence.

Age of maturation in mammals is often associated with attainment of a threshold body mass (Sadleir 1969), which could be more difficult to attain as competition for resources increases or resources diminish or become less accessible. Historically the average age for first reproduction in adult female polar bears is 5 to 6 years (Lentfer et al. 1980, Amstrup and Durner 1996, Wiig 1998). Craighead and Mitchell (1982) reported that in grizzly bears "reproductive longevity approximates physical longevity." Until recently, data from long-term monitoring regarding reproductive senescence of individual polar bears was unavailable or had not been analyzed. Richardson et al. (2005a) analyzed data from Western Hudson Bay and found that reproductive senescence in female began with the onset of survival senescence at about 20 years of age. Reproductive senescence in male polar bears was determined from paternity assignments using 20 microsatellite loci and occurred at about 17 years of age (Richardson et al. 2005a). Senescence in females resulted in reductions in litter size, cub mass, and the proportion of females with young.

H. Survival

Polar bears are long-lived mammals in large part not known to be susceptible to disease, parasites, or injury. The oldest known female polar bear in the wild was 32 years of age and the oldest known male was 28, though few polar bears in the wild live to be older than 20 (Stirling 1990). The longest lived captive bear in a zoo in London lived to be 41 years old (Stirling 1988). Due to extremely low reproductive rates polar bears require a high rate of survival to maintain population levels. Taylor et al. (unpubl. data) describes survival rates that vary by age class and population which range from 35-75% for cubs-of-the-year, 63-98% for 1-4 year old bears, 95-99% for adults age 5-20, and 72-99% for adults greater than 20 years of age (Table 2). High survival rates are required for population growth or stability for a species with inherently low productivity potential**.**

In general, survival rates increase with age up to approximatly 20 years of age. Cubs-of-the-year have the lowest survival rates. Survival of cubs is dependent on their weight when they exit dens (Derocher and Stirling 1992). Most cub mortality occurred early in the period after emergence from the den (Amstrup and Durner 1995, Derocher and Stirling 1996). In the Hudson Bay region during the 1980s, the survival rate of more than 200 cubs from spring through the ice-free period of autumn was 44% (Derocher and Stirling 1996). In the Beaufort Sea, survival of cubs was approximately 65% from den exit to the end of their first year of life. Survival of Hudson Bay cubs from their first to their second autumn was 35% (Derocher and Stirling 1996). Annual survival of yearlings ranged from 43% to 53%. Survival rates during the second year of life improved with 86% surviving to weaning (Amstrup and Durner 1995). Derocher and Stirling (1996) suggested that a heavy harvest accounted for much of the yearling mortality in Hudson Bay. Elsewhere, early age mortality is thought to be associated with starvation (Derocher and Stirling 1996).

Survival of cubs to weaning stage, generally 27-28 months, is estimated to range from 15% to 56% of births. In one Hudson Bay study only 15% of the cubs born survived through their second autumn. This differs from a 56% survival from birth to weaning of cubs in the Beaufort Sea. Even at the higher survival rates approximately 50% of the cubs do not survive to the subadult stage. Survival rates for sub-adults are poorly understood because collars cannot be used on rapidly growing individuals and measuring survival by other means is problematic. Population age structure data indicate that subadults aged 2–5 years survive at lower rates than adults (Amstrup 1995), probably because their hunting and survival skills are not fully developed (Stirling and Latour 1978). Eberhardt (1985) hypothesized that the survival of adult marine mammals must be in the upper 90% range to sustain polar bear populations. Survival estimates derived from Hudson Bay, where the intensity of marking exceeds all other study areas, have ranged between 0.86 and 0.90 (Derocher and Stirling 1995a, Lunn et al. 1997). Recent studies using telemetry monitoring of individual animals estimated that survival of adult females in prime age groups may exceed 96% (Amstrup and Durner 1995), and survival estimates are a reflection of the characteristics and qualities of an ecosystem to maintain the health of individual bears.

Polar bears that avoid serious injury may become too old and feeble to catch food, and most are generally believed to die of old age. Local and widespread climatic phenomena that make seals less abundant or less available also can significantly affect polar bear populations through survival or production (Kingsley 1979, DeMaster et al. 1980, Amstrup et al. 1986, Stirling 2002).

Injuries sustained in fights over mates or in predation attempts can lead to mortalities of polar bears (Amstrup et al. 2006b). In an extensive review of ursid parasites, Rogers and Rogers (1976) found that seven endoparasites had been reported in polar bears. Only *Trichinella* spp., however, had been observed in wild polar bears. Certain species of nematodes and cestodes reported in captive polar bears have not occurred in the wild. *Trichinella* can be quite common in polar bears and has been observed throughout their range. Concentrations of this parasite in some tissues can be high, but infections are not normally fatal (Rausch 1970, Dick and Belosevic 1978, Larsen and Kjos-Hanssen 1983, Taylor et al. 1985).

III. HABITAT CHARACTERISTICS

A. SEA ICE

Sea ice is the defining characteristic of the marine Arctic. "Approximately two-thirds of the Arctic is ocean, including the Arctic Ocean and its shelf seas plus the Nordic, Labrador, and Bering seas" (ACIA 2005). The two primary forms of sea ice are seasonal (or first year) ice and perennial (or multi-year) ice. Seasonal or first-year ice is in its first winter of growth or first summer of melt. Its thickness in undeformed floes ranges from a few tenths of a meter near the southern margin of the ice extent to 2.5 m in the high Arctic at the end of winter. Some first-year ice survives the summer and becomes multi-year ice. This ice develops its distinctive hummocky appearance through thermal weathering, becoming harder and almost salt-free over several years. In the present climate, old multi-year ice floes that have not been deformed by pressure ridges are about 3 m thick at the end of winter. The extent area of sea ice decreases from roughly 15 million km^2 in March to 7 million km^2 in September, as much of the first-year ice melts during the summer (Cavalieri et al. 1997, Parkinson et al. 1999). The area of multi-year sea ice, mostly over the Arctic Ocean basins, the East Siberian Sea, and the Canadian polar shelf, is about 5 million km^2 (Johannessen et al. 1999). Land-fast ice (or fast ice) may be present in some areas for up to 10 months each year depending on coastal geometry or persistence of grounded ice ridges (stamukhi). Within the Canadian Archipelago in late winter, land-fast ice covers channels up to 200 km wide and covers an area of 1 million km^2. Some of this ice is trapped for decades as multi-year land-fast ice (Reimnitz et al. 1995). Land-fast ice may create habitat for some species (e.g. ringed seal birth lairs, migrating fish species in brackish under-ice waters); may facilitate the formation of polynyas (predictable areas of open water surrounded by sea ice in winter) in some areas; and may impede navigation in others (e.g. the Northwest Passage).

Sea ice is an important component of the climate system. It provides insulation between the ocean and atmosphere and reflects back toward space most of the solar radiation reaching it. Its impacts extend far south of the Arctic, perhaps globally, e.g., through impacting deepwater formation that influences global ocean circulation. Ice flow in the Arctic often includes a clockwise circulation of sea ice within the Canada Basin and a transpolar drift stream that carries sea ice from the Siberian shelves to the Barents Sea and Fram Strait. The European-most portion of the clockwise circulation merges with the Arctic portion of the transpolar drift stream. On average, 10% of Arctic sea ice exits through Fram Strait each year. Sea ice also leaves the Arctic via the Canadian Archipelago, from whence it flows into Baffin Bay, joining in situ seasonal sea ice in Baffin Bay and drifting south along the Labrador coast. The remnants reach Newfoundland in March. At the ice edge in this location, the supply of sea ice from the north balances the loss by melt in the warm ocean waters. Similar "conveyor belt" sea-ice regimes also exist in the Barents and Bering Seas, where northern regions of growth export ice to temperate waters. A small amount of ice exits the Arctic through the narrow Bering Strait.

Arctic marine ecosystems are unique in having a very high proportion of shallow water and coastal shelves (ACIA 2005). In common with terrestrial and freshwater ecosystems in the Arctic, they experience strong seasonality in sunlight and low temperatures and are also influenced by freshwaters delivered mainly by the large rivers flowing into the Arctic Ocean mainly from Siberia (ACIA 2005). Ice cover is an important physical characteristic, affecting heat exchange between water and atmosphere, light penetration to organisms in the water below, and providing a biological habitat above, within, and beneath the ice. The marginal ice zone, at the edge of the pack ice, is important for plankton production and plankton-feeding fish (ACIA 2005). In general, arctic marine ecosystems are relatively simple, productivity and biodiversity are low, and species are long-lived and slow growing (ACIA 2005).

The simplicity of arctic marine ecosystems, together with the specialization of many of its species, makes them potentially quite sensitive to environmental changes (ACIA 2005).

1. Polar bear-ice relationships - general

Polar bears are distributed throughout the ice-covered waters of the circumpolar Arctic (Stirling 1988), and are reliant on the sea ice as their primary habitat (Amstrup 2003). Polar bears depend on sea ice as a substrate to hunt and eat seals, seek mates and breed, make long-distance movements to terrestrial maternity denning areas, or for maternity denning (Stirling and

Derocher 1993). Polar bear distributions are not uniform throughout the Arctic, but depend upon the type of sea ice and its location and extent over time, availability of prey, and reproductive status (Durner et al. 2004). Mauritzen et al. (2003b) indicated that habitat use by female polar bears during certain seasons may involve a trade-off between selecting habitats with abundant prey availability versus the use of safer, retreat habitats with less prey. Their findings indicate that population distribution may not be solely a reflection of prey availability, but instead other factors may operate to influence distributions.

The sea ice environment is highly dynamic and follows annual patterns of expansion and contraction. Movements of sea ice are related to winds, currents, and seasonal temperature fluctuations that promote its formation and degradation. A number of systems exist to classify sea ice (NOAA 2000). These systems generally categorize the stage of development, form, concentration, and type of ice. Stirling et al. (1993) defined seven types of sea-ice habitat and classified polar bear use of these ice types based on the presence of bears or tracks in order to determine habitat preferences. The seven types of sea ice were: stable fast ice with drifts; stable fast ice without drifts; floe edge ice; moving ice; continuous stable pressure ridges; coastal low level pressure ridges; and fiords and bays. In another assessment of polar bear – habitat relationships the authors categorized ice types/zones in Alaska as follows: pack ice; shore-fast ice; transition zone ice; and polynyas and leads (USFWS 1995).

As reported by Stirling (1993), stable fast ice with drifts was suitable for ringed seal haul-out and birth lairs. This habitat is most prevalent in the mouths of bays and near coastlines or offshore islands because that is where the annual ice is most stable. Stable fast ice without drifts did not contain habitats preferred by ringed seals for constructing birth lairs and maintaining breathing holes with lower risk from predation. Floe edge habitat was suitable for bearded seals of all age and sex classes and non-breeding ringed seals. Moving ice shifting constantly because of wind and ocean currents was generally not thought to be stable enough to be suitable for ringed seal birth lair habitat (Wiig et al. 1999), though bearded seals of all age and sex classes and non-breeding ringed seals were generally abundant in this habitat and some ringed seals have been observed to occupy and pup in offshore active ice environs. Continuous heavy pressure ice was a compressed aggregate of rough, stable ice that was generally unsuitable for seals. Coastal pressure ridges accumulate drifted snow and they were noted as being suitable for ringed seal haul-out and birth lairs. Fiords and bays such as in Prince Albert Sound, Victoria Island, NWT, Canada, developed snow-drifted pressure ridges and cracks that refroze and remained flat, and were used by ringed seals for birth lairs and breathing holes (Smith and Stirling 1975). Although ringed seals were abundant polar bears were not commonly seen in fiords and deep bays such as Prince Albert Sound (Stirling et al. 1993) and in East and Northwest Greenland. Fiord and large deep bay habitat are not widespread in the Arctic. Polar bears were not evenly distributed over these sea-ice habitats, but concentrated on the floe ice edge, on stable fast ice with drifts, areas of moving ice (Stirling 1990, Stirling et al.1993).

As reported by USFWS (1995), pack ice consists of annual and multi-year ice that is in constant motion caused by winds and currents. Pack ice is used by polar bears for traveling, feeding and denning and it is the primary summer habitat for Alaska polar bears. Shore-fast ice is ice that has become grounded near shore and may include pressure ridges caused by the movement of pack ice against it. Shorefast ice is important in the spring for feeding on seal pups, traveling, and occasionally denning. The transition zone is located seaward of the shore-fast ice and may be highly dynamic depending on environmental conditions. It is characterized by lead systems (linear openings) that open and close between the active pack ice and shore-fast ice. The transitions zone is important in the winter and spring for feeding and travel. Leads and polynyas (nonlinear openings) that are predictable in their location are called recurring polnyas and lead systems. Open water at recurring leads and polynyas attract seals and other marine mammals and are used by polar bears for feeding, especially during the winter. Ephemeral leads and polynyas are used opportunistically by polar bears for hunting.

2. Polar bear – ice relations - specific

Stirling et al. (1993, 1998) observed a strong preference by polar bears in the Beaufort Sea for the floe edge, fast ice with drifts, and moving ice with less than 7/8 ice cover. The preference is almost certainly because these areas are where seals are most accessible to polar bears for hunting.

Polynyas a preferred habitat of polar bears, represent areas of increased biological productivity at all trophic levels, especially when they occur over continental shelves (Stirling 1997). Recurring polynyas may be preferred habitat for ringed seals because their location is predictable, they afford resting areas, and may operate as a barrier to escape predation from polar bears (Stirling 1997). In the Canadian Arctic, polar bears concentrate each year at the North Water polynya in Smith Sound and northwestern Baffin Bay, and at smaller permanent polynyas at Cardigan Strait-Hell Gate, Penny Strait-Queens Channel, and in the eastern entrance to Fury and Hecla Strait (Stirling 1980). Polar bears also concentrate at shore leads that may freeze and open where seals maintain their breathing holes (Stirling 1980). Changes in wind and current patterns or ice ablation and formation processes could alter the location and persistence of these polynyas (ACIA 2005).

In the Viscount Melville Sound area Messier et al. (1992) and Ferguson et al. (2001) found that ringed seals occurred at lower densities than in most other areas of polar bear habitat from Alaska east to West Greenland (Stirling and Øritsland 1995) possibly because there is greater proportion of multi-year ice in this area, which is less preferred by ringed seals. Ringed seals tend to be concentrated along tidal cracks and pressure ridges that parallel the island coastlines (Kingsley et al. 1985). By contrast, in the southern Beaufort Sea, the annual ice that predominates is more dynamic and allows a greater amount of sunlight into the water column to support primary productivity. Consequently the Southern Beaufort Sea has more variable ice habitats and supports higher densities and numbers of ringed seals and polar bears (Stirling et al. 1982, Kingsley et al. 1985, Stirling and Øritsland 1995).

Given the differences in ringed seal densities, polar bears in the Beaufort Sea may spend more time in winter actively foraging, and those in the Viscount Melville Sound area may spend more time resting and conserving energy. Messier et al. (1992) reported that long periods of "sheltering" were common among bears wintering in Viscount Melville Sound, and attributed this behavior to the poor foraging conditions there. Another factor may be the greater predictability of the foraging conditions in the stable ice of the High Arctic. With less change in the character of the sea-ice after freeze-up, polar bears may be able to determine where the best hunting areas will be in early winter. Predictable sea-ice conditions could help bears minimize midwinter searching for good hunting areas and maximize benefits of sheltering (Ferguson et al. 2001). The fluctuating sea-ice condition in regions like the Beaufort Sea or Baffin Bay, however, may require modifications of foraging strategy from month to month or even day to day during break-up, freeze-up, or periods of strong winds (Ferguson et al. 2001). Polar bears are adaptable enough to modify their foraging patterns for the extreme range of sea-ice scenarios (Ferguson et al. 2001).

Polar bears must move throughout the year to adjust to the changing distribution of sea ice and seals (Stirling 1988, USFWS 1995). In some areas, like Hudson Bay and James Bay, bears remain on land when the sea ice retreats in the spring, where they must fast for several months (up to eight months for pregnant females) before freeze-up again in the fall (Stirling 1988, Derocher et al. 2004). Other populations unconstrained by land masses, such as those in the Barents, Chukchi and Beaufort Seas, spend each summer on the multiyear ice of the polar basin (Derocher et al. 2004). In island areas such as the Canadian Arctic archipelago or Svalbard and Franz Josef Land archipelagos, bears stay with the ice most of the time, but in some years they may spend up to a few months on land (Mauritzen et al. 2001). Most populations use terrestrial habitat partially or exclusively for maternity denning, therefore, females must adjust their movements in order to access land at the appropriate time (Stirling 1988, Derocher et al. 2004).

Polar bears appear to have good navigational ability and are able to return to previously used areas after long distances of active and passive transport (Mauritzen et al. 2003a, Amstrup 2003). As radiotelemetry studies have shown, female polar bears show only general fidelity to seasonal feeding areas (Ferguson et al. 1997, Amstrup et al. 2000b). A quantitative analysis of the movements of female polar bears over a multi-year period in the Beaufort Sea has made it possible to develop models to predict polar bear distribution (Durner et al. 2004). These models may be useful in making short-term predictions of polar bear distribution and abundance and assist in predicting and responding to initial impacts from threats such as oil spills, and longer term changes associated with ice regime changes (Durner et al. 2004).

3. Variations in sea ice and polar bear

Yearly sea ice changes in response to environmental factors may in turn have consequences on the distribution and productivity of polar bears as well as their prey. In the southern Beaufort Sea heavy ice conditions in the mid-1970s and mid-1980s caused significant declines in productivity of ringed seals (Stirling 2002). Each event lasted approximately three years and caused similar declines in the natality of polar bears and survival of subadults, after which reproductive success and survival of both species increased again. The changes in the sea ice environment, and their consequent effects on polar bears, are demonstrable in parallel fluctuations in the mean ages of polar bears killed each year by Inuit hunters (Stirling 2002).

Telemetry data from radio-collared female polar bears confirm that individuals occupy home ranges (or "multi-annual activity areas") which they seldom leave (Amstrup 2003). The size of a polar bear's home range is determined, at least in part, by the annual pattern of freeze-up and break-up of the sea ice, and therefore by the distance a bear must travel to obtain access to prey (Stirling 1988, Durner et al. 2004). A bear that has consistent access to ice, leads, and seals may have a small home range, while bears in areas such as the Barents, Greenland, Chukchi, Bering, or Baffin seas may have to move many hundreds of kilometers each year to remain in contact with sea ice from which they can hunt (Born et al. 1997, Mauritzen et al. 2001, Ferguson et al. 2001, Amstrup 2003, Wiig et al. 2003). Figure 1 depicts population boundaries based on differing movement patterns.

B. Maternal Denning Habitat

Throughout their range, most pregnant female polar bears excavate dens in snow located on land in the fall- early winter period (Harington 1968, Lentfer and Hensel 1980, Ramsay and Stirling

1990, Amstrup and Gardner 1994). The only known exceptions are in Western and Southern Hudson Bay where polar bears excavate earthen dens and later reposition into adjacent snow drifts (Jonkel et al 1972, Richardson et al. 2005b), and in the southern Beaufort Sea where a portion of the population dens in snow caves located on pack and shorefast ice. Successful denning by polar bears requires accumulation of sufficient snow for den construction and maintenance. Adequate and timely snowfall combined with winds to cause snow accumulation leeward of topographic features create denning habitat (Harington 1968). Polar bears give birth in the dens during midwinter (Kostyan 1954, Harington 1968, Ramsay and Dunbrack 1986). Survival and growth of cubs depends on the warmth and stable environment within the maternal den (Blix and Lentfer 1979). Family groups emerge from dens in March and April when cubs are approximately three months old.

Distribution of Denning. Most polar bear dens occur on land in "core areas" of each populations' range (Harington 1968). Large numbers of pregnant female polar bears repeatedly and predictably concentrate their denning within these relatively small geographic regions. The location of these "core" denning areas are well known and include particular islands of the Svalbard Archipelago north of Norway (Lønø 1970, Larsen 1985), Franz Josef Land, Novaya Zemlya, and Wrangel Island and Herald Island in Russia (Uspenski and Chernyavski 1965, Uspenski and Kistchinski 1972), and the west coast of Hudson Bay, (Harington 1968, Jonkel et al. 1975, Stirling et al. 1977b, Ramsay and Andriashek 1986, Ramsay and Stirling 1990). In portions of their range, polar bears den in a more diffuse pattern with dens scattered over large areas at low density (Lentfer and Hensel 1980, Stirling and Andriashek 1992, Amstrup 1993, Amstrup and Gardner 1994, Messier et al. 1994, Born 1995, Ferguson et al. 2000a, Durner et al. 2001, 2003). Areas of known low density denning occur on the north slope of Alaska (Lentfer and Hensel 1980, Amstrup 1993, Amstrup and Gardner 1994, Durner et al. 2001, 2003), Chutotka Peninsula of Russia (Stishov 1991b, Stishov et al. 1991, Stishov 1998), East and Northwest Greenland (Born 1995), and Banks Island, Simpson Peninsula, eastern Southhampton Island, eastern Baffin Island and other less definable areas in Canada (Messier et al. 1994, Born 1995, Ferguson et al. 2000a).

Habitat characteristics of denning areas vary and include the rugged mountains and fiord lands of the Svalbard archipelago, or the large islands north of the Russian coast (Uspenski and Chernyavski 1965, Lønø 1970, Uspenski and Kistchinski 1972, Larsen 1985), low relief topography characterized by tundra with riverine banks and coastal bluffs of Hudson Bay (Ramsay and Andriashek 1986, Ramsay and Stirling 1990) and North Slope of Alaska (Amstrup 1993, Amstrup and Gardner 1994, Durner et al. 2001, 2003), and offshore pack ice pressure ridge habitat. The common characteristic of all denning habitat is topographic features that catch snow in the autumn and early winter (Durner et al. 2003). The northern Alaskan coast gets minimal snowfall. However, the landscape is so flat and snow is blown continuously throughout the winter creating drifts in areas of relief. Most polar bear dens occur relatively near the coast with the exception of Western Hudson Bay, where females regularly den 29 to 118 km inland to traditional denning areas (Kolenosky and Prevett 1983, Stirling and Ramsay 1986).

Fidelity to Denning Locales. Amstrup and Garner (1994) followed 27 females for up to four maternity dens. Bears that denned once on pack ice were more likely to den on pack ice than on land in subsequent years, and vice versa. Similarly, bears were faithful to general geographic areas. Those that denned once in the eastern half of the Alaskan coast were more likely to den there than to the west in subsequent years. When all years were considered, denning polar bears preferred some areas, but no areas were used by collared bears in all years. Weather, ice conditions, and prey availability, all of which varied annually, probably determined where bears denned. Those annual variations and the long-distance movements of polar bears (Amstrup et al. 1986, Amstrup et al. 2000b; Garner et al.1990) make seasonal recurrence at exactly the same location unlikely.

The only other region where data are available on fidelity to denning areas is Hudson Bay. There, pregnant females initiate their over winter denning period in earthen dens they occupy in summer. During winter, they burrow into adjacent snow drifts (Watts and Hansen 1987). There was greater fidelity to local areas than in the Beaufort Sea, but site-specific philopatry was not apparent (Ramsay and Stirling 1990).

Despite general fidelity to local areas, the overall distribution of denning along the west coast of Hudson Bay shifted inland over a 20-year period (Ramsay and Stirling 1990). Because bears are able to return to the same area, the reason for the shift is not clear but may be related to adult males occupying the areas nearest the coast and precluding use by females. A similar shift appears to be occurring in the Beaufort Sea region as well. In the southern Beaufort Sea a trend of decreasing use of pack ice for denning has been detected (Fischbach et al., in prep.). Analysis of satellite telemetry data revealed that from 1985-1994, 63.8% of known dens were located on sea ice, compared to 36.4% of dens from 1995-2004. The potential reasons for the change in distribution included reductions in hunting pressure on land; availability of bowhead whale carcasses in the fall on land; climate induced changes in sea ice characteristics; availability of prey; and/or other unidentified ecological factors. Harington (1968), Larsen (1985), and Lønø (1970) concluded that variation in the local pattern of sea-ice movements during the preceding summer and autumn accounts for annual changes in the distribution of winter dens. Multiple-year trends in changing sea-ice patterns clearly could alter denning and other behavioral patterns.

Denning Chronology. Pregnant female polar bears enter their dens in the autumn (September to November) after drifts large enough to excavate a snow cave are formed. The annually variable snow and ice conditions determine when and where bears enter their dens each autumn. Polar bears depart dens in the spring (February-April) when their cubs are able to survive in the outside climate (Blix and Lentfer 1979, Amstrup 1995).

Polar bears are largely food deprived while on land in the ice-free period. During this time, they survive by mobilizing stored fat. Pregnant females that spend the late summer on land and then go right into dens may not feed for 8 months (Watts and Hansen 1987, Ramsay and Stirling 1988). This may be the longest period of food deprivation of any mammal, and it occurs at a time when the female must give birth and nourishment to her new cubs.

Satellite telemetry data confirm that the chronology of denning varies somewhat between populations. In the Beaufort Sea, mean dates of den entry were 11 and 22 November for land (*n*

= 20) and pack-ice (*n* = 16) dens, respectively (Amstrup and Gardner 1994). Female bears continued foraging right up to the time of den entry, and then they denned nearby. The mean date of emergence was 26 March for pack ice dens (*n* = 10) and 5 April for land dens (*n* = 18). Messier et al. (1994) reported the mean date of entry and exit varied somewhat among years depending on sea-ice, snow, and weather conditions. Messier et al. (1994) reported the mean entry into maternal dens in the Canadian Arctic was 17 September and mean emergence was 21 March. Females and their cubs remained near dens for a mean 13 (SE=3) days in the spring before leaving the denning area. This may indicate an earlier and more protracted denning period at higher latitudes than in the Beaufort Sea. Ferguson et al. (2000a) observed that bears denning at higher latitudes entered their dens a bit later than those to the south, but that exit times did not differ by latitude. They reported a mean den entry of 15 September (1 September–7 October), a mean exit of 20 March (15–28 March), and a mean 180 days in dens (163–200 days). As noted earlier, initiation of denning depends on sufficient snow accumulation to allow excavation of a den cavity. For bears denning on sea-ice or moving from sea-ice to land denning habitat, timing of sea ice consolidation can alter the onset of denning. Sea-ice dens must be in ice stable enough to stay intact for up to 164 days while possibly being moved hundreds of kilometers by currents (Amstrup 2003, Wiig 1998).

Scott and Stirling (2002) examined the chronology of terrestrial den use by polar bears in Western Hudson Bay as indicated by tree growth ring anomalies associated with disturbance from den construction in the area of the root mass. Tree growth rings were evaluated in the black spruce (*Picea mariana*) around and above 31 den sites. Trees sampled at these den sites ranged in age from 46 to 236 years (n = 83, mean = 136). Some individual den sites dated back at least 200 years. Increased denning activity in the area was correlated with reductions in disturbance due to humans at theYork Factory. Mark-recapture studies undertaken from 1970 to 2000 indicate that female polar bears in the Western Hudson Bay population have a long-term fidelity to this specific area for maternity denning, and the area has used for denning area for several hundred years (Scott and Stirling 2002).

IV. Population Status and Trend (excerpted from the PBSG 14th Working Group Proceedings)

A. Distinct Population Segments

Just as the labile nature of the sea-ice results in annual variability in the distribution of suitable habitat for polar bears, it also eliminates any benefit to polar bears of defending territories. The location of resources is less predictable than resources on which terrestrial predators depend. Seals tend to be distributed over very large areas at low densities (Stirling and Øritsland 1995). Furthermore, their distribution, density, and productivity are extremely variable among years (DeMaster et al. 1980, Stirling et al. 1982, Stirling and Øritsland 1995). Absence of strict fidelity, especially during breeding and denning seasons (Garner et al. 1994b, Amstrup and Gardner 1994), essentially prohibits defendable territories. Males similarly must be free of the need to defend territories if they are to maximize their potential for finding mates each year (Ramsay and Stirling 1986). Although there may be limited spatial segregation among individual polar bears, telemetry studies have demonstrated spatial segregation among groups or stocks of polar bears in different regions (Schweinsburg and Lee 1982, Amstrup et al. 1986, 2000b, Garner et al. 1990, 1994, Messier et al. 1992, Amstrup and Gardner 1994, Wiig 1995, Bethke et al.1996, Ferguson et al. 1999, Mauritzen et al. 2002).

B. Status and distribution

The total number of polar bears worldwide is estimated to be 20,000-25,000. Polar bears are not evenly distributed throughout the Arctic, nor do they comprise a single nomadic cosmopolitan population, but rather occur in 19 relatively discrete populations (Figure 1). The following population summaries are the result of discussions of the IUCN/SSC Polar Bear Specialist Group held in Seattle, Washington in June 2005, and have been updated with results that became available as of June 2006. The information on each population is based on the status reports and revisions given by each nation. Population sizes and associated uncertainty in estimates, historic and predicted human-caused mortality, population trends, and rationale for determinations of status are presented. Where data allowed, or the approach was deemed appropriate for a jurisdiction, results of stochastic population viability analyses (PVA) to estimate the likelihood of future population decline are presented.

Status Table Structure

Population Size

Table 1 presents population sizes and uncertainty in the estimates as ± 2 standard errors of the mean (SE), or ranges. These estimates are based on scientific research using mark and recapture analysis or aerial surveys and the years in which data were collected is presented to give an indication of the current reliability of population estimates. For some populations, scientific data were not available and population estimates were extrapolated from density estimates and/or local traditional ecological knowledge (TEK). In some cases this also includes simulations based on the minimum size necessary to support local knowledge of population trends. Although these data are presented in addition to, or in some cases as an alternative to, dated scientific estimates, methods other than mark and recapture analysis or aerial surveys have unknown margins of error and in most cases, inestimable errors.

Human-Caused Mortality

For most populations, particularly those in North America, harvesting polar bears is a regulated activity. In many cases, harvesting is the major cause of mortality for bears. In most jurisdictions the total numbers of bears killed by humans in pursuit of sport and subsistence hunting, accident, and in defense-of-life or property are documented. Where data allow, the 5-year mean of known human-caused mortality (removals) for each population is presented. Also, the anticipated removal rate of polar bears in each jurisdiction based on known increases in hunting quotas and/or the average removal rate of polar bears by jurisdiction over the past 5 years is presented.

Trend and Status

Qualitative categories of trend and status are presented for each polar bear population (Table 1). Categories of trend include an assessment of whether the population is currently increasing, stable, or declining, or if insufficient data is available to estimate trend (data deficient). Categories of status include our assessment of whether populations are not reduced, reduced, or severely reduced from historic levels of abundance, or if insufficient data is available to estimate status (data deficient).

Population Viability Analysis

For some populations, recent quantitative estimates of abundance and parameters of survival and reproduction are available to determine likelihoods of future population decline using PVA. The PVA model RISKMAN (Taylor et al. 2001a) is used to estimate risks of future declines in polar bear populations given demographic parameters and uncertainty in data. However, commentors noted that RISKMAN continues to be a work in progress and, although a useful tool, RISKMAN is an extremely complicated model which has not been thoroughly subjected to peer review. The model and documentation detailing the model's structure are available at http://www.nrdpfc.ca/riskman/riskman.htm. Publications based on the RISKMAN model include Eastridge and Clark (2001), McLoughlin et al. (2003), and Taylor et al. (2002).

RISKMAN can incorporate stochasticity into its population model at several levels, including sampling error in initial population size, variance about vital rates due to sample size and annual environmental variation (survival, reproduction, sex ratio), and demographic stochasticity. RISKMAN uses Monte Carlo techniques to generate a distribution of results, and then uses this distribution to estimate population size at a future time, population growth rate, and proportion of runs that result in a population decline set at a predetermined level by the user. The latter approach was adopted to estimate persistence probability.

The approach to variance in this simulation was to pool sampling and environmental variances for survival and reproduction. The approach was chosen because: 1) variances for reproductive parameters often did not lend themselves to separating the sampling component of variance from environmental variance, and 2) it allows the risks of population decline including all sources of uncertainty in the data (i.e. pooling sampling error with environmental error presents more conservative outcomes of population persistence) to be quantified.

For each population model, the frequency of occurrence of population declines and/or increases after 10 years was reported as the cumulative proportion of total simulation runs (2,500 simulations). Model projections using these criteria were chosen because: 1) the population inventory cycle for most areas is planned to be 10–15 years in duration, and 2) we do not advocate using PVA over long time periods in view of potential significant changes to habitat resulting from Arctic climate change. In individual runs populations could recover from 'depletion', but not from a condition where all males or all females or both were lost. Required population parameter estimates and standard error inputs included annual natural survival rate (stratified by age and sex as supported by the data), age of first reproduction, age-specific litter production rates for females available to have cubs (i.e. females with no cubs and females with 2-year-olds), litter size, the sex ratio of cubs, initial population size, and the sex, age, and family status distribution of the harvest. Input data are shown in Tables 1-3.

The standing age distribution measured from captured bears was always female-biased, likely due to long-term harvesting of males in populations for which simulations were performed (Table 1). Because we wished to err on the side of caution, for all simulations we used the stable age distribution expected for the population at the anticipated annual removal rate as the initial age/sex distribution (i.e. initializing the population at the stable age distribution produced more conservative outcomes compared to that of the existing standing age distribution). The harvest selectivity and vulnerability array was identified by comparing the standing age distribution of the historical harvest of populations to the total mortality, stable age distribution. Harvest was stratified by sex, age (cubs and yearlings, age 2–5, age 6–19, and age >20) and family status (alone, with cubs and yearlings, or with 2-year-olds). We ran harvest simulations using natural survival rates (without harvest), upon which anticipated annual removal rates (i.e. human-caused mortality from all sources) were added.

C. Population Summary

1. East Greenland (EG)

No inventories have been conducted in recent years to determine the size of the polar bear population in eastern Greenland. Satellite-telemetry has indicated that polar bears range widely along the coast of eastern Greenland and in the pack ice in the Greenland Sea and Fram Strait (Born et al. 1997, Wiig et al. 2003). However, various studies have indicated that more or less resident groups of bears may occur within this range (Born 1995, Sandell et al. 2001). Although there is little evidence of a genetic difference between populations in the eastern Greenland and Svalbard – Franz Josef Land regions (Paetkau et al. 1999), satellite telemetry and movement of marked animals indicate that the exchange between these populations is minimal (Wiig 1995, Born et al. 1997, Wiig et al. 2003).

During 1999-2003, the annual catch in eastern and southwestern Greenland averaged 70 bears (range, 56-84 bears per year) (Born and Sonne 2005). The catch of polar bears taken in southwestern Greenland, south of 62º N, must be added to the catch statistics from eastern Greenland because polar bears arrive in the southwestern region with the drift ice that comes around the southern tip from eastern Greenland (Sandell et al. 2001). During 1993 (first year of instituting a new catch recording system) and 2003 there was no significant trend in the catch of polar bears in eastern and southwestern Greenland (Born and Sonne 2006). Greenland introduced polar bear quotas taking effect on 1 January 2006. The total quota for 2006 is 50 polar bears for the two East Greenland municipalities Ittoqqortoormiit (30) and Ammassalik (20). The maximum quota for those municipalities in Southwest Greenland that hunt bears coming from the East Greenland population is 7 for 2006.

Despite an increasing practice by hunters from Scoresby Sound in central East Greenland to go further north to take polar bears during spring, there is no information to indicate an overall increase in hunting by East Greenlanders (Sandell et al. 2001). Based on harvest sampling from 109 polar bears in Scoresby Sound during 1999-2001, the proportion of adult (=independent) female polar bears in the catch in eastern Greenland is estimated at 0.43 (Danish National

Environmental Research Institute, unpubl. data).

Given the estimates of the proportion of adult females in the catch and an annual catch of about 70 bears (i.e. eastern and southwestern Greenland combined), a minimum population of about 2000 individuals would be needed to sustain this take. However, the actual number of animals in the exploited population is unknown.

During the last decades, the ice in the East Greenland area has diminished both in extent (Parkinson et al. 1999, Parkinson 2000b) and thickness (ACIA 2004, Yu, Y. et al. 2004). It has been predicted that this trend will continue in this century (Rysgaard et al. 2003). Furthermore, polar bears in East Greenland have relatively high body burdens of organic pollutants (Norstrom et al. 1998, Dietz et al. 2004) and levels of these pollutants seem to have increased between 1990 and 1999-2001 (Dietz et al. 2004). Several studies indicate that organic pollutants may have negatively affected polar bears in this region (overveiw in Born and Sonne 2006).

The effects of Arctic warming on East Greenland polar bears have not been documented. However, considering the effects of climate change in other parts of the Arctic (e.g.Western Hudson Bay), these environmental changes may also be in effect and cause concern about how polar bears in East Greenland may be negatively affected.

2. Barents Sea (BS)

The size of the BS population was estimated to be about 3000 in August 2004 (Aars et al. 2006) which suggests that earlier estimates based on den counts and ship surveys (Larsen 1986) were too high. This suggestion is further supported by ecological data that indicate the population grew steadily the first decade after protection from hunting in 1973, and then either continued to grow or stabilized after that. Denning occurs on several islands both on Franz Josef Land (Belikov and Matveev 1983) and Svalbard (Larsen 1985). Studies on individual movement and population ecology using telemetry data and mark-recapture methods have been conducted in the Svalbard area since the early 1970s (Larsen 1972, 1986, Wiig 1995, Mauritzen et al. 2001, 2002). Studies on movements using telemetry data show that some polar bears associated with Svalbard are very restricted in their movements but bears from the Barents Sea range widely between Svalbard and Franz Josef Land (Wiig 1995, Mauritzen et al. 2001). Population boundaries based on satellite telemetry data indicate that the Barents Sea is a natural population unit, albeit with some overlap to the east with the Kara Sea population (Mauritzen et al. 2002). Although overlap between the Barents Sea and East Greenland may be limited (Born et al. 1997), low levels of genetic structure among all these populations indicates substantial gene flow (Paetkau et al. 1999). The BS population is currently unharvested with the exception of bears killed in defense of life and property (Gjertz and Persen 1987, Gjertz et al. 1993, Gjertz and Scheie 1998). The population was depleted by over-harvest but a total ban on hunting in 1973 in Norway and in 1956 in Russia allowed it to increase (Larsen 1986, Prestrud and Stirling 1994). High levels of PCBs have been detected in samples of polar bears from this area which raises concern about the effects of pollutants on polar bear survival and reproduction (Skaare et al. 1994, Bernhoft et al. 1997, Norstrom et al. 1998, Andersen et al. 2001, Derocher et al. 2003). Recent studies suggest a decline and levelling of some pollutants (Henriksen et al. 2001) while new pollutants have been discovered (Wolkers et al. 2004). Oil exploration in polar bear habitat may increase in the near future (Isaksen et al. 1998). The natural history of this population is described by Lønø (1970), and Derocher (2005).

3. Kara Sea (KS)

This population includes the Kara Sea and overlaps in the west with the BS population in the area of Franz Josef Land and Novaya Zemlya archipelagos. Data for the Kara and Barents Seas, in the vicinity of Franz Josef Land and Novaya Zemlya, are mainly based on aerial surveys and den counts (Parovshikov 1965, Belikov and Matveev 1983, Uspenski 1989, Belikov et al. 1991, Belikov and Gorbunov 1991, Belikov 1993). Telemetry studies of movements have been done throughout the area but data to define the eastern boundary are incomplete (Belikov et al. 1998, Mauritzen et al. 2002). The population size estimate is unknown. Reported harvest activities have been limited to defense kills and an unknown number of illegal kills; these are not thought to be having an impact on the size of the population. However, contaminant levels in rivers flowing into this area and recent information on nuclear and industrial waste disposal raise concerns about the possibility of environmental damage. Recent studies show that polar bears from the Kara Sea have some of the highest organochlorine pollution levels in the Arctic (Andersen et al. 2001, Lie et al. 2003).

4. Laptev Sea (LV)

The LV population area includes the western half of the East Siberian Sea and most of the Laptev Sea, including the Novosibirsk and possibly Severnaya Zemlya islands (Belikov et al. 1998). The estimate of population size for the Laptev Sea (800-1200) is based on aerial counts of dens on the Severnaya Zemlya in 1982 (Belikov and Randala 1987) and on anecdotal data collected from 1960 through the 1980s on the number of females coming to dens on Novosibirsk Islands and on the mainland coast (Kistchinski 1969, Uspenski 1989). This estimate should therefore be regarded as preliminary. Reported harvest activities in this population are limited to defense kills and an apparently small but unknown number of illegal kills. The current levels of harvest are not thought to be having a detrimental impact on the population (Belikov et al. 2002, Aars et al. 2005).

5. Chukchi Sea (CS)

Cooperative studies between the U.S. and Russia have revealed that polar bears in this area, also known as the Alaska-Chukotka population, are widely distributed on the pack ice of the northern Bering, Chukchi, and eastern portions of the East Siberian seas (Garner et al. 1990, Garner et al. 1994a, Garner et al. 1995). Based upon these telemetry studies, the western boundary of the population was set near Chaunskaya Bay in northeastern Russia. The eastern boundary was set at Icy Cape, Alaska, which also is the previous western boundary of the southern Beaufort Sea (SB) population (Amstrup et al. 1986, Amstrup and DeMaster 1988, Garner et al. 1990, Amstrup 1995, Amstrup et al. 2004, Amstrup et al. 2005). This eastern boundary constitutes a large overlap zone with bears in the SB population.

Estimates of the size of the population have been derived from observations of dens, and aerial surveys (Chelintsev 1977, Stishov 1991*a*, Stishov 1991*b*, Stishov et al. 1991). However, these estimates have wide ranges (*ca.* 200-500) and are considered to be of little value for management. Reliable estimates of population size based upon mark and recapture are not available for this region, although recent studies provide data for analyses using new spatial modelling techniques, as reported in the SB population section. Probabilistic distribution information for zones of overlap between the CS and BS populations is now available. This information can be used to more accurately describe sustainable harvest levels once defensible estimates of abundance are developed (Amstrup et al. 2004, Amstrup et al. 2005). The approximate boundaries of this population for illustration purposes are as described above and as reported previously (Lunn et al. 2002a).

The status of the CS population, which was believed to have increased after the level of harvest was reduced in 1972, is now thought to be uncertain or declining (Aars et al. 2006). Measuring the population size remains a research challenge (Evans et al. 2003) and recent reports of substantial levels of illegal harvest in Russia are cause for concern. Legal harvesting activities are currently restricted to Inuit in western Alaska. In Alaska, average annual harvest levels declined by approximately 50% between the 1980s and the 1990s (Schliebe et al. 1998) and have remained at low levels in recent years. There are several factors potentially affecting the harvest level in western Alaska. The factor of greatest direct relevance is the substantial illegal harvest in Chukotka. In addition, other factors such as climatic change and its effects on pack ice distribution, as well as changing demographics and hunting effort in native communities (Schliebe et al. 2002) could influence the declining take. Recent measures undertaken by regional authorities in Chukotka may have reduced the illegal hunt (Kochnev, Kavry pers. comm.). The unknown rate of illegal take makes the stable designation uncertain and tentative and as a precaution the Chukchi population is designated as declining.

Implementation of the *United States-Russia Agreement on the Conservation and Management of Polar Bear* is designed to ensure that a scientifically-based, sustainable management program is instituted. Management will include active involvement of Native hunters' organizations from

Alaska and Chukotka. On December 9, 2006 the United States Congress passed the "United States-Russia Polar Bear Conservation and Management Act of 2006." This Act provides the authorities in the U.S. to fully implement the Agreement noted earlier.

As with the Beaufort Sea population, the primary concerns for this region are the impacts of climate change, human activities including industrial development within the near-shore environment, increases in the atmospheric and oceanic transport of contaminants into the region, and possible over-harvest of a stressed or declining population.

6. Southern Beaufort Sea (SB)

The SB polar bear population is shared between Canada and Alaska. During the early 1980s, radio-collared polar bears were followed from the Canadian Beaufort Sea into the eastern Chukchi Sea of Alaska (Amstrup et al. 1986, Amstrup and DeMaster 1988). Radio-telemetry data, combined with earlier tag returns from harvested bears, suggested that the SB region comprised a single population with a western boundary near Icy Cape, Alaska, and an eastern boundary near Pearce Point, NWT, Canada (Amstrup et al. 1986, Amstrup and DeMaster 1988, Stirling et al. 1988). Recognition that the polar bears within this region were shared by Canada and Alaska prompted development of the "Polar Bear Management Agreement for the Southern Beaufort Sea" (Agreement) between the Inuvialuit Game Council (IGC) of Canada, and the North Slope Borough (NSB) of Alaska. The Agreement was ratified by both parties in 1988. The text of the Agreement included provisions to protect bears in dens and females with cubs, and stated that the annual sustainable harvest from the SB polar bear population would be shared between the two jurisdictions. Harvest levels also were to be reviewed annually in light of the best scientific information available (Treseder and Carpenter 1989, Nageak et al. 1991). An evaluation of the effectiveness of the Agreement during the first 10 years (Brower et al. 2002) concluded that the Agreement had been successful in ensuring that the total harvest, and the proportion of the harvest comprised of adult females, remained within sustainable limits. The evaluation also noted that increased monitoring efforts and continued restraint in harvesting females were necessary to ensure continued compliance with the provisions of the Agreement.

Early estimates suggested the size of the SB population was approximately 1800 polar bears, although uneven sampling was known to compromise the accuracy of that estimate (Amstrup et al. 1986, Amstrup and DeMaster 1988, Amstrup 1995). New population estimation techniques are emerging and continue to be refined (Amstrup et al. 2001, Amstrup et al. 2005, McDonald and Amstrup 2001). The field work for an intensive capture-recapture effort in the SB region, coordinated between the U.S. and Canada, was completed in spring 2006 and a final population analysis and report will be available by summer 2007. The preliminary analysis of the joint data was completed in June 2006. That analysis indicated the population of the region between Icy Cape and Pearce Point is now approximately 1500 polar bears (95% confidence intervals approximately 1000 - 2000). Further analyses are likely to tighten the confidence intervals, but not likely to change the point estimate appreciably. Although the confidence intervals of the current population estimate overlap the previous population estimate of 1,800, other statistical and ecological evidence (e.g. high recapture rates encountered in the field) suggest that the current population is actually smaller than has been estimated for this area in the past. Observations of changes in polar bear body condition and unusual hunting behaviors in polar bears (e.g. cannibalism, digging through solid ice to find seals) suggest foraging success may have declined (Amstrup et al. 2006b). These observations parallel those made in western Hudson Bay (see below), where changes in sea ice, caused by warmer temperatures, have caused a population reduction (Stirling and Parkinson 2006). Although the new SB population estimate is preliminary, we believe it should be used for current status assessments.

Stirling (2002) reviewed the ecology of polar bears and seals in the Canadian sector of the Beaufort Sea from 1970 through 2000. Research incorporating the collection and analysis of radio-telemetry data in the SB region has continued on a nearly annual basis through present time. Recent analyses of radio-telemetry data using new spatial modelling techniques suggest realignment of the boundaries of the SB area (Amstrup et al. 2004, Amstrup et al. 2005). We now know that nearly all bears in the central coastal region of the Beaufort Sea are from the SB population, and that proportional representation of SB bears decreases to both the west and east. For example, only 50% of the bears occurring in Barrow, Alaska and Tuktoyaktuk, NWT are SB bears, with the remainder being from the CS and northern Beaufort Sea (NB) populations, respectively. The recent radio-telemetry data indicate that bears from the SB population seldom reach Pearce Point, which is currently on the eastern management boundary for the SB population.

Historically, a principal assumption of the Agreement was that polar bears harvested within the SB region came from a single population. However, our improved understanding of the spatio-temporal use patterns of bears in the SB region provides the foundation for improved harvest management, based on the geographic probability of bears occurring in specific areas at specific times of the year (Amstrup et al. 2005). Assignment of new boundaries based upon this information will probably necessitate a readjustment of the total size of the SB population, to correspond with a smaller geographic area. This adjustment is likely to reduce the estimated size of the SB population because some polar bears formerly assigned to the SB will be re-assigned to the NB and CS populations. For purposes of this report, however, we continue to use the previously-published boundaries for the SB population. This population is assessed using the sustainable yield criteria previously reported.

The primary management and conservation concerns for the SB population are: 1) climate warming, which continues to increase both the expanse and duration of open water in summer and fall; 2) human activities, including hydrocarbon exploration and development occurring within the near-shore environment; 3) changing atmospheric and oceanic transport of contaminants into the region; and 4) possible inadvertent over-harvest of the SB population, if it becomes increasingly nutritionally-stressed or declines due to some combination of the afore-mentioned threats.

7. Northern Beaufort Sea (NB)

Studies of movements and population estimates of polar bears in the eastern Beaufort Sea have been conducted using telemetry and mark-recapture at intervals since the early 1970s (Stirling et al. 1975, 1988, DeMaster et al. 1980, Lunn et al. 1995). As a result, it was recognized that there were separate populations in the North and South Beaufort Sea areas and not a single population as was suspected initially (Stirling et al. 1988, Amstrup 1995, Taylor and Lee 1995, Bethke et al. 1996). The density of polar bears using the multi-year ice north of the main study area was lower than it was further south. The estimate of 1,200 polar bears (Stirling et al. 1988) for the NB population was believed to be unbiased at the time but the northwestern coast of Banks Island was not completely surveyed because of perceived conflicts with guided sport hunters in the area at that time. A coordinated, intensive mark and recapture study covering the whole of the Beaufort Sea and Amundsen Gulf was completed in 2006 and a final analysis and report will follow. Until this new estimate is available, the previous estimate and quota will continue to be used for management purposes. The harvest is being closely monitored and appears to be sustainable (Stirling, pers. comm.)

Recent analyses, using data from satellite tracking of female polar bears and new spatial modelling techniques, indicate the boundary between NB and the SB populations needs to be adjusted, probably expanding the area occupied by bears from NB and retracting that of SB (Amstrup et al. 2004, Amstrup et al. 2005).

The primary concerns for this population are from climate warming that continues to expand both the expanse and duration of open water in summer and fall, changing characteristics of atmospheric and oceanic transport of contaminants into the region, and possible inadvertent over-harvest of a population stressed or declining as a result of the previous threats.

8. Viscount Melville Sound (VM)

A 5-year study of movements and size of the VM population, using telemetry and mark-recapture, was completed in 1992 (Messier et al. 1992, 1994, Taylor et al. 2002). Population boundaries are based on observed movements of female polar bears with satellite radio-collars and movements of bears tagged in and out of the study area (Bethke et al. 1996, Taylor et al. 2001b). The current population estimate of 215 was based on population data collected prior to 1993 (Taylor et al. 2002). When quotas were originally allocated in the 1970s, the size and productivity of the population was thought to be greater because they occurred in such a large geographic area. However, this area is characterized by heavy multi-year ice and low densities of ringed seals (Kingsley et al. 1985), and the productivity and density of polar bears was lower than initially expected. Consequently, quotas were reduced and a 5-year moratorium on hunting began in 1994/95. Hunting resumed in 1999/2000 with an annual quota of 4 bears.

In 1999, the former Northwest Territories was divided into two new territories: NWT and Nunavut, and resulted in the VM population being shared between the two jurisdictions. In 2004/2005 the annual quota was increased to 7 bears (NWT – 4, Nunavut – 3). The population is regarded as severely reduced in relation to historic population size (Aars et al. 2006).

9. Norwegian Bay (NW)

The NW polar bear population is bounded by heavy multi-year ice to the west, islands to the north, east, and west, and polynyas to the south (Stirling 1980, 1997, Taylor et al. 2001b, unpubl. data). From data collected during mark-recapture studies, and from satellite radio-tracking of adult female polar bears, it appears that most of the polar bears in this population are concentrated along the coastal tide cracks and ridges along the north, east, and southern boundaries (Taylor et al. 2001b). The preponderance of heavy multi-year ice through most of the central and western areas has resulted in low densities of ringed seals (Kingsley et al. 1985) and, consequently, low densities of polar bears. Based on preliminary data, the current estimate for this population based on data collected during 1993-1997 is 190 bears (Taylor et al., unpubl. data). Survival rate estimates for the NW population were derived from pooled Lancaster Sound (LS) and NW data because the populations are adjacent, and because the number of bears captured in Lancaster Sound was too small for reliable survival estimates. Recruitment estimates were derived from the standing age distribution (Taylor et al. 2000). The harvest quota for the NW population was reduced to 4 bears (3 males and 1 female) in 1996. This population is reported as declining (Aars et al. 2006).

10. Lancaster Sound (LS)

The central and western portion of the LS population region is characterized by high biological productivity and high densities of ringed seals and polar bears (Schweinsburg et al. 1982, Stirling et al. 1984, Kingsley et al. 1985, Welch et al. 1992). The western third of this region (eastern Viscount Melville Sound) is dominated by heavy, multi-year ice and apparently low biological productivity, as evidenced by low densities of ringed seals (Kingsley et al. 1985). In the spring and summer, densities of polar bears in the western third of the area are low, however, as break-up occurs, polar bears move west to summer on the multi-year pack-ice. Recent information on the movements of adult female polar bears monitored by satellite radio-collars, and mark-recapture data from past years, has shown that this population is distinct from the adjoining Viscount Melville Sound (VM), M'Clintock Channel (MC), Gulf of Boothia (GB), BB, and Norwegian Bay (NW) populations (Taylor et al. 2001b). For PVA in this status report, survival rates of polar bears in the NW and LS populations were pooled to minimize sampling errors. The current population estimate of 2,541 bears is based on an analysis of both historical and current mark-recapture data to 1997 (Taylor et al., unpubl. data). This estimate is considerably larger than a previous estimate of 1,675 that included Norwegian Bay (Stirling et al. 1984), and was considered to be conservative. Taylor et al. (unpubl. data) also estimate a suite of survival and recruitment parameters (Table 2) that suggest this population has a lower recruitment rate than previously estimated.

11. M'Clintock Channel (MC)

The current population boundaries for the MC population of polar bears are based on recovery of tagged bears and movements of adult females with satellite telemetry collars in adjacent areas (Taylor and Lee 1995, Taylor et al. 2001b). These boundaries appear to be a consequence of large islands to the east and west, the mainland to the south, and the heavy multi-year ice in Viscount Melville Sound to the north. A six-year mark-recapture study covered most of this area in the mid-1970s (Furnell and Schweinsburg 1984). An estimate of 900 bears was derived from the data collected within the boundaries of the MC population, as part of a study conducted over a larger area of the Central Arctic (Furnell and Schweinsburg 1984). More recently, local hunters suggested 900 might be too high, so the Canadian Polar Bear Technical Committee accepted a recommendation to reduce the estimate to 700.

Following the completion of a mark-recapture inventory in spring 2000, the population estimate was 284 (Taylor et al., in press). Natural survival and recruitment rates (Table 2) were also estimated at values lower than previous standardized estimates (Taylor et al. 1987). The Government of Nunavut implemented a moratorium on hunting for the 2001/2002 and 2002/2003 hunting seasons. The current annual quota for MC is 3 bears. The population is regarded as to be severely reduced (Aars et al. 2006).

12. Gulf of Boothia (GB)

The boundaries of the GB polar bear population are based on genetic studies (Paetkau et al. 1999), movements of tagged bears (Stirling et al. 1978, Taylor and Lee 1995), movements of adult females with satellite radio-collars in the Gulf of Boothia and adjacent areas (Taylor et al. 2001b), and interpretations by local Inuit hunters of how local conditions influence the movements of polar bears in the area. An initial population estimate of 333 bears was derived from data collected as part of a study conducted over a larger area of the Central Arctic (Furnell and Schweinsburg 1984). Although population data from Gulf of Boothia were limited, local hunters reported that the population was stable or had increased since the time of the Central Arctic polar bear survey. Based on Inuit knowledge, recognition of sampling deficiencies, and polar bear densities in other areas, in the 1990s an interim estimate of 900 for the GB population was established.

Following the completion of a mark-recapture inventory in spring 2000, the population was estimated to number 1,523 bears (Taylor et al., unpubl. data). Natural survival and recruitment rates (Table 2) were estimated at values higher than the previous standardized estimates (Taylor et al. 1987).

13. Foxe Basin (FB)

Based on 12 years of mark-recapture studies, tracking of female bears with conventional radios, and satellite tracking of adult females in Western Hudson Bay and southern Hudson Bay, the FB population of polar bears appears to occur in Foxe Basin, northern Hudson Bay, and the western end of Hudson Strait (Taylor and Lee 1995). During the ice-free season, polar bears are concentrated on Southampton Island and along the Wager Bay coast and significant numbers of bears are also encountered on the islands and coastal regions throughout the Foxe Basin area. A total population estimate of 2,119 bears was developed in 1996 (Taylor, unpubl. data) from a mark-recapture analysis based on tetracycline biomarkers (Taylor and Lee 1994). The marking effort was conducted during the ice-free season and distributed throughout the entire area. The population estimate is believed to be accurate, but dated. Simulation studies suggest that the harvest prior to 1996 reduced the population from about 3,000 bears in the early 1970s to about 2,100 bears in 1996. Harvest levels were reduced in 1996 to permit slow recovery of this population, provided that the kill in Québec did not increase.

In December 2004, TEK indicated that the population had increased. After consultations with native communities, Nunavut increased the harvest quota to a level consistent with a population level of 2,300 bears. Co-management discussions with Québec are ongoing. Survival and recruitment rates used for risk assessment are based on the rates obtained for the adjacent BB population (Taylor et al. 2005).

14. Western Hudson Bay (WH)

The distribution, abundance, and population boundaries of the WH polar bear population have been the subject of research programs since the late 1960s (Stirling et al. 1977b, Stirling et al. 1999, Derocher and Stirling 1995a ,Derocher and Stirling 1995b, Taylor and Lee 1995, Lunn et al. 1997). Over 80% of the adult population is marked, and there are extensive records from capture-recapture studies and tag returns from polar bears killed by Inuit hunters. During the open water season, the WH population appears to be geographically segregated from the Southern Hudson Bay (SH) population to the east and the FB population to the north. During the winter and spring, the 3 populations mix extensively on the sea ice covering Hudson Bay (Stirling et al. 1977b, Derocher and Stirling 1990, Stirling and Derocher 1993, Taylor and Lee 1995). The size of the WH population was estimated to be 1,200 bears in autumn, in 1988 and 1995 (Derocher and Stirling 1995*a*, Lunn et al. 1997). At that time, the size of the WH population appeared to be stable, and the harvest was believed to be sustainable.

Over the past three decades, there have been significant declines in the body condition of adult male and female polar bears, and in the proportion of independent yearlings captured during the open water season in Western Hudson Bay (Derocher and Stirling 1992, 1995*b*, Stirling and Lunn 1997, Stirling et al. 1999, Lunn and Stirling, unpubl. data). Over the same period, the average date of spring break-up of the sea ice in the region has advanced by three weeks (Stirling et al. 1999, 2004), presumably due to increasing spring air temperatures. Warming rates in Western Hudson Bay between 1971 and 2001 ranged from a minimum 0.5° C per decade at Churchill, Manitoba, to 0.8° C per decade at Chesterfield Inlet, Nunavut (Gagnon and Gough 2005). Stirling et al. (1999) documented a significant correlation between the timing of sea ice break-up and the body condition of adult female polar bears (i.e. early break-up was associated with poor body condition). Stirling et al. (1999) also suggested that the declines in various life history parameters of polar bears in Western Hudson Bay were the result of nutritional stress associated with the trend toward earlier break-up, which in turn appears to be due to long-term warming (Stirling and Parkinson 2006).

An updated analysis of capture-recapture data from the WH population was completed in 2005 (Regehr et al., in prep.). Between 1987 and 2004, the estimated number of polar bears in the WH population declined from 1,194 to 935, a reduction of about 22%. This decline appears to have been initiated by progressive declines in the body condition and survival of cubs, subadults, and bears 20 years of age and older, caused by the earlier break-up of spring sea ice. Once the population began to decline because of changing environmental conditions, the existing harvest was no longer sustainable, and the additive effects of climate change and over-harvest most likely accelerated the decline in abundance between 1987 and 2004. The harvest sex ratio of 2 males per female has resulted in skewed sex ratio within the population of 65% female and 35% male polar bears (Regehr et al., unpubl. data).

Concurrent with the recent re-assessment of the size of the WH population, an increased number of polar bears have been reported in and around human settlements along the coast of Western Hudson Bay. In some communities, this increase in polar bear sightings has been interpreted as evidence that the size of the WH population is increasing. Based on this perception, the government of Nunavut in December 2004 increased its quota for the number of polar bears that could be harvested from the WH population from 55 to 64 polar bears. In order to sustain this increased level of harvest, Nunavut estimated that the size of the WH population would have to be at least 1,400 bears which is the population estimate currently used by Nunavut for management purposes. An alternate explanation for the apparent increase in polar bears in the vicinity of human settlements and hunting camps is that, because of declines in body condition associated with the earlier sea ice break-up, polar bears in Western Hudson Bay have less time to accumulate the fat reserves that they depend on during the open water season. As polar bears deplete their fat reserves toward the end of the open water season, they are more likely to seek alternative food sources around human settlements to sustain themselves until freeze-up (Stirling and Parkinson 2006).

15. Southern Hudson Bay (SH)

Boundaries of the SH polar bear population are based on movements of marked bears and telemetry studies (Jonkel et al. 1976, Kolenosky and Prevett 1983, Kolenosky et al. 1992, Taylor and Lee 1995). Recently completed research using satellite telemetry collared bears was aimed at refining the boundaries of this population and estimating the population size and rates of birth and death (Obbard et al., unpubl. data). The current estimate of the size of the population comes from a 3-year (1984–1986) mark-recapture study, conducted mainly along the Ontario coastline (Kolenosky et al. 1992). This study and the more recent telemetry data have documented seasonal fidelity to the Ontario coast during the ice-free season, and some intermixing with the WH and FB populations during months when the bay is frozen over. In 1988, the results of a modelling workshop included an increase in the population estimate from 900 to 1,000 bears because portions of the eastern and western coastal areas were not included during original sampling. Additionally, the area away from the coast may have been under-sampled due to difficulties in detecting polar bears inland in treed habitat (i.e. below the tree line). Thus, some classes of bears, especially pregnant females, may have been under-sampled. The estimate of 1,000 bears in this status report is considered dated. The final year of a mark-recapture inventory was completed in fall 2005 and a new population estimate should be available soon.

Based on the estimate of 1,000 bears, the total harvest by Nunavut, Ontario, and Québec appears to be sustainable. Recent analysis of coastal survey data (Stirling et al. 2004) suggests that polar bear numbers in SH have remained unchanged in recent years. A pattern of decline in body condition was documented for the SH population when comparing bears captured in 1984-86 with those captured in 2000-04 (Obbard et al, 2006); however, it is unknown whether changes in demographic parameters like those described by Stirling et al. (1999) and Derocher et al. (2004) have occurred.

16. Kane Basin (KB)

Based on the movements of adult females with satellite telemetry collars and recaptures of tagged animals, the boundaries of the KB polar bear population include the North Water Polynya (to the south of KB), and Greenland and Ellesmere Island to the west, north, and east (Taylor et al. 2001b). Polar bears in Kane Basin do not differ genetically from those in Baffin Bay (Paetkau et al. 1999). Prior to 1997, this population was essentially unharvested in Canadian territory because of its distance from Grise Fiord, the closest Canadian community, and because conditions for travel in the region are typically difficult. However, this population has occasionally been harvested by hunters from Grise Fiord since 1997, and continues to be harvested on the Greenland side of Kane Basin. In some years, Greenland hunters have also harvested polar bears in western Kane Basin and Smith Sound (Rosing-Asvid and Born 1990, 1995).

Few polar bears were encountered by researchers along the Greenland coast from 1994 through 1997, possibly because of previously intense harvest pressure by Greenland hunters. The current estimate of the KB population is 164 (Taylor, unpubl. data) and the best estimate of the Greenland kill is 10 bears per year during 1999-2003 (Born 2005b, Born and Sonne 2005). However, the actual number being taken by Greenland hunters is uncertain (Born 2001, Born and Sonne 2005) and must be validated. The Canadian quota for this population is 5 and if Canadian Inuit continue to harvest from this area, over-harvest and population depletion could occur. The annual combined Canadian and Greenlandic take of 10-15 from the KB population is unsustainable (Table 1). This population is classified as declining by the PBSG (Aars et al. 2006). Although the habitat appears suitable for polar bears on both the Greenland and Canadian sides of Kane Basin, the densities of polar bears on the Greenland side were much lower than on the Canadian side, suggesting that this population may have been larger in past years, and could be managed for population increase. Co-management discussions between Greenland and Canada are continuing. Greenland has decided to move to a quota system taking effect on 1 January 2006 (Lønstrup 2005). The total 2006 quota is 30 bears for the municipality of Qaanaaq (NW Greenland) that harvest polar bears in Kane Basin. However, it has not been specifically stated how many of the 30 bears can be taken in Kane Basin.

17. Baffin Bay (BB)

Based on the movements of adult females with satellite collars and recaptures of tagged animals, the area in which the BB population occurs is bounded by the North Water Polynya to the north, Greenland to the east and Baffin Island to the west (Taylor and Lee 1995, Taylor et al. 2001b). A relatively distinct southern boundary at Cape Dyer, Baffin Island, is evident from the movements of tagged bears (Stirling et al. 1980) and recent movement data from polar bears monitored by satellite telemetry (Taylor et al. 2001b). A study of microsatellite variation did not reveal any genetic differences between polar bears in Baffin Bay and Kane Basin, although Baffin Bay bears differed significantly from Davis Strait and Lancaster Sound bears (Paetkau et al. 1999). An initial population estimate of 300–600 bears was based on mark-recapture data collected in spring 1984–1989 in which the capture effort was restricted to shore-fast ice and the floe edge off northeast Baffin Island (Schweinsburg and Lee, unpubl. data). However, recent work has shown that an unknown proportion of the population is typically offshore during the spring and, therefore, unavailable for capture. A second study was carried out annually during the months of September and October 1993–1997, when all polar bears were ashore in summer retreat areas on Bylot and Baffin islands (Taylor et al. 2005). Based on those data Taylor et al. (2005) estimated the number of polar bears at 2,074 bears.

The BB population is shared with Greenland, which until January 1, 2006 did not limit the number of polar bears harvested. Using mark-recapture, Taylor et al. (2005) estimated the Greenland annual removal at 18–35 bears for the period of 1993–1997. However, Born (2002) had reported that the estimated Greenland average annual catch of polar bears from the BB population was 73 in1993-1998. More recently, Born and Sonne (2006) indicated the BB average annual kill from 1999-2003 for Greenland was 115 (range: 68-206 bears per year) with an increasing trend. In December 2004, based on reports from Inuit hunters that polar bear numbers in BB had grown substantially, Nunavut increased its BB polar bear quota from 64 to 105 bears.

The BB population appears to be substantially over-harvested and is classified as declining by the PBSG (Aars et al. 2006, Stirling and Parkinson 2006). The current (2004) estimate of population size is less than 1,600 bears based on simulations using the pooled Canadian and Greenland harvest records (Table 1). Co-management discussions between Greenland and Canada are ongoing. Greenland introduced polar bear quotas taking effect on January 1, 2006. If the total 2006-quota for those municipalities in NW and W Greenland that catch bears from the BB populations (i.e. Qaanaaq to Sisimiut) is summed, a total of 97 polar bears can be taken in Greenland from BB (assuming that 20 of a quota of 30 in Qaanaaq are taken from BB; see Kane Basin).

18. Davis Strait (DS)

Based on the movements made by tagged animals and, more recently, of adult females with satellite telemetry, the DS population includes polar bears in the Labrador Sea, eastern Hudson Strait, Davis Strait south of Cape Dyer, and along the eastern edge of the Davis Strait-southern Baffin Bay pack ice. When bears occur in the latter area they are subject to catch from Greenlanders (Stirling and Kiliaan 1980, Stirling et al. 1980, Taylor and Lee 1995, Taylor et al. 2001b). A genetic study (Paetkau et al. 1999) indicated significant differences between bears from Davis Strait and both Baffin Bay and Foxe Basin. The initial population estimate of 900 bears for the DS population (Stirling et al. 1980) was based on a subjective correction from the original mark-recapture estimate of 726 bears, which was felt to be too low because of possible bias in the sampling. In 1993, the Canadian Polar Bear Technical Committee increased the estimate to 1,400 bears to account for bias in sampling created by the inability of researchers to survey the extensive area of offshore pack ice (Stirling and Taylor, unpubl. data). Traditional ecological knowledge also suggested that the population had increased over the last 20 years. The principal justification for this adjustment is based on the observation that the annual harvest has been sustained for the last 20 years and on non-quantitative observations that continue to suggest the population has increased.

The PBSG has indicated that the DS population was either stable or perhaps declining due to over-harvest (PBSG 1995, 1998, 2002). However, in December 2004, Nunavut increased its polar bear quota in DS from 34 to 46 bears based on Inuit reports that the population had increased since 1996. In order to sustain this increased level of harvest, Nunavut estimated that the size of the DS population would have to be at least 1,650 bears; this is the population estimate currently used by Nunavut for management purposes. A mark-recapture study is currently underway to assess the size of the DS population. Within Canada, this population is harvested by Inuit from Nunavut, Québec, and Labrador. The combined harvest by Canadian jurisdictions and Greenland (*ca.* 1 per year in Greenland during 1999-2003, Born and Sonne 2006) totalled 65 (Table 1). Co-management discussions between Greenland and Canada are continuing (Lønstrup 2005). Greenland introduced polar bear quotas taking effect on 1 January 2006. If the total 2006 quota for those municipalities in West Greenland (i.e. Maniitsoq and Nuuk) that catch bears from the DS population is summed, a total of 5 polar bears can be taken in Greenland from the DS population. A population inventory began in summer of 2005 to develop a scientific estimate of population numbers. Survival and recruitment rates used for risk assessment are based on the rates obtained for the adjacent BB population (Taylor et al. 2005).

19. Arctic Basin (AB)

The AB population is a geographic catch-all to account for bears that may be resident in areas of the circumpolar Arctic that are not clearly part of other populations. Polar bears occur at very low densities in this region, and it is known that bears from other populations use the area (Durner and Amstrup 1995). As climate change continues, it is anticipated that this area may become more important for polar bears as a refugia but a large part of the area is over the deepest waters of the Arctic Ocean and biological productivity is thought to be low (Gosselin et al. 1997).

C. PBSG Status Summary

Table 3 summarizes the current status for 18 populations (excluding the Arctic Basin) as: data deficient (6); reduced (4); severely reduced (2); and not reduced (6). The table summarizes observed or predicted trends for the populations as follows: data deficient (6); increasing (2); declining (5); and stable (5). The estimated risk for population declines due to harvest within the next 10 years was categorized as: no estimate (7); very high (3); higher (2); lower (4); and very low (2).

For six populations, data and information were insufficient to make assessments or prediction of status or trend. One of these populations, the Chukchi Sea, is thought to be in decline due in part to severe overharvest during the past 10-15 years. Accurate biological data to assess status, trend and risk to population was not available for six of the populations. Of the populations for which data are available to assess status and trend, only two are noted to be increasing, and both of these populations had been severely reduced in the past and are recovering under conservative harvest limits. The two populations that have long time series of data, Western Hudson Bay and Southern Beaufort Sea, are both declining. Due to large confidence intervals for the earlier SB abundance estimate a statistically significant measure of trend is, however, not possible.

Anthropogenic and natural changes in Arctic environments, as well as recognition of the shortcomings of our knowledge of polar bear ecology, are increasing the uncertainties of polar bear management. Higher temperatures and erratic weather fluctuations, which are symptoms of global climate change, are increasing across the range of polar bears. Following the predictions of climate modellers, such changes have been most prevalent in Arctic regions (Stirling and Derocher 1993, Stirling and Lunn 1997, Stirling et al. 1999, Derocher et al. 2004), and have already altered local and global sea-ice conditions (Gloersen and Campbell 1991, Vinnikov et al. 1999, Serreze et al. 2000, Parkinson and Cavalieri 2002, Comiso 2002a, 2003, Holland and Bitz 2003, Gough et al. 2004). Because changes in sea-ice are known to alter polar bear numbers and productivity (Stirling and Lunn 1997, Stirling et al. 1999, Derocher et al. 2004), effects of global climate change can only increase future uncertainty and may increase risks to the welfare of polar bear populations.

Persistent organic pollutants, which reach Arctic regions via air and water currents, and their potential effects, also increase uncertainty for the welfare of polar bears. Although our understanding of polar bear population dynamics has greatly improved with increasing development of analysis methods (Lebreton et al. 1992, Amstrup et al. 2001, McDonald and Amstrup 2001, Manly et al. 2003, Taylor et al. 2002, Taylor et al. 2005) a need for continued collection of accurate and timely population data in order to minimize uncertainty brought about by environmental change.

V. Discussion of Listing Factors

The Act identifies five factors to be considered in evaluating a species for listing: (1) The present or threatened destruction, modification, or curtailment of the species' habitat or range; (2) overutilization for commercial, recreational, scientific, or educational purposes; (3) disease or predation; (4) the inadequacy of existing regulatory mechanisms; and (5) other natural or manmade factors affecting the species' continued existence.

In the context of the ESA, the term "threatened species" means any species (or subspecies) or, for vertebrates, Distinct Population Segment (DPS) that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range. The term "endangered species" means any species that is in danger of extinction throughout all or a significant portion of its range. The principal considerations in the determination of whether or not a species warrants listing as a threatened or an endangered species under the ESA are the threats that now confront the species, and the probability that the species will persist in "the foreseeable future." The ESA does not define the term "foreseeable future." The IUCN/Polar Bear Specialist Group, in reassessing the status of polar bears globally in June 2005, applied the criteria described in the IUCN/SSC Red List process and three generations as the time span. Generations, as defined by IUCN, are calculated as the age of sexual maturity (5 years) plus 50% of the length of the life time reproductive period (20 years). Based on these calculations, the projected period for 1 generation was calculated at 15 years and the projected period for 3 generations was calculated as 45 years.

For other species evaluated for listing as threatened, such as the Yellowstone cutthroat trout (*Oncorhynchus clarki bouvieri*), the status assessment report (May et al. 2003) considered the "foreseeable future" to be 4 to 10 generations, depending on the productivity of the environment. For the greater sage grouse (*Centrocercus urophasianus*) the status review agreed by consensus that given all of the uncertainties, a reasonable timeframe for "foreseeable future" for the threatened definition was approximately 30 to 100 years [approximately 10 greater sage-grouse generations or 2 sagebrush habitat regeneration cycles(70 FR 2244)]. These time frames were considered reasonable and appropriate for each status review as the time frame is long enough to take into account multi-generational dynamics of life-history and ecological adaptation, yet short enough to incorporate social and political change that affects species management.

In this status review we have adopted the three generation limit from the IUCN Red List criteria for analysis. Given the IUCN criteria, the life-history and population dynamics of polar bears, documented changes to date in both multi-year and annual sea ice, and the direction of projected rates of change of sea ice in future decades, we chose 45 years as the “foreseeable future”.

We examined each of the listing factors in the context of present-day distribution of polar bear. We incorporate by reference published information on each of the listing factors. The evaluation of the five factors with respect to polar bear populations is presented below.

A. Present or Threatened Destruction, Modification, or Curtailment of the Species’ Habitat or Range

1. Arctic Climate Change- Overview

Recently, two comprehensive reports prepared by panels of leading scientists have been published that describe the current state of climate change globally and the impact on the Arctic specifically. The first report, the Intergovernmental Panel on Climate Changes, *Climate Change 2001: The Scientific Basis* (IPCC 2001), is a detailed assessment of current and predicted future climates around the globe. The Intergovernmental Panel on Climate Change (IPCC) was established by World Meterological Organization and United Nations Environment Programme to assess scientific, technical and socio-economic information relevant for the understanding of climate change, its potential impacts and options for adaptation and mitigation. The other document, *Arctic Climate Impact Assessment* (ACIA 2005), addresses the changes that will likely occur in the Arctic and their consequences. The ACIA report was an international project of the Arctic Council and the International Arctic Science Committee (IASC), to evaluate and synthesize knowledge on climate variability, climate change, and increased ultraviolet radiation and their consequences. This assessment was prepared over a period of five years by an international team of over 300 scientists, other experts, and knowledgeable members of the indigenous communities. Shorter overview of observational evidence of Arctic change, in addition to changes in sea ice including shrinking glaciers, thawing permafrost, and Arctic greening, are given by Morison et al. (2000), Sturm et al. (2003) and by Comiso and Parkinson (2004), and Parkinson (in press).

Observed Changes in Arctic Sea Ice

Sea ice is the defining characteristic of the marine Arctic (ACIA 2005). It is the primary method through which the Arctic exerts leverage on global climate, by mediating the exchange of radiation, sensible heat, and momentum between the atmosphere and the ocean (ACIA 2005). This section describes observed changes in Arctic sea ice over the past several decades.

Sea ice extent and thickness. Sea-ice extent in the Arctic has a strong seasonal cycle. It is typically at its maximum [14–15 million square kilometers (sq km)] in March and minimum (6–7 million sq km) in September (Parkinson et al. 1999). There is considerable interannual variability both in the maximum and minimum extent of sea ice. In addition, there are decadal and inter-decadal fluctuations in the areal sea-ice extent due to changes in atmospheric pressure patterns and their associated winds, continental discharge, and influx of Atlantic and Pacific waters (Gloersen 1995, Mysak and Manak 1989, Kwok 2000, Parkinson 2000b, Polyakov et al. 2003, Rigor et al. 2002, Zakharov 1994).

Observations have shown a decline in late summer Arctic sea ice extent of 7.7 % per decade and in the perennial sea ice area of 9.8 % per decade (Stroeve et al. 2005, Comiso 2006), a lesser decline of 2.7 % per decade in yearly averaged sea ice extents (Parkinson and Cavalieri 2002). The estimated rate of decrease in late summer sea ice coverage has increased as the satellite data record has lengthened: From 1978 through 2001 the trend was -6.5 % per decade, through 2002 it increased to -7.3 % per decade, and through 2004 it was -7.8 % per decade. Record low minimum extents in the ice cover during the last four years (2002-2005) caused an acceleration of the negative trend in the extent of the perennial ice cover (i.e. summer ice minima) from -6.5% per decade to -8.5% per decade (Stroeve et al., in press, Comiso 2006).

Observations have likewise shown a thinning of the Arctic sea ice of 32 % from the 1960s and 1970s to the 1990s in some local areas (Rothrock et al. 1999, Yu, Y. et al. 2004), with an overall thinning of about 2.5-3.75 % per decade (ACIA 2005). Lindsay and Zhang (2005) suggest that feedback mechanisms caused a tipping point in Arctic sea ice thinning in the late 1980s, sustaining the continual decline in the sea ice cover. Zhang and Walsh (2006) investigated the reproduction of the sea ice state in the IPCC models and found generally consistent results and an amplified seasonal cycle in sea ice area. They found that the model predicts multiyear ice area shrinks more rapidly than the total sea ice area, which is consistent with observational studies (Johannessen et al. 1999, Comiso 2002b). As multiyear ice is generally much thicker than first-year ice, a decline in the multiyear ice amplifies the seasonal melting of the sea ice.

The predominant reasons for amplified decreases in the extent of sea ice are: (a) the sea ice albedo feedback (i.e. less sea ice cover, which has a high reflectivity, causes more absorption of solar radiation in the ocean and hence more heat storage in the ocean, and a warmer ocean further delays formation of new sea ice cover in the fall); (b) the thinning of the sea ice (including the reduction in perennial ice (Comiso 2002b), which leads to more rapid melting of sea ice; (c) an increase in melt season length (Stroeve et al., in press, Comiso 2006) which enhances the ice albedo feedback, and decrease in ice season length (Parkinson 2000b), which limits the winter ice extent and the average thickness of ice during the season; and (d) the recent transport of multiyear ice out of the Arctic Ocean (Lindsay and Zhang 2005, Kwok et al. 2005).

In addition to these direct sea ice processes, oceanic circulation plays an important role. Pierce et al. (2006) compared ocean temperature observations with results from two climate models that include anthropogenic forcing and found close agreement. Both model and observation show the largest increase in ocean temperature in the North Atlantic. Similarly, Polyakov et al. (2005) analyzed ocean observations of the Atlantic Water (a water mass that enters the Arctic Ocean and Barents Sea via the Norwegian Sea) and concluded that the Arctic Ocean is in transition towards a warmer state, which has implications for the Arctic sea ice cover. The variability in both the temperature and velocity of the inflow of Atlantic waters in the Barents Sea appears to drive changes in the Arctic surface air temperature (Goose and Holland 2005).

Melt period. The length of melt period is considered an important factor affecting sea ice cover, especially ice thickness (Hakkinen and Mellor 1990, Laxon et al. 2003). An accumulating body of observations points to an earlier melt onset in spring and lengthening of the melt season, favoring less total ice cover at summer's end (Stroeve et al. 2005). Comiso (2003) examined trends from 1981 to 2001 using satellite thermal infrared (AVHRR) data on surface temperatures, and calculated an increase in the melt season of 10-17 days per decade. Subsequently, Comiso (2005) evaluated 1981-2003 AVHRR data and determined that the length of the sea ice melt season is increasing at a rate of approximately 13.1 days per decade. This result is different from Comiso's (2003) previous estimates for sea ice in that ocean areas that become ice-free in spring and summer are included in the analysis. Comiso (2005) states that the relatively high value is probably an important reason for the current rapid decline of the perennial ice cover. Note that a longer melt period means a shorter ice growth season which also means less extent and thickness of the ice cover.

Further support for extended melt periods comes from Belchansky and Douglas (2004) based on passive microwave satellite retrievals (SSM/I) (Stroeve et al. 2005). Belchansky and Douglas (2004) found that "consecutive year changes (1994-2001) in January multiyear ice volume were significantly correlated with duration of the intervening melt season."

In 2005, NSIDC reported that for 2002-2005, melt began earlier on average in all four years, and was most widespread in 2002 and 2005 (NSIDC 2005). The 2005 melt season arrived the earliest, occurring approximately 17 days before the mean melt onset date (NSIDC 2005).

Early onset of melt can have other consequences as well. For example, according to Derocher et al. (2004), in the Western Hudson Bay, break-up of the annual ice is now occurring approximately 2.5 weeks earlier than it did 30 years ago (Stirling et al. 1999, Stirling and

Parkinson 2006. Stirling and Lunn, unpubl. data). An advanced date of ice break-up in recent years may also be inferred from qualitave evaluation of satellite data for the Arctic.

The longer melt season is linked to a shorter ice season throughout much of the seasonal sea ice region. Maps of the trend in ice-season length from 1979 through 1996 as determined from satellite data show the ice season decreasing by as much as 8 days per year in the eastern Barents Sea and by lesser amounts throughout much of the rest of the Arctic (Parkinson 2000a).

Land-fast ice. Fast ice grows seaward from a coast and remains in place throughout the winter. Typically, it is stabilized by grounded pressure ridges at its outer edge, and therefore extends to the draft limit of such ridges, usually about 20 to 30 m. Fast ice is found along the coasts of Siberia, the White Sea, northern of Greenland, the Canadian Archipelago, Hudson Bay, and western and northern Alaska.

Polynyas. Polynyas are semi-permanent open water regions ranging in area up to thousands of square kilometers. Flaw leads occur at the border of fast ice when offshore winds separate the drift ice from the fast ice. Polynyas and flaw leads are environmentally important for several reasons (AMAP 1998):

- they are areas of high heat loss to the atmosphere;
- they typically form the locus of sea-ice breakup in spring;
- they are often locations of intense biological activity; and
- they are regions of deep-water formation.

Other Observed Changes in Arctic Climate

Observed recent trends for various snow and ice parameters of the Arctic cryosphere (taken largely from Table 18.3 of ACIA 2005) are briefly summarized as follows:

Snow cover	Snow-cover extent in the Northern Hemisphere has decreased by 5 to 10% since 1972; trends of such magnitude are rare in Global

	Climate Model (GCM) simulations.
Glaciers	Glaciers throughout the Northern Hemisphere have shrunk dramatically over the past few decades (Dyurgerov and Meier 1997), contributing about 0.15 to 0.30 mm/yr to the average rate of sea-level rise in the 1990s.
Permafrost	Permafrost temperatures in most of the Arctic and subarctic have increased by several tenths of a degree to as much as 2 to 3 ºC (depending on location) since the early 1970s. Permafrost thawing has accompanied the warming.
River discharge	River discharge has increased over much of the Arctic during the past few decades and the spring discharge pulse is occurring earlier.
Breakup and freeze-up	Earlier breakup and later freeze-up of rivers and lakes across much of the Arctic have lengthened the ice-free season by 1 to 3 weeks.
Sea-level rise	Global average sea level rose between 10 and 20 cm during the 20th century (IPCC 2001). This change was amplified or moderated in particular regions by tectonic motion or isostatic rebound.
Precipitation	Observations suggest that precipitation has increased by approximately 8 % across the Arctic over the past 100 years, although measurement uncertainties and the sparseness of data from certain regions limit confidence in these results . In addition to the overall increase, changes in the characteristics of precipitation have also been observed. Much of the precipitation increase appears to be coming as rain, mostly in winter and to a lesser extent in autumn and spring. The increasing winter rains, which fall on top of existing snow, cause faster snowmelt. Rain-on-snow events have increased significantly across much of the Arctic. For example, over the past 50 years in western Russia, rain-on-snow events have increased by 50 %.

Projected Changes in Arctic Climate

Background. To assess future climate change impacts on ecosystems, possible changes in physical climate parameters must first be projected (ACIA 2005). Physical climate change projections must, in turn, be calculated from changes in external factors that can affect the physical climate (ACIA 2005). Physically-based climate models are used to obtain climate scenarios – plausible representations of future climate that are consistent with assumptions about future emissions of greenhouse gases and other pollutants (i.e. emissions scenarios) and with present understanding of the effects of increased atmospheric concentrations of these components on the climate (ACIA 2005). In its Third Assessment Report, the IPCC (2001) produced a Special Report on Emissions Scenarios (SRES) to project a variety of future emissions scenarios that encompass a range of possible futures based on how societies, economies, and energy technologies are likely to evolve, and can be used to estimate the likely range of future emissions that affect the climate (ACIA 2005).

Of the various types of climate models, global coupled atmosphere-ocean general circulation models (AOGCMs) are widely acknowledged as the principal, and most promising rapidly developing tools for simulating the response of the global climate system to increasing green house gas (GHG) concentrations. In its Third Assessment Report, the IPCC (2001) concluded that state-of-the-art AOGCMs in existence at the turn of the century provided "credible simulations of climate, at least down to subcontinental scales and over temporal scales from seasonal to decadal", and as a class were "suitable tools to provide useful projections of the future climate" (McAvaney et al. 2001).

Projected temperature and sea level changes. The IPCC report states that the "global average temperature and sea level are projected to rise under all IPCC SRES scenarios." The globally averaged surface temperature is projected to increase by somewhere between 1.4 and 5.8° C over the period 1990 to 2100 depending on model parameters and the assumptions made on future CO_2 emissions. The projected rate of warming is much larger than the observed changes during the 20th century and is very likely to be without precedent during at least the last 10,000 years. Specifically for the Arctic, models suggest that global warming is amplified in high northern latitudes (Holland and Bitz 2003). A comparison of results from 15 models has shown that the range of simulated polar warming in the Arctic is from 1.7 to 4.3 times the global mean warming (Holland and Bitz 2003). Furthermore, the IPCC reports says "There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities" and "human influences will continue to change atmospheric composition throughout the 21st century". Hansen et al. (2005) suggest that the warming trend would change considerably if actions were taken soon enough to keep the atmospheric gases from increasing.

Projected changes in sea ice cover. For the future, all evidence points to the likelihood of continued Arctic warming and continued decreases in the Arctic sea ice cover in the 21st century (Comiso 2006), due to increasing global temperatures despite a large degree of uncertainty of the actual increase. The anthropogenic climate change impact on sea ice cover is implicated in Vinnikov et al. (1999) and Johannessen et al. (2004) who have shown that the observed decrease in Arctic sea ice extent cannot be explained by natural climate variations. Although there is a large degree of uncertainty regarding the actual increase in global temperature, because of the long residence time of CO_2 in the atmosphere, even a rapid reduction in CO_2 emissions would not stop an increase in global temperature unless the countering cooling effects of aerosols or other factors are stronger than currently thought. Extrapolation of linear trends into the future and different model assumptions, results in large uncertainties about the future of the Arctic sea ice. Gregory et al. (2002) used four IPCC *Special Report on Emission Scenarios* (SRES) to model the future of the Arctic sea ice, including extreme scenarios for global temperatures increases of (a) 1.9K and (b) 4.2K between 1990 and 2090. For scenario (a) the September sea ice area is projected to decrease from its current value of 4 million sq km in September to less than 2 million sq km by 2100. For scenario (b), however, the Arctic is projected to be sea ice free in summer by 2080. Using results from 12 IPCC 4th Assessment models, the analysis of Zhang and Walsh (2006) projects a transition towards a seasonal sea ice cover particularly in SRES scenarios. They also note that natural variability does not appear to have a significant impact on the trends. With the amplification of global warming in the Arctic region, there is a strong likelihood of no sea ice cover during summer in the Arctic Ocean by the end of the 21st century (Johannessen et al. 2004). During the satellite era, the Arctic winter ice maximum had been basically stable with the trend in extent being negative but only about -1.5% per decade. Such modest trend compared to the trend during the summer minima of about -8.5% per decade was puzzling since the effect of greenhouse warming was projected by models to be pronounced during the winter when the region is in darkness and long wave radiation is dominant. This may change soon with the observation of record low extents during winter maxima in 2005 and also in 2006 (Comiso, in press). The winter maximum extent in 2005 and 2006 were both about 6% lower than average values indicating significant decline in the winter ice cover. In both cases, the observed surface temperatures were also significantly warmer and the onset of freeze-up was later than normal. In both years, onset of melt also happened early. A continued decline would mean an advance to the north of the $0^{o}C$ isotherm and a warmer ocean in the peripheral seas of the Arctic. This in turn would cause further decline in the winter ice cover. More abrupt and earlier change in sea ice extant has also been shown by Holland *et. al*. (2006), whose modeling studies indicate possible significant and abrupt changes to Arctic sea ice cover by as early as mid-21st century. The research team indicated that heat absorption in open ice-free waters was operating to accelerate the rate of warming and loss of additional ice. The research indicated that future changes in sea ice may more dramatic than any changes observed to date. The modeling effort involved simulation tests to validate observed patterns of changes in sea-ice.

Land-fast ice. Fast ice is not explicitly included in climate model scenarios (ACIA 2005). Although reductions in the extent, thickness, and stability of fast ice are likely to occur, the implications of climate change for fast ice is recognized as a gap in knowledge. Many potential impacts of climate change will be mediated through land-fast ice (ACIA 2005). It protects unstable coastlines and coastal communities from wave damage, flooding by surges, and ice ride-up. It creates a unique and perhaps necessary habitat for northern species such as the ringed seal. It blocks channels, facilitating the formation of polynyas important to northern ecosystems in some areas (ACIA 2005).

Polynyas. Polynyas such as the North Water Polynya in northern Baffin Bay, owe their existence, at least in part, to winds that move sea ice from the area of its formation southward, so maintaining the area as open water even in the middle of winter. If the winds change in direction or intensity, the number and size of polynyas are also likely to change (ACIA 2005). The ACIA (2005) report discusses possible changes to specific polynya (e.g. St. Lawrence Island polynya region), and the potential implications of those changes to marine flora and fauna.

Other Predicted Changes in Arctic Climate

Predicted trends for various snow and ice parameters of the Arctic cryosphere (taken largely from Table 18.3 of ACIA 2005) are briefly summarized as follows:

Snow cover	Although increased evaporation (from warming) is likely to lead to some local increases in snow, snow-cover extent as a whole is projected to decrease by about 13% by 2071–2090 under the projected increase in mean annual temperature of about 4 ºC. The projected reduction is greater in spring. Owing to warmer conditions, some winter precipitation in the form of rain is likely to increase the probability of ice layers over terrestrial vegetation.
Glaciers	The loss of glacial mass through melting is very likely to accelerate throughout the Arctic, including the Greenland Ice Sheet. These changes will increase the rate of sea-level rise.
Permafrost	Over the 21st century, permafrost degradation is likely to occur over 10 to 20% of the present permafrost area, and the southern limit of permafrost is likely to move northward by several hundred kilometers.
River discharge	Models project that total river discharge is likely to increase by an additional 5 to 25% by the late 21st century.
Breakup and freeze-up	The trend toward earlier breakup and later freeze-up of rivers and lakes is very likely to continue, consistent with increasing temperature. Breakup flooding is likely to be less severe.
Sea-level rise	Models project that glacier contributions to sea level rise will accelerate in the 21st century. Combined with the effects of thermal expansion, sea level is likely to rise by 20 to 70 cm (an average of 2 to 7 mm/year) by the end of the 21st century.

The ACIA (2005) report presents the following summary of general features of projected changes in the arctic atmosphere relevant to marine processes (Table 9.1 from ACIA 2005), and the most likely scenarios for changes in oceanographic conditions within the ACIA region by 2020, 2050, and 2080 (Table 9.4 from ACIA 2005).

Table 9.1. Changes in surface and boundary forcing based on model projections and/or extrapolation of observed trends. Unless otherwise specified these projected changes are very likely to happen.

	2020	2050	2080
Air temperature			
annual mean[a]	1–1.5 °C increase	2–3 °C increase	4–5 °C increase
winter	2.5 °C increase	4 °C increase	6 °C increase in the central Arctic
summer	0.5 °C increase	0.5–1.0 °C increase	1 °C increase
seasonality	Reduced seasonality (warmer winters compared to summer)		
interannual variability	No change	No change	No change
Wind			
means	While changes in winds are expected, there is at present no consistent agreement from general circulation models as to the magnitude of the changes in either speed or direction		
storm frequency	Possible increase in storm intensity regionally (Labrador, Beaufort, Nordic Seas); in general, winter storms will decrease slightly in intensity because the pole to equator temperature gradient decreases		
storm tracks	Probable northward shift in storm tracks		
regional issues	In areas of sea-ice retreat, there will be an increase in wind-driven effects (currents, waves) because of longer fetch and higher air–sea exchange		
Precipitation/runoff			
mean[b]	2% increase	6% increase	10% increase
seasonality	Decreased seasonality in runoff related to earlier snow melt. Seasonality in precipitation unclear		
snow on ice	1–2% increase	3–5% increase	6–8% increase
Sea level	5 cm rise	15 cm rise	25 cm rise
Cloud cover			
general	3% increase	5% increase	8% increase
spring, autumn	4–5% increase	5–7% increase	8–12% increase
winter, summer	1–2% increase	3–5% increase	4–8% increase
Cloud albedo	Not available	Not available	Not available

[a]These numbers are averages and should be higher in the central Arctic and lower over southern regions; [b]based on the estimates of precipitation minus evaporation in Chapter 6.

Table 9.4. Summary of changes projected in ocean conditions according to the five ACIA-designated models relative to baseline conditions. Unless otherwise specified these projected changes are very likely to happen.

	2020	2050	2080
Sea ice			
duration	Shorter by 10 days	Shorter by 15–20 days	Shorter by 20–30 days
winter extent	6–10% reduction	15–20% reduction	Probable open areas in high Arctic (Barents Sea and possibly Nansen Basin)
summer extent	Shelves likely to be ice free	30–50% reduction from present	50–100% reduction from present
export to North Atlantic	No change	Reduction beginning	Strongly reduced
type	Some reduction in multi-year ice, especially on shelves	Significant loss of multi-year ice, with no multi-year ice on shelves	Little or no multi-year ice
landfast ice	Possible thinning and a retreat in southern regions	Probable thinning and further retreat in southern regions	Possible thinning and reduction in extent in all arctic marine areas
Sea surface temperature			
winter/summer (outside THC regions and depending upon stratification and advection)	An increase by about the same amount as the air temperatures in ice-free regions. No change in ice-covered regions		
seasonality	All shelf seas to undergo seasonal changes	30–50% of Arctic Ocean to undergo seasonal changes	50–100% of Arctic Ocean to undergo seasonal changes
Mixed-layer depth	Increase during summer in areas with reduced ice cover and increased wind		
Currents	In regions affected by THC, modifications to the THC will change the strength of the currents		
Ocean fronts	Fronts are often tied to topography but with altered current flows, may rapidly shift their position		
Light exposure	With decreasing ice duration and areal extent, more areas to be exposed to direct sunlight		
Nutrient levels	Substantial increases over the shelf regions due to retreat of the sea ice beyond the shelf break	High levels on shelves and in deep arctic basins; higher levels due to deeper mixed layer in areas of reduced ice cover	

Summary Statements

Excerpted from ACIA, 2005:

Changes in climate that have already taken place are manifested in the decrease in extent and thickness of Arctic sea ice, permafrost thawing, coastal erosion, changes in ice sheets and ice shelves, and altered distribution and abundance of species in polar regions (high confidence). Climate change in Polar Regions is expected to be among the largest and most rapid of any region on the Earth, and will cause major physical, ecological, sociological, and economic impacts, especially in the Arctic, Antarctic Peninsula, and Southern Ocean (high confidence). Polar Regions contain important drivers of climate change. Once triggered, the changes may continue for centuries, long after greenhouse gas concentrations are stabilized, and cause irreversible impacts on ice sheets, global ocean circulation, and sea-level rise (medium confidence). (ACIA 2005)

Excerpted from ACIA, 2005:

Changes in the Arctic are very likely to have significant impacts on the global climate system. For example, a reduction in snow-cover extent and a shrinking of the marine cryosphere would increase heating of the surface, which is very likely to accelerate warming of the Arctic and reduce the equator-to-pole temperature gradient. Freshening of the Arctic Ocean by increased precipitation and runoff is likely to reduce the formation of cold deep water, thereby slowing the global thermohaline circulation. It is likely that a slowdown of the thermohaline circulation would lead to a more rapid rate of rise of global sea level, reduce upwelling of nutrients, and exert a chilling influence on the North Atlantic region as Gulf Stream heat transport is reduced. It would also decrease the rate at which CO_2 is transported to the deep ocean. Finally, temperature increases over permafrost areas could possibly lead to the release of additional CH_4 into the atmosphere. If seabed temperatures rise by a few degrees, hydrated CH_4 trapped in solid form could also escape into the atmosphere (ACIA 2005).

2. Biological effects on polar bears

Polar bears are completely dependent upon Arctic sea-ice habitat for survival. They need sea ice as a platform from which to hunt their primary prey, ringed seals, to make seasonal migrations between the sea ice and their terrestrial denning areas, and for resting and mating.

Lentfer (1972) first noted that a general warming trend had been observed in the Arctic prior to the 1950s, and that the polar bear could be adversely impacted by warming via changes in the sea ice and snow cover. Lentfer (1972) hypothesized that a general warming of the Arctic could adversely affect denning since alteration in ice conditions could result in fewer bears reaching some preferred denning areas. Vibe (1967) indicated that to successfully den and produce offspring bears and ringed seals require relatively stable climates with an absence of periods of thawing and melting of snow during the winter. Warming trends would reduce the extent of suitable denning areas or access to them. Loss of ice cover, a possibility described by Budyko (1966), was believed to result in a severe impact on denning and the food chain supporting the polar bear. Stirling and Smith (2004) documented a decline in the survival rate of ringed seal pups, on the coast of southeastern Baffin Island, due the consequences of unusually warm temperatures and rain events which melted their pupping lairs thus exposing them to predation by polar bears and thermoregulatory stress. IPCC (2001) reported that most of the warming that occurred during the 20th century, came during two periods, from 1910-1945, and from 1976-2000. During an 18 year period, Parkinson (2000) noted that annual variability was high, both in the sea ice season length and monthly distribution. Climatic warming is likely to result in greater inter-annual variability and thus the response of polar bear populations is also likely to be highly variable.

For polar bears and other species, the evaluation and quantification of cause and effect relationships between climate change and specific life history parameters or population status and trend are extremely difficult and require long time series of data that are only available for a few populations. In the absence of lengthy time series of data on polar bears scientists have been required to sample key parameters over time or compare these parameters to averaged benchmarks for other population or populations, acknowledging that natural variation related to system carrying capacity and environmental factors are inherent within each of the population units.

Observed and predicted changes in ice cover, characteristics, and timing have profound effects on polar bears. Sea ice is a highly dynamic habitat with different types, forms, stages, and distributions that all operate as a complex matrix in determining biological productivity and use by marine organisms, including seal species. Polar bear use of sea ice is not uniform and their preferred habitat is the annual ice located over continental shelf and inter-island archipelagos that circle the Arctic Basin. Ice seals demonstrate a similar preference to these ice habitats.

Hudson Bay in Canada is considered an area that typifies change in the Arctic due to its relatively southern location and occurrence on a divide between a warming and a cooling region (AMAP 2003). It is an ideal area to study the impacts of global climate change. Hudson Bay has the most significant long term time series of data on the ecology of polar bears and the site of the first documented evidence of major and ongoing impacts to polar bears from global warming.

Stirling and Derocher (1993) predicted an array of impacts to polar bears from global warming, including reduced abundance of and access to seals and effects on the marine ecosystem that influence productivity. Stirling and Derocher (1993) noted that changes in polar bear parameters such as declining body condition, lowered reproductive rates, and reduced cub survival were present in the Western Hudson Bay population, but at that time the changes could not be linked to global warming. In subsequent years, a multi-disciplinary research continued to document the relationships between climate, sea ice, and physiological and demographic parameters of polar bear (Stirling et al. 1999, Derocher et al. 2004, Stirling and Parkinson 2006) as well as similar relationships for other species such as thick-billed murres (*Uria lomvia*) (Gaston et al. 2003). Using data from a 19-year period, Stirling et al. (1999) established a statistically significant link between global warming and observed impacts to polar bear physical and reproductive parameters, including body condition and natality.

Hudson Bay is a relatively closed system and is ice-free in the summer and freezes over in the winter (Parkinson et al. 1987, Gough et al. 2004). Typically it is completely covered in ice from January to May and is ice-free from mid-August to late October (Parkinson et al. 1987, Gough et al. 2004), with intermediate levels of ice forming or breaking up in the intervening periods. Break-up begins first in James Bay, at the southern end of Hudson Bay close to the western shoreline, due to warm winds, and also in the eastern region of Hudson Bay, from spring runoff (Gough et al. 2004). The last place to breakup in the spring, however, is often the southwestern region of Hudson Bay (Gough et al. 2004), part of the Southern Hudson Bay polar bear population's territory and south of the terrestrial denning area of the Western Hudson Bay polar bear population. Gough et al. (2004) found that the trend towards earlier break-up of the ice in the southwestern region of Hudson Bay and the northwestern region of James Bay was consistent with the results of Stirling et al. (1999) and Derocher et al. (2004).

a. Increased polar bear movements or travel

Global warming is expected to decrease the thickness of multi-year sea ice and therefore increase the rate of movement of the ice flow (Derocher et al. 2004). Since polar bears catch very few seals in open water, sea ice is the essential platform from which they hunt (Stirling 1988, USFWS 1995, Derocher et al. 2004).

Polar bear body temperature will stay fairly constant at walking speeds up to 4 km per hour (about 2.5 mph) at air temperatures ranging from -15° C to -25° C (approximately -4° F to -12° F), (Øritisland 1969 p. 381, Stirling 1988 p. 144). After that, however, body temperature begins to climb rapidly, until at about 7 km per hour (4.2 mph), it is about 39° C (100° F), which is equivalent to a fever in humans (Øritisland 1969 p. 381, Stirling 1988 p. 144). In addition, to move at this relatively slow speed, a polar bear must burn 13 times more energy than it would if it were lying down (Hurst et al. 1982a, Hurst et al. 1982b, Stirling 1988). These factors explain why a polar bear's average lumbering gait, which it can maintain for hours, is only about 5.5 km per hour (3.5 mph) (Hurst et al. 1982a, Hurst et al. 1982b, Stirling 1988).

Polar bears are inefficient walkers (and runners), expending about twice the average energy use of other mammals when walking (Best 1982, Hurst et al 1982a, Hurst et al. 1982b). The inefficiency of polar bear locomotion likely explains why polar bears are not known to hunt musk oxen (*Ovibos moschatus*) or snow geese(*Anser caerulescens*), potential prey species that co-occur with the polar bear in many areas (Lunn and Stirling 1985). The energy needed to catch such species would almost certainly exceed the amount of energy a kill would provide (Stirling 1988).

Polar bears tend to walk against the movement of ice in order to adjust their movements to habitat suitability rather than seek areas of fixed location (Mauritzen et al. 2003a). Increased rates and extent of ice movement will require additional efforts and energy expenditure for bears to maintain their position near preferred habitats (Derocher et al. 2004). Ferguson et al. (2001) found that polar bears inhabiting areas of highly dynamic ice had much larger activity areas and movement rates compared to those populations inhabiting more stable, persistent ice habitat. This finding suggests adaptation by polar bears to a fluid or moving environment. However, even in the areas of highly dynamic ice movement, there was predictability in inter-annual location of the habitat (Mauritzen et al. 2003b). The areal extent, timing (rate of movement) and distances of ice retraction in recent years in certain areas of the Arctic brings to question the ability of polar bears to adapt to this rapidly changing landscape. If the ice moves more quickly or becomes more fragmented, polar bears would likely have to use more energy to maintain contact with the ice and these increased energetic costs could result in lower survival and recruitment. (Derocher et al. 2004). During summer periods the remaining ice in much of the central Arctic is now positioned away from more productive continental shelf waters and over much deeper, less productive waters, such as in the Beaufort and Chukchi Seas of Alaska. If the width of leads or extent of open-water increases, the transit time for bears and the need to swim or to travel will increase (Derocher et al. 2004). Polar bears are capable of swimming great distances, but exhibit a strong preference for sea ice (Derocher et al. 2004). However, polar bears will also abandon sea ice for land once the sea-ice concentration drops below 50% (Derocher et al. 2004, Stirling et al. 1999). Researchers believe this is likely due to the increased energetic costs of locomotion since moving through highly fragmented sea ice is difficult and likely more energy intensive than walking over consolidated sea ice (Derocher et al. 2004). Derocher et al. (2004) suggest that as habitat patch sizes decrease, available food resources are likely to decline, resulting in reduced residency time and thus increased movement rates.

Although data on the energetic costs of swimming are not available, it is likely that swimming is more costly than walking (Hurst et al. 1982a, Hurst et al. 1982b) even though walking is relatively energy intensive for polar bears compared to other mammals (Best 1986). Subadult polar bears are more vulnerable than adults to environmental effects (Taylor et al. 1987). Observations of density dependent and density independent effects on populations of other marine mammals indicate that environmental effects typically manifest as reductions in annual breeding success and reduced subadult survival rates (Eberhardt and Siniff 1977). Therefore the relative impacts of an increased need for travel, and corresponding energy expenditures, will disproportionately impact younger animals (Derocher et al. 2004).

Another possible impact is that as movement of sea ice increases and areas of unconsolidated ice increase, some bears may lose contact with the main body of ice and drift into unsuitable habitat from which it may be difficult to return (Derocher et al. 2004). This already occurs in some areas such as Southwest Greenland and offshore from the island of Newfoundland (Derocher et al. 2004). Increased frequency of such events could negatively impact survival rates and contribute to population declines (Derocher et al. 2004). The earlier-than-normal break-up of ice in Hudson Bay in 1999 may have contributed to an extremely rare extralimital sighting of a polar bear at Burnett Lake in Saskatchewan at 59° 02' N, 102° 18' W (Goodyear 2003).

Space-use patterns of polar bears differ widely both within and among populations (Derocher et al. 2004). Amstrup et al. (2001) and Taylor et al. (2001b) found that space-use patterns were not substantially different between males and females although there is not much data on the space-use patterns of males. Due to these differences, impacts from climate change on populations will likely show large geographic variation and may also impact individual bears in different ways (Derocher et al. 2004).

b. Polar bear distribution changes and access to prey

In Western Hudson Bay, break-up of the annual ice occurs approximately 2.5 weeks earlier than it did 30 years ago (Stirling et al. 1999), reducing the amount of time that bears are able to feed on seals during late spring and early summer, the most important time of the year for feeding purposes (Derocher et al. 2004). A highly significant relationship between break-up of the sea ice and condition of the bears when they come ashore has been determined (Stirling et al. 1999). Bears that arrive ashore earlier have foregone feeding opportunities and consequently have lower fat reserves required for a 4-month open water fasting period (Derocher et al. 2004). Declining reproductive rates, subadult survival, and body mass (weights) have resulted from the progressively earlier break-up of the sea ice caused by an increase in spring temperatures (Stirling et al. 1999, Derocher et al. 2004).

Stirling et al. (1999) found a statistical correlation between year and breakup date which was just below the accepted level. However, that was updated in Stirling et al. (2004, p. 22) as follows: "These results are consistent with a significant trend toward earlier breakup in the total area occupied through the winter by the Western Hudson Bay bear population ($r = 0.497$, $df = 29$, $p = 0.0044$)." In years of large ice extent, the date of break-up tended to be later while the date of freeze-up was earlier, and conversely in years with relatively low ice extent. The 20-year period 1979-1998 revealed a trend of earlier spring breakup that approached statistical significance (Stirling et al. 1999). The earlier breakup was probably due to spring air temperatures in the region warming at a rate of 0.2-0.3º C per decade since 1950 (Skinner et al. 1998). There was no trend for the timing of freeze-up and consequently the increase in the number of ice-free days was due to the trend for an earlier break-up (Stirling et al. 1999, Gough et al. 2004).

The earlier spring breakup was highly correlated with the mean dates on which telemetry collared female polar bears came ashore (Stirling et al. 1999). Between 1991 and 1998, female bears with radio collars came ashore an average of 24.6 days after break-up, indicating that they remained on the ice to hunt seals well after a significant reduction in total ice cover (Stirling et al. 1999).

Stirling et al. (1999) reported a significant decline in body condition (weights) of both male and female adult polar bears since the 1980s in Western Hudson Bay, which was interrupted by improved condition in 1992 and 1993. They also found a statistically significant relationship over the 19 year study between the date of break-up, body condition of the adult females coming ashore and natality (Stirling et al. 1999). Earlier break-up dates related to poorer body condition of females coming on shore and resulted in lower natality rates (Stirling et al. 1999). Adult female polar bears in the study showed a strong fidelity to specific terrestrial areas that took precedence over remaining on drifting ice. A positive relationship between body mass of females with cubs and survival of cubs was also established (Derocher and Stirling1996, 1998). The survival of cubs from when they left their dens in early March to the following August-September when the radio-collared females and accompanying cubs were re-sighted also declined from 60-65% in the 1980s to just over 50% through the late 1980s and early 1990s and then increased to 70-80% through the mid-to-late 1990s (Stirling et al. 1999). The proportion of yearlings that had already been weaned in the annual capture samples fluctuated greatly, but overall the proportions of independent yearlings declined from about 60% in 1982 to 15-20% since 1991, however, there was no statistically significant trend between the proportion of lone yearlings and the time of break-up in the same year (Stirling et al. 1999).

In 1992 and 1994 radio-collared females arrived on shore later than in other years (Stirling et al. 1999). In 1992, break-up occurred three weeks later than usual, probably due to the short-term cooling effect of the eruption of Mount Pinatubo, and radio-collared animals arrived later based on a later break-up (Stirling et al. 1999). The additional feeding opportunities resulted in both males and females being in better condition than in other years (Stirling et al. 1999). Both cub production and survival of cubs was significantly greater in the following year (Stirling et al. 1999). Following 1994, condition of males and females, cub production rates, and the proportion of lone yearlings began to decline again (Stirling et al. 1999).

The Western Hudson Bay population had far higher natality than any other polar bear population in the early to mid 1980s (Stirling et al. 1999). In some of those years, females successfully weaned up to approximately 40% of their cubs at 1.5 years of age, as opposed to the 2.5 years of age that is the norm in other populations that have been studied (Stirling et al. 1999). In the late 1980s and early 1990s, a long-term decline in both natality and condition of adult males and females was observed (Stirling et al. 1999). Stirling et al. (1999) cautioned that, although downward trends in the population had not been detected, if trends continued in the same direction “they will eventually have a detrimental effect on the ability of the population to sustain itself.” Population level declines have now been determined based on a recent analysis of an ongoing mark-recapture population study and the earlier predictions of Stirling et al (1999) have been proven. Between 1987 and 2004, the number of polar bears in the Western Hudson Bay population declined from 1,194 to 935, a reduction of about 22% (Regehr et al., in prep.). This decline appears to have been initiated by the progressively earlier sea ice breakup resulting from climate change. Progressive declines in the condition and survival of cubs, subadults, and bears 20 years of age and older, probably initiated the decline in the size of the Western Hudson

Bay population. Once the population began to decline, the existing harvest was no longer sustainable and this also contributed to further reduction in the population (Regehr et al., in prep.).

Starting in the 1990s, Schliebe et al. (2006a) reported an increasing trend of use of coastal areas in the southern Beaufort Sea by polar bears during the fall open water period. Weekly aerial surveys were flown during the interval from when polar bears first appear in coastal areas until polar bear numbers have decreased as they return to sea-ice environments as it develops near shore. An analysis of the number of bears using coastal habitats and the distance to the pack ice was conducted. The study period included record extreme minima ice conditions for the month of September in four of the six years (Schliebe et al. 2006a). Food sources in the form of bowhead whale carcass remains from native subsistence hunting were available in all years of the study. In all years, the number of bears on shore increased to a certain date and then decreased as pack ice became available near-shore. There was a significant relationship between the mean distance to ice edge and the numbers of bears observed on the coast. As distance to ice increased, the number of bears near shore increased; conversely as ice advanced toward shore the number of bears near shore decreased. These results suggest that environmental factors, possibly similar to those that operated in Western Hudson Bay, are influencing the distribution of polar bears in the southern Beaufort Sea. They also suggest that increased use of coastal areas may continue to occur if minimal ice conditions become more common in the future as predicted (Serreze et al. 2000, Serreze and Barry 2005).

Gleason et al. (2006) analyzed 27 years (1979-2005) of fall bowhead whale aerial survey data in the Alaska Beaufort Sea. In addition to bowhead whale observations, other important environmental data and other marine mammal sightings were also recorded. Annual surveys were conducted roughly between Sept. 1 and October 20th. The northern extent of the surveys was generally between 72º and 71º10' N latitude, between 148º – 156º W. Their study was divided into three periods (1979-1986, 1987-1996, and 1997-2005). The September distribution of polar bears during the three periods changed from bears being primarily associated with offshore ice (83%) during 1979-1986, to a distribution predominated by observations on land

(80%) and in open water (20%) during 1997-2005. These findings are consistent with the lack of pack ice (concentrations >50%) caused by a retraction of ice in the study area during the latter period (Stroeve et al. 2005, Comiso 2002a, b, 2003, 2005).

For analysis of long-term changes in sea ice dynamics, Gleason et al. (2006) selected two 50km^2 blocks, one near Barrow and one near Kaktovik, as representative subsamples for a more detailed analysis. Ice type and concentration for September and October for each block over the three previously described periods were evaluated. Ice types were classified as old (multi-year), new (first year), and no ice. The most obvious change in trend of ice types for both Barrow and Kaktovik was an increase in the "no ice" category and a decline in the "old" and "new" ice types. Further analysis of the percentage of ice present (<25%, 25-75%, >75%) within the 50km^2 blocks over the study confirmed a strong trend of declining ice coverage in September for both Barrow and Kaktovik during 1997-2005. The results for October, although less dramatic, were consistent with the trend of declining ice coverage.

Gleason et al. (2006) findings are consistent with those reported by Schliebe et al. (2006a), and confirm a notable increasing trend in use of coastal areas by polar bears in the southern Beaufort Sea in recent years. The proximate cause for changes in polar bear distribution are thought to be retraction of pack ice far to the north for greater periods of time in the fall, and later freeze-up of coastal waters. The long time series of data for their study is unique to the southern Beaufort Sea population of polar bears. Other populations exhibiting larger numbers of polar bears onshore include Chukchi Sea, Baffin Bay, Davis Strait, and the Western Hudson Bay. Similar long-term datasets are not available to show if pack ice position or other environmental factors are influencing the distribution of bears in these populations. Durner et al. (2006) evaluated habitat selection of radio-collared adult female polar bears occupying the southern Beaufort Sea. The authors found a general shift to the north and east in distribution of polar bears during summer and fall periods over time. Models used also indicated that during the study, polar bears used ice habitat over relatively shallow water close to an ice-water interface characterized by high total ice concentration.

Indications of potential distribution changes have been noted during a similar period of time for the northern coast of Chukotka (Kochnev 2006) and distribution changes have been noted on Wrangel Island, Russia (Ovsyanikov pers. comm.). Kochnev (2006) reports that in the autumn seasons of 1990, 1991, 1993, 1995, 1996, and 1997 the ice edge retreated 80-380 km to the north and to the west of Wrangel Island. During these years walruses occupied coastal haulout sites in substantial numbers for protracted periods of time. Walrus carcasses on the beaches became a food-source for polar bears and was the main factor attracting bears to these locations (Kochnev 2001). Following a walrus mortality event such as a stampede, the number of bears increased and usually reached a peak in the second half of October.

The relationship between number of bears present and walrus carcasses continued to exist until the freezing of the sea. When bears reached their maximum density in the study areas before sea froze over and the level of walrus mortality was low, bears usually consumed available food and departed when sea ice began to consolidate. The relationship between the maximum number of polar bears, the number of dead walruses, quantity of accessible food, and the distance of the ice-edge from Wrangel Island was evaluated. The regression analysis revealed that the strongest correlation was between bear numbers and distance to the ice-edge, although there were also less strong relationships with the number of walrus carcasses present, and walrus biomass availability (Kochnev 2006).

In Baffin Bay, traditional Inuit knowledge studies and anecdotal reports indicate that in many areas that greater numbers of polar bears are being encountered on land during the summer and fall open water seasons. Interviews were conducted with elders and senior hunters in the three Nunavut communities that harvest polar bears from the BB population (Dowsley 2005). Interviews focused on changes in the polar bear population, observations on the climate during the past 15-20 years, and people's views of bear management. Details of the interview and comments are presented in Dowsley and Taylor (2005). A qualitative analysis allows greater latitude in interpretation and consideration of the context of the responses and other associated responses than a quantitative analysis. The results from the quantitative analysis found that Inuit knowledge is variable depending upon the community and experiences of the respondent (Dowsley 2005).

Most respondents (83%) believed that the population had increased because more bears were seen near the communities and near cabins and camps, and hunters encountered bear signs in areas not previously used by bears. Some people noted that these observations could reflect a change in bear behavior rather than an increase in population. Many (62%) respondents believed that bears were less fearful of humans now than 15 years ago. Most (57%) respondents reported bears to be skinnier now and 5 people in one community reported an increase in fighting among bears (Dowsley 2005).

Respondents also discussed climate change and they indicated that there was more variability in sea ice environment in recent years than in the past. Some indicated a general trend for ice floe edge to be closer to the shore than in the past, the sea ice to be thinner, fewer icebergs present, and glaciers receding. Fewer grounded icebergs, from which shorefast ice forms and extends, were thought to be partially responsible for the shift of the ice edge nearer to shore. Respondents were uncertain if climate change was affecting polar bears or what form the effects may be taking (Dowsley 2005).

Stirling and Parkinson (2006, p. 263) evaluated sea ice conditions and distribution of polar bears in five populations in eastern Canada: Western Hudson Bay, Eastern Hudson Bay, Baffin Bay, Foxe Basin, and Davis Strait. Their analysis of satellite imagery beginning in the 1970s indicates that the sea ice is breaking up at progressively earlier dates, so that bears must fast for longer periods of time during the open water season. Stirling and Parkinson (2006, pp. 271-272) point out that long-term data on population size and body condition of bears from the Western Hudson Bay, and population and harvest data from the Baffin Bay population indicate that these populations are declining or likely to be declining. The authors indicate that as bears in these populations become more nutritionally stressed, the numbers of animals will decline and the declines will probably be significant. Based on the recent findings of Holland et al. (2006) these events are predicted to occur within the foreseeable future as defined in this rule (Stirling, pers. comm. 2006).

c. Access to and Alteration of Denning Areas

Many female polar bears repeatedly return to specific denning areas on land (Harrington 1968, Schweinsburg et al. 1984, Garner et al. 1994b, Ramsay and Stirling 1990). In order for a bear to reach a preferred terrestrial den site, either the ice must drift close enough or must freeze early enough in the fall for pregnant females to be able to walk to shore, or they swim to the coast in time to dig a den in late October or early November (Derocher et al. 2004). The relationship between increasing distance from the pack ice to historical den areas or habitat and successful reproduction is difficult to forecast. In addition to increased travel distances another habitat component for which no forecasts or models exist is the amount and quality of snow that provides suitable denning strata. Areas of concentrated land denning include the islands of Kong Karls Land, Nordaustlandet, Edgeøya, and Barentstøya in the Svalbard Archipelago north of Norway (Larsen 1985), Franz Josef Land, Novaya Zemlya, Wrangel Island in Russia, the west coast of Hudson Bay, and the Arctic National Wildlife Refuge on the Beaufort Sea coast in the U.S. (Amstrup 2002). Larger interannual variation in the distance between the ice and denning areas is already occurring (Derocher et al. 2004). As global warming progresses, the distance between the edge of the pack ice and land will increase (ACIA 2005). Derocher et al. (2004) theorized that as distance increases between the southern edge of the pack ice, where some polar bear populations spend the summer, and coastal areas, where pregnant females den, it will become increasingly difficult for pregnant females to reach their presently preferred locations. Most high density denning habitat is located at more southerly latititudes. Therefore for those populations denning at high latitude in the Canadian archipelago islands the effects may be less or the effects may become evident until much later than for the more southerly populations, which will likely be affected first.

Some climate models predict the complete disappearance of summer sea ice by 2100 (ACIA 2005). One regional model predicts the complete disappearance of sea ice from Hudson Bay by 2050 (Gough and Wolfe 2001). The average of five models used by ACIA (2005) projects large distances between summer sea ice and polar bear terrestrial denning sites. Additionally, the ACIA projections are based on the IPCC B2 emissions scenario and uses climate sensitivity measures that may be conservative or understated and losses of sea ice may be much greater than predicted. A number of scientists have predicted more extreme projections of the timing and extent of polar pack ice retraction (Zhang and Walsh 2006) although a few climatologists dispute these findings regarding climate change (Kandekar 2004, Kandekar et al. 2005).

Derocher et al. 2004 predicted that under any of these climate change scenarios, pregnant female polar bears will likely be unable to reach many of the most important denning areas in the Svalbard Archipelago, Franz Josef Land, Novaya Zemlya, Wrangel Island, Hudson Bay, and the Arctic National Wildlife Refuge and north coast of the Beaufort (Derocher et al. 2004). Scientists do not know how quickly female polar bears that previously denned on land might learn to exploit alternate denning habitat such as the drifting pack ice if they were unable to access land, or if they would respond this way at all (Derocher et al. 2004), or if drifting pack ice would continue to be a suitable substrate for denning.

Another anticipated impact of a climate change on polar bear denning will be the thinning of sea ice and likely increased drift rates of ice floes (Derocher et al. 2004). In northern Alaska, between 1981 and 1991, approximately 53% of polar bear maternity dens were found on drifting multiyear ice several hundred kilometers north of the coast (Amstrup and Gardner 1994, Derocher et al. 2004). While those bears appeared to successfully raise cubs, between den entry and emergence, these dens drifted between 19 and 997 km from their location when the female first entered them (Amstrup and Gardner 1994). Increased drifting of sea ice with maternity dens could cause females with small cubs to travel longer distances and expend additional energy to return to the core of their normal home range (Derocher et al. 2004). Cubs emerging from dens in optimal habitats could also experience reduced survival (Derocher et al. 2004). Although use of pelagic denning habitat is minor overall, it provides important habitat for some populations and suggests that this habitat may be available for use by females that find their land den areas unsuitable. The stability of pack ice and its use for denning in the future, however, are uncertain.

In some locations, female polar bears might adopt the current denning strategy used by bears in the Western Hudson Bay population, where pregnant females leave the ice at break-up and summer in the same locations where they ultimately den (Derocher et al. 2004). This strategy requires females to accumulate sufficient fat stores to fast for up to approximately 8 months before they can return to sea ice to resume feeding on seals (Derocher et al. 2004). If the sea ice these bears use is over the deep polar basin where seal densities are low pregnant females may not be able to meet the energetic requirements for such a long period of fasting and nursing cubs (Derocher et al. 2004).

In addition to changes in access to or movement of denning areas, in traditional denning areas, there may be changes in the habitat available for denning (Derocher et al. 2004). For example, in Hudson Bay, pregnant females make extensive use of terrestrial dens dug into permafrost peat banks under black spruce in riparian areas (Derocher et al. 2004). Some dens may be used repeatedly (by different bears) over a period of over 200 years (Scott and Stirling 2002). As temperatures warm, fire frequency will increase, and in fire areas it will destabilize the riparian banks where polar bear dens occur, making the banks unsuitable for denning (Richardson 2004, Derocher et al. 2004).

Climate change could also impact populations where females den in snow (Derocher et al. 2004). Insufficient snow would prevent den construction or result in use of poor sites where the roof could collapse (Derocher et al. 2004). Too much snow could necessitate the reconfiguration of the den by the female throughout the winter (Derocher et al. 2004). Changes in amount and timing of snowfall could also impact the thermal properties of the dens (Derocher et al. 2004). Since polar bear cubs are born helpless and need to nurse for three months before emerging from the den, major changes in the thermal properties of dens could negatively impact cub survival (Derocher et al. 2004). For example of the importance of dens was the fate of two polar bear cubs that were born unexpectedly to a captive female in December, 1978 in an outdoor uninsulated cage when the temperature was approximately -45°. Both cubs died within two days (Blix and Lentfer 1979).

Finally, unusual rain events are projected to increase throughout the Arctic in winter (ACIA 2005), and increased rain in late winter and early spring could cause ringed seal den collapse (Stirling and Smith 2004). Den collapse following a warming period was observed in the Beaufort Sea and resulted in the death of a mother and her two young cubs (Clarkson and Irish 1991). After March 1990 brought unseasonable rain south of Churchill, Manitoba, researchers observed large snow banks along creeks and rivers used for denning that had collapsed because of the weight of the wet snow, and noted that had there been maternity dens in this area the bears likely would have been crushed (Stirling and Derocher 1993).

d. Open water swimming

Monnett and Gleason (2006) observed 315 live polar bears during aerial surveys in September 1987–2003. Of these12 (3.8%) were in open water, which was defined as greater than 2 km north of the Alaska Beaufort Sea coastline or barrier islands. No polar bear carcasses were observed during this period. During aerial surveys in early September 2004, 51 polar bears were seen and of those 10 (19.9%) were in open water variable distances from the sea ice and land. In September 2004, the sea ice edge was 160-320 km from shore representing record minimal ice conditions. On surveys following a major regional storm with wind speeds recorded at 46-54 km/hr and seas estimated at 2 meters, four dead polar bears were seen floating in open water and it is presumed that the animals drowned. In general, wave height (sea state) increases as a function of the amount of open water surface area. Spatial extrapolation of these data indicated that as many as 36 bears may have been swimming in the area and that 27 bears may have died as a result of the high offshore winds. This suggests that the survival rate of swimming bears under these conditions was low (9/36 = 25%). No detection correction factors for bears present but not observed were incorporated into the analysis, therefore the estimates could be considered an underestimate of the actual number affected. Swimming and floating bears are difficult to see from survey altitudes of 457 m under ideal conditions and some may have sunk or drifted out of the study area so the number of deaths due to the combination of ice and storm conditions was likely much larger. Monnett and Gleason (2006) speculate that mortalities due to offshore swimming during late-ice (or mild ice) years may be an important and unaccounted source of natural mortality given energetic demands placed on individual bears engaged in long-distance swimming. This evidence suggests that drowning-related deaths of polar bears may increase in the future if the observed trend of regression of pack ice and/or longer open water periods continues. The effect of ice reduction and increases in areas of open water will cause an increase in the size of waves since fetch is gathered over greater distances than in a marine environment where there is no sea ice to buffer wave action (Monnett and Gleason 2006). Evidence of such mortality has also been reported by Julian Dowdeswell, Head of the Scott Polar Research Institute of England, who observed one exhausted and one apparently dead polar bear stranded at sea east of Svalsbard in 2006.

Derocher (2004) indicates that as sea ice becomes more unstable due to decreased ice thickness and increased winds, some bears near the edge or southern limit of the pack ice may lose contact with the main body of ice and drift into areas from which return may be difficult. This has occurred in Southwest Greenland and Newfoundland.

e. Demographic Effects on Polar Bear

Derocher et al. (2004) predict a cascade of demographic impacts on polar bear populations as a result of global warming. Polar bear characteristics, including specialized diet, habitat specialization, large body size, low fecundity, long lifespan, low genetic variability, and sensitivity to events that alter adult female survival rates, are all associated with high extinction risk (McKinney 1997, Bessinger 2000, Owens et al. 2000). In general, Derocher et al. (2004) predict demographic impacts that will adversely affect female reproductive rates and juvenile survival first and will only affect adult female survival rates under severe conditions.

Physical condition of polar bears has been shown to determine the welfare of individuals, and ultimately, through their reproduction and survival, the welfare of populations (Stirling et al.

1999, p. 304; Regehr et al. in prep). Declines in fat reserves during critical times in the polar bear life cycle are likely to lead to an array of impacts (Derocher et al. 2004). Because female polar bears accrue body fat throughout their lives until approximately 15 years of age, the age of first successful reproduction could be delayed as growth rates and fat stores of females are reduced (Derocher et al. 2004). A decline in body condition will reduce the proportion of pregnant females that are able to initiate denning (Derocher et al. 2004). Females with lower fat stores will likely produce more single cub litters, fewer cubs overall, as well as lower cub body weights and lower survival rates (Derocher and Stirling 1998). This is because body mass in adult females is correlated with cub mass at den emergence which is in turn correlated with cub survival (Derocher and Stirling 1996). A higher proportion of females that do initiate denning are likely to abandon the effort mid-winter (Derocher et al. 2004). Insufficiency of maternal resources or poor hunting conditions in the early spring after den emergence could lead to increased cub mortality (Derocher et al. 2004). For example, researchers believe that young cubs are unable to survive immersion in icy water for more than approximately 10 minutes (Blix and Lentfer 1979; Larsen 1985). This is because young cubs have little insulating fat, and the fur of polar bear cubs loses its insulating value when wet (though the fur of adults sheds water and recovers its insulating properties quickly), and therefore core body temperature drops rapidly in young polar bear cubs when they are immersed in icy water (Blix and Lentfer 1979). If declining sea ice forces females to swim from den areas to pack ice, cub mortality could increase due to hypothermia (Derocher et al. 2004). In addition, sea ice conditions that include broken and more fragmented ice may require young cubs to enter water more frequently and for more prolonged periods of time.

Reductions in sea ice, as discussed above, will alter ringed seal distribution, abundance, and availability for polar bears. Such reductions will, in turn, decrease polar bear body condition (Derocher et al. 2004, p. 165). Derocher et al. (2004, p. 165) projected that most females in the Western Hudson Bay population may be unable to reach the minimum 189 kg (417 lbs) body mass required to successfully reproduce by the year 2012.

> Furthermore, with the extent of winter sea ice projected to be reduced in the future, opportunities for increased feeding to recover fat stores during this season may be limited. Mortality of polar bears is thought to be the highest in winter when fat stores are low and energetic demands are greatest. Pregnant females are in dens during this period using fat reserves and not feeding. Polar bears hunt seals at their breathing holes, however, increased open water or fragmented ice will provide seals alternatives to establishing breathing holes, likely reducing their availability to polar bears and decreasing bear hunting success (Derocher et al. 2004, p. 167).

Derocher et al. (2004) cautions that reduced reproductive rates in females may be difficult to measure, and that declines will likely be highly variable (Derocher et al. 2004). In general, Derocher et al. (2004) predict demographic impacts will adversely affect female reproductive rates and juvenile survival first while adult female survival would be affected under more severe conditions. Time lags in the system may initially obscure trends, but if conditions decline sufficiently adult survival may be impacted and sudden population declines could occur (Derocher et al. 2004). Because researchers believe mortality of polar bears is already highest in winter when fat stores are low, and because polar bears already use winter dens when necessary to conserve fat stores, Derocher et al. (2004) believe it is unlikely that the impacts described above could be compensated for with increased feeding in winter.

In general, Derocher et al. (2004, p. 170) predict demographic impacts will adversely affect female reproductive rates and juvenile survival first while adult female survival rates would be affected under severe conditions. Regehr et al. (2005, p. 233) showed that while the Western Hudson Bay population has declined 22 percent since 1987, this decline was not uniform across all age classes of bears. Survival of prime-adult polar bears (age 5 to 19 years) was stable over the course of the study; however, survival of juvenile, subadult, and past prime age polar bears declined as a function of earlier spring sea ice breakup date.

Polar bear distribution changes in relation to changing sea ice environs associated with greater periods of fasting on land, and consequent reductions in body condtion and ultimate reductions in demographic factors such as recruitment and survival of polar bears in Western Hudson Bay have been document (Stirling et al. 1999; Regehr et al. in prep.) and discussed in detail previously (see also Distribution Section). Recent research results indicate that the Southern Beaufort Sea population has also been subject to dramatic changes in the sea ice environment beginning in the winter of 1989 to 1990 (Regehr et al. 2006, p. 2). These changes were linked initially through direct observation of distribution changes during the fall open water period. With the exception of the Western Hudson Bay population, the Southern Beaufort Sea population has the most complete and extensive time series of life history data, dating back to the late 1960s. A 5-year coordinated capture-recapture study of this population to evaluate changes in the health and status of polar bears and life history parameters such as reproduction, survival, and abundance was completed in 2006. Results of this study indicate that the estimated population size has gone from 1,800 bears (Amstrup et al. 1986, p. 244; Amstup 2000, p. 146) to 1,526 polar bears in 2006 (Regehr et al. 2006, p. 16). The precision of the earlier estimate of 1,800 polars was low, and consequently the 2006 estimate of 1,526 is not statistically significantly different. Amstrup et al. (2001, p. 230) provides an additional population estimate of as many as 2,500 bears for this population in the late 1980s, although the statistical variance could not be calculated and thus precludes comparative value of the estimate. Survival rates, weights, and skull sizes were compared for 2 periods of time, 1967 to 1989 and 1990 to 2006. In the later period, estimates of total survival for cubs declined significantly from .65 (Amstrup and Durner 1995, p. 1316) to .43. Cub weights also decreased slightly. The authors believed that poor survival of new cubs may have been related to declining physical condition of females entering dens and consequently of the cubs born during recent years as reflected by smaller skull measurements. Also, between years during the 5-year study, a general decline in survival rates for cubs, females older than cubs, and males older than cubs was noted. In addition, body weights for adult males decreased significantly and skull measurements were reduced since 1990. Since male polar bears continue to grow into their teen years (Derocher et al. 2005, p. 898), if nutritional intake was similar since 1990, the size of males should have increased (Regehr et al. 2006, p. 18). The observed changes reflect a trend toward smaller size adult male bears. Although a number of the indices of population status were not independently significant, nearly all of the indices illustrated a declining trend. In the case of Western Hudson Bay, declines in cub survival and physical stature were recorded for a number of years (Stirling et al. 1999, p. 300; Derocher et al. 2004, p. 165) before a statistically significant decline in the population size was confirmed (Regehr et al. in prep.). Amstrup (pers. comm. 2006) indicates that if the trends in loss of sea ice continue as predicted, then, similar to the conditions for the Western Hudson Bay population, the ultimate effect will be a significant decline in the population trend for the Southern Beaufort Sea population. This declining trend will occur within the 45-year period determined to be the foreseeable future.

In further support of the interaction of environmental factors, nutritional stress and their effect on survival rates for polar bears, several unusual mortality events have been documented in the southern Beaufort Sea. During the winter and early spring of 2004, three observations of polar bear cannibalism were recorded (Amstrup et al. 2006, p. 1). Similar observations had not been recorded in that region despite studies extending back for decades. In the fall of 2004, four polar bears were observed to have drowned while attempting to swim between shore and distant pack ice in the Beaufort Sea. Despite offshore surveys extending back to 1987, similar observations had not previously been recorded (Monnett and Gleason 2006, p. 3). In spring of 2006, three adult female polar bears and one yearling were found dead. Two of these females and the yearling had no fat stores and apparently starved to death, while the third adult female was too heavily scavenged to determine a cause of death. This mortality is suspicious because prime age females have had very high survival rates in the past (Amstrup and Durner 1995, p. 1315). Similarly, the yearling that was found starved was the offspring of another radio-collared prime age female whose collar had failed prior to her yearling being found dead. Annual survival of yearlings, given survival of their mother, was previously estimated to be 0.86 (Amstrup and Durner 1995, p. 1316). The probability, therefore, that this yearling died while its mother was still alive was only approximately 14 percent. Regehr et al. (2006, p. 27) indicate that these anecdotal observations, in combination with changes in survival of young and declines in size and weights reported above suggest mechanisms by which a changing sea ice environment can affect polar bear demographics and population status.

Evidence of declining body condition for polar bears in Western Hudson Bay suggests that there should be evidence of parallel declines in adjacent populations experiencing similar environmental conditions. A recent report of the analysis polar bear condition in Southern

Hudson Bay compares body condition for two periods of time 1984-1986 and 2000-2005 (Obbard et al. 2006). The authors found that the average body condition for all age and reproductive classes combined was significantly poorer for Southern Hudson Bay bears captured from 2000 to 2005 than for bears captured from 1984 to 1986. The mean condition value for all classes combined differed significantly among years ($P < 0.001$) as follows: (1984, 1986) > (1985, 2002) > (all other years).

For individual age and reproductive classes considered separately, average body condition in the period from 2000-2005 was significantly poorer than in the period from 1984-86. The differences between periods were significantly greater for the solitary females, adult females, and subadult classes than for the male class of bears. The change in condition from 1984–86 to 2000–05 was greatest for solitary females, followed by subadults, and adult females accompanied by young. The decline in condition was least, yet still statistically significant, for adult males.

The results indicate a declining trend in condition for all age and reproductive classes of polar bears since the mid-1980s. The results further reveal that the decline has been greatest for pregnant females and subadult bears—trends that will likely have an impact on future reproductive output and subadult survival.

The authors evaluated inter-annual variability in condition in relation to the timing of ice melt and to duration of ice cover in the previous winter. A non-significant negative correlation between condition and date of break-up for the two periods of time existed. Similarly, a non-significant negative correlation between body condition and the duration of ice cover in the previous winter for the periods was determined. Based on the results the authors found that neither variation in the sea ice break-up date nor duration of ice cover in the previous winter as singular factors fully explained the variation in condition among years despite strong evidence of a significant trend towards both later freeze-up and earlier break-up (Gough et al. 2004, Gagnon and Gough 2005), and the significant negative trend in body condition.

The authors believe that the results suggest that other factors or combinations of factors (that likely also may include later freeze-up and earlier break-up) are operating to affect body condition in Southern Hudson Bay polar bears. These factors may include unusual spring rain events that occur during March or April when ringed seals are giving birth to pups in on-ice birthing lairs (Stirling and Smith 2004), depth of snow accumulation and roughness of the ice that vary over time and also affect polar bear hunting success (Stirling and Smith 2004, Ferguson et al. 2005), changes in the abundance and distribution of ringed seals, and reduced pregnancy rates and of reduced pup survival in ringed seals from western Hudson Bay during the 1990s (Ferguson et al. 2005, Stirling 2005).

3. Biological effects on polar bear prey

a. Prey Availability

Major declines in sea-ice habitat will also likely result in a decline in polar bear abundance over time due to reduced availability of prey (Derocher et al. 2004). The effects of declining ice habitat on seals will vary depending on the location, timing and extent of reductions. It is possible that reduced ice cover and increased open water periods with warmer water will enhance primary productivity and promote growth of fishes and invertebrates preyed upon by ringed and bearded seals. Increased food sources for seals may increase seal physical condition and contribute to higher productivity. While these effects may have some initial benefits for polar bears, Derocher et al. (2004) believe that they will be transitory in their timing and with increased area and duration of open water, polar bears will have reduced access to prey during critical periods of the year. Ultimately productivity of ringed seals is likely to diminish and their distribution change over time. The Arctic food web is driven by the complex interactions between ice, light penetration, nutrient supply, and productivity (Tynan and DeMaster 1997, Rosing-Asvid 2006, Grebmeier et al. 2006). Due to the Arctic Ocean's relatively low species diversity, it may be particularly vulnerable to trophic-level alterations caused by global warming (Derocher et al. 2004). Grebmeier et al. (2006 p. 1461) found that a major ecosystem shift is occurring in the Northern Bering Sea which is indicated by decrease in benthic prey populations, which could affect Pacific walrus and bearded seal populations, an increase in pelagic fish, a reduction in sea ice, and an increase in the air and sea water temperatures. Arctic cod (*Boreogadus saida*), one of the primary prey species of ringed seals, is strongly associated with sea ice throughout its range and makes use of the underside of the ice to escape from predators (Gaston et al. 2003). It is therefore likely that a decrease in seasonal ice cover could have adverse effects on Arctic cod (Tynan and DeMaster 1997, Gaston et al. 2003). It is uncertain if other forage fish species will pioneer into open water habitats and provide seals with alternate forage species (Derocher et al. 2004).

Ringed seals are the primary prey of the polar bear in most areas, though bearded seals, walrus, harbor seals (*Phoca vitulina*), harp seals, hooded seals, and beluga whales are sometimes taken and may be locally important to some populations (Stirling and Archibald 1977, Smith 1980, Smith 1985, Iverson et al. 2006). A study of seal prey consumed by polar bears in three major regions of the Canadian arctic: Davis Strait; Western Hudson Bay; and the Beaufort Sea, revealed that diets differed among the regions, and within the region for Davis Strait. In the Beaufort Sea ringed seals comprised 98% of diet. In Western Hudson Bay ringed seals accounted for 80% of the diet in the early 1990s indicating important foraging in ice covered habitat. Ringed seal consumption declined later in the 1990s concurrent with earlier ice breakup, and the proportion of bearded and harbor seals increased, both species are less reliant on ice than ringed seals. Throughout Davis Strait, harp seals comprised 50% of bears' diet, consistent with the increase in harp seal populations in this region. Off southern Labrador near the whelping patch, harp seals comprised 90% of diets and in northern Davis Strait, near a major whelping patch, hooded seals made up the majority of the diet (Iverson et al. 2006, Stirling and Parkinson 2006). Polar bears have been observed using terrestrial food items such as blueberries, snow geese, and reindeer, but researchers do not believe that these alternate foods represent significant sources of energy (Derocher et al. 2004). Further, the inefficiency of polar bear locomotion noted above likely explains why polar bears are not known to hunt musk oxen (*Ovibos moschatus*) or snow geese (*Anser caerulescens*), potential prey species that co-occur with the polar bear in many areas (Lunn and Stirling 1985). The energy needed to catch such species would almost certainly exceed the amount of energy a kill would provide (Stirling 1988).

Polar bear populations are known to fluctuate based on prey availability (Stirling and Lunn 1997). During the winters of 1973-1974 and 1974-1975, ringed and bearded seal numbers in the Beaufort Sea dropped by about 50% and productivity by about 90%, apparently in response to severe ice conditions (Stirling 1980, Stirling 2002). Numbers and productivity of polar bears also declined markedly in response (Stirling 1980, Stirling 2002). A similar reduction in seal productivity, with a subsequent decline in polar bear productivity, occurred in the mid-1980s as well **(**Stirling and Øritsland 1995, Stirling 2002).

Stirling and Øritsland (1995) calculated that a hypothetical polar bear population containing 1,800 bears would need approximately 77,400-80,293 ringed seals per year for all bears to meet their nutritive requirements. Kingsley (1998) estimated that the polar bears in Baffin Bay and associated waters (N= *ca*. 4000) would need to eat 120,000 to 160,000 ringed seals per year to sustain themselves. In the absence of solid data, it has generally been assumed that seal populations occur at high numbers and are relatively stable and that there are enough ringed seals to fulfill the needs of both polar bears and Inuit hunters (Ferguson et al. 2005). However, one study found an unexpectedly low pregnancy rate and proportion of young-of-the-year among ringed seals in an open water sample from Arviat in 1991-1992 (Holst et al. 1999, Ferguson et al. 2005), and a follow up study with data from 1998-2000 also found a lower than expected pregnancy rate and proportion of young-of-the-year. These results indicate that ringed seal recruitment may be in decline, and that ultimately ringed seal populations, and therefore food availability for polar bears, may decline as well (Stirling 2002).

Ice-associated seals, including the ringed seal, may be particularly vulnerable to habitat loss from changes in the extent or concentration of Arctic ice because they depend on pack-ice habitat for pupping, foraging, molting, and resting (Tynan and DeMaster 1997, ACIA 2004, Derocher et al. 2004). The southern edge of ringed seal ranges may also shift north, because ringed seals stay with the ice as it annually advances and retreats (Tynan and DeMaster 1997). Whether ringed seals will continue to move north with retreating ice over the deeper less productive Arctic Basin waters and whether forage fishes that they prey on will also move north is uncertain. Increased amounts of open water may reduce the hunting efficiency of polar bears because seals may become less restrained by their need to maintain breathing holes and haul-out sites and thus become less predictable for foraging bears (Derocher et al. 2004). Bears have only rarely been reported to capture a ringed seal in open water (Furnell and Oolooyuk 1980), so it is unlikely that hunting in ice-free water would compensate for loss of ice access to ringed seals (Derocher et al. 2004). It is unlikely that increased take of other species such as bearded seals, walrus, or harbor seals, even where they are available, could or would compensate for reduced availability of ringed seals (Derocher et al. 2004).

It has been suggested that several species of seals which currently occur at the southern edge of the range of polar bears could expand northward. In the north Pacific this could include the harbor seal, spotted seal (*Phoca largha*) and the ribbon seal (*Phoca fasciata*). In the north Atlantic, harp (*Phoca greenlandica*) and hooded seals (*Crystophora cristata*) could expand northward and come into contact with polar bears particularly if the whelping grounds move to more northern latitudes (Derocher et al. 2004). However harp and hooded seals are also dependent on the sea ice and thus may also be reduced. Born (2005a) reported on the potential effects as follows:

> Early ice break-up in years with "light" ice conditions may also influence other ice-breeding pinniped than ringed seals. Extremely small sized 1981 year-class of harp seals in eastern Canada and high juvenile mortality from starvation and cold stress was likely due to light ice conditions during 1981 (Sergeant 1991) indicating that early ice breakup at the harp seal whelping patches may lead to increased mortality (Johnston et al. 2005). One may speculate if early ice break-up may also negatively influence other ice breeding pinnipeds like the ribbon and spotted seals in the Bering Strait region.
>
> Yearly variation in sea ice cover may have significant effects on harp and hooded seals. In light ice years the quantity of ice that is appropriate for whelping can be greatly

reduced, and female seals may crowd into whelping areas and produce pups in high densities (Johnston et al. 2005). It has been suggested that such crowding may increase the risks of disease transmissions and subsequently the risk of epizootics (Fay 1974) but the effects of crowding at the harp and hooded seal whelping patches are largely unknown (Johnston et al. 2005). Repeated years (1967, 1981, 2001, and 2002) with little or no ice in the Gulf of St. Lawrence resulted in years with almost zero production of harp seal pups, compared to hundreds of thousands in good ice years (ACIA 2004). Hooded seals may shift to heavier ice for whelping. Shifts in the more northerly whelping areas reportedly occur during periods or warmer climate and diminished ice (Burns 2002). In recent years the position of the hooded seal whelping patch near Jan Mayen has changed position likely as an effect of decreased sea ice in East Greenland, and the number of seal there has decreased (Haug, pers. comm.).

Cooper et al. (2006) observed at least nine apparently orphaned Pacific walrus in waters as deep as 3,000 m in July and August 2004 in the Canada Basin of the Arctic Ocean. Given limited visibility from the ship, many additional calves may have been separated in the overall study area. These conditions appear to be related to the transport of unusually warm (7° C) Bering Sea water into this area north of Alaska. Walruses invest considerable maternal resources while caring for calves on seasonally ice-covered continental shelves for periods of up to 2 years or more and only rarely separate from their young. Although these observations suggest that the Pacific walrus population may be ill-adapted to rapid seasonal sea-ice retreat off Arctic continental shelves, the adult females could have been killed during Alaska Native subsistence hunts from the villages of Wainwright and Barrow.

Decreases in Arctic cod abundance have already been recorded and correlated with shrinking ice cover. Gaston et al. (2003) inferred changes in Arctic cod abundance in northern Hudson Bay by analyzing the composition of the diet fed to thick-billed murre chicks (*Uria lomvia*) (Gaston et al. 2003). Between 1980-82 and 1999, the percentage of cod in the diet of thick-billed murre chicks fell from 51.5% to 18.9%, while the percentage of capelin (*Mallotus villosus*) increased from 6.7% to 41% over the same time period. The extent of ice cover, greater than 10% on July

15th of each year, also declined significantly between 1981 and 1999. Gaston et al. (2003:231) concluded that the trends observed related to real changes in fish populations that suggest a switch from an Arctic to a subarctic fish community occurred from 1997 onwards. Given the relative ecology of arctic cod and capelin, the trends identified seem best explained by changes in the oceanography of northern Hudson Bay, perhaps driven by temperature increases over recent decades.

Babaluk et al. (2000) report the first records of sockeye (*Oncorhynchus nerka*) and pink salmon (*Oncorhynchus gorbuscha*) from Banks Island and other records of Pacific salmon in NWT. The authors report capture of eight sexually mature sockeye and one sexually mature pink salmon in the subsistence fishery in the Sachs River estuary at Sachs Harbour, Banks Island, NWT in August 1993. They also report a first record for coho salmon (*Oncorhynchus kisutch*) in Great Bear Lake, NWT. These capture locations are well outside the known distributions for the species. A pink salmon captured in the West Channel, Mackenzie River near Aklavik, NWT, and a chum salmon (*Oncorhynchus keta*) from Cache Creek, NT, also represent new capture locations within the distribution of the species. In sum, these numerous sightings of extra-limital occurrence of a variety of species are indicative of environmental change in the marine systems, likely associated with the warming trend of marine waters. Some of these species could potentially become established and may provide prey for ringed seals and/or polar bears.

b. Seal productivity

Ringed seal pups are born between mid-March and mid-April, nursed for about six weeks, and weaned prior to spring break-up in June (Smith 1987, Ferguson et al. 2005). During the weeks of nursing, ringed seal pups spend about half of their time in lairs excavated in snow covering the top of the sea ice, and about half underwater diving (Smith 1987). During this time period both ringed seal pups and adults are hunted by polar bears (Ferguson et al. 2005). One common hunting method used by polar bears is to locate a seal lair by smell and then crash through the top of the den and seize the surprised seal (Stirling 1988).

Ferguson et al. (2005) demonstrated that decreasing snow depth, possibly influenced by the timing of spring break-up, may have a detrimental effect on ringed seal recruitment in Western Hudson Bay. These researchers examined trends in ringed seal recruitment in Western Hudson Bay relative to snow depth, snowfall, rainfall, temperature in April and May, the North Atlantic Oscillation ("NAO") from the previous winter, and timing of spring break-up. Samples from 639 ringed seals killed by Inuit hunters between 1991-1992 and 1999-2001 were used to determine the age of seals killed and to generate a survivorship curve which represents the number of seals born in any year that survived to be included in the hunt (Ferguson et al. 2005). The relative difference from the expected survivorship was the dependent variable in correlated regression analyses of environmental factors (Ferguson et al. 2005). Snowfall and ringed seal recruitment varied from lower than average in the 1970s, to higher in the 1980s and lower in the 1990s (Ferguson et al. 2005).

The study demonstrated that decreasing snow depth in April and May may be linked to decreased recruitment in ringed seals in Hudson Bay (Ferguson et al. 2005). Reduced snowfall may also result in less snow drift accumulation leeward of pressure ridges, and consequently reduced protection for pups from predators that are afforded easier access (Ferguson et al. 2005). Warming temperatures may also melt snow covered ringed seal birth lairs and contribute to the decreased recruitment (Ferguson et al. 2005). Therefore, pups in lairs with thin snow roofs are more vulnerable to predation than pups in lairs with thick roofs (Ferguson et al. 2005). Ringed seal pup survival can also be affected by hypothermia resulting from exposure if lairs collapse (Ferguson et al. 2005). Continued access to birth lairs for thermoregulation is probably critical to the survival of pups when temperatures fall below 0° C (Stirling and Smith 2004). Ferguson et al. (2005 p. 121) concluded "Earlier spring break-up of sea ice together with snow trends suggest continued low pup survival in Western Hudson Bay."

In a similar study of variation in reproduction and body condition of the ringed seal in Prince Albert Sound, Harwood et al. (2000) found that an early spring break-up in 1998 negatively impacted the growth, condition, and probably the survival of unweaned pups. Early breakup in

1998 was believed to have caused an interruption in lactation in adult females, which in turn negatively affected the condition and growth of pups. The authors indicate that the event occurred when food appeared to be abundant and available for the other age classes of ringed seals (Harwood et al. 2000). Earlier ice break-ups similar to those documented by Harwood et al. (2000) and Ferguson et al. (2005) are predicted to be more frequent in occurrence based on climate change models and as a result a decrease in productivity and abundance of ringed seals is predicted. Similar to earlier break-up or reduced snow cover, increased rain on snow events during the late winter could also negatively impact ringed seal recruitment by damaging or eliminating snow covered pupping lairs, increasing exposure and the risk of hypothermia, and facilitating predation by polar bears and Arctic foxes (*Alopex lagopus*) (Stirling and Smith 2004). In April and May of 1979, researchers evaluated the distribution and density of ringed seal lairs on the Hall Peninsula of southeastern Baffin Island in Nunavut (Stirling and Smith 2004). During this study predation on seals by polar bears was also evaluated from on ice and aerial observations (Stirling and Smith 2004). The role of polar bear predation and environmental factors on ringed seal distribution (Hammill and Smith 1989, Hammill and Smith 1991) and reproduction (Stirling and Lunn 1997) has been documented for other populations as well. Rain fell steadily or sporadically on the study area during April 9-11 (Stirling and Smith 2004). Before the rain event in April, there were two other periods during late March and early April when daily maximum temperatures were at or close to freezing (Stirling and Smith 2004). Outside of these periods weather was normal for this area. The roofs of 40% (6/15) of the haul-out and birth lairs found by the end of March and 50% (15/30) of those located in the first week of April had already melted and collapsed, something not seen before at these latitudes (Stirling and Smith 2004). After the rain event of April, at least 28% of the lairs in one area had collapsed (Stirling and Smith 2004). Following the rain event, many instances of adult seals and pups laying on the bare ice, exposing the pups to hypothermia were noted. Predation of pups by polar bears was observed, and the researchers "suspect that most of the pups in these areas were eventually killed by polar bears (Stirling and Archibald 1997), arctic foxes (Smith 1976), or possibly gulls (Lydersen and Smith 1989). Stirling and Smith (2004) also observed ravens (*Corvus corvax*) feeding on the carcasses of ringed seal pups, but did not know if they killed the pups or were only scavenging (Stirling and Smith 2004).

Stirling and Smith (2004) state that the observations from 1979 have direct relevance to the impact of climate change on polar bears:

> Should early season rain become regular and widespread at some future time, we predict that mortality of ringed seal pups will increase, especially in more southerly parts of their range, and that local populations may be significantly reduced….a significant decline in ringed seal numbers, especially in the production of young, is capable of producing negative effects on the reproduction and survival of polar bears (Stirling and Smith 2004).

Ringed seals, and consequently polar bears, may also be impacted by changes in trophic dynamics. Changes in climate, sea-ice extent, and the timing of sea-ice formation and break-up will have variable affects on the lower trophic levels of the food web upon which polar bears depend (Derocher et al. 2004).

c. Reduced Access to Prey

Reductions in sea ice, which ringed seals use for birth lairs, will alter ringed seal distribution and abundance. Scientists predict that the decreases in adult body condition, natality, and cub survival in the Western Hudson Bay polar bear population observed to date due to earlier break-up dates and a shorter seal-hunting period will continue until female polar bears are in such poor condition that they do not reproduce (Derocher et al. 2004). Using parameters including the amount of polar bear body mass lost during fasts, predicted lengthening of the fasting period and shortening of the feeding period, and the apparent 189 kg body weight needed for females to reproduce, Derocher et al. (2004) calculate that most females in the Western Hudson Bay population may be unable to successfully reproduce somewhere between 2012 and 2014.

Derocher et al. (2004) note that these calculations are simplifications, and that long-term trends may not be readily observable due to shorter-term fluctuations as climate change proceeds, but the authors predict, overall, a continuing gradual decline in population-related parameters that ultimately lead to population losses. Trends toward either earlier break-up or later freeze-up, or both, will likely occur in other areas in addition to Western Hudson Bay where polar bears seasonally use the land, such as Foxe Basin and south-eastern Baffin Island (Derocher et al. 2004). Those populations will likely experience impacts comparable to those already observable in Western Hudson Bay (Stirling et al. 1999). Changes in the timing of sea-ice formation and break-up and the loss of the polar bear's sea-ice habitat will pose increasing risk to polar bears as global warming advances (Derocher et al. 2004), and ultimately all polar bear populations will suffer.

While predicting changes in trophic dynamics from climate change is complex and difficult, the likely impact on Arctic cod is significant for the polar bear. Global warming could increase productivity of some Arctic waters in the short term (Hammil and Smith 1991, Stirling and Smith 2004). As Tynan and DeMaster (1997) observed, "one of the central questions regarding climate change and the effects on Arctic marine mammals is whether a reduction of sea ice will increase productivity in a way that maintains suitable densities of important prey species, such as arctic cod." In northern Hudson Bay it does not appear that arctic cod will maintain former levels of abundance during periods of reduced sea ice habitat. Moreover, if areas of leads, polynyas, and open water shift northward to areas over the less productive waters of the deep polar basin, there may be little increase in productivity since the deep polar basin waters are less productive to begin with (Tynan and DeMaster 1997). This could negatively impact other polar bear prey species. Species such as bearded seals and Pacific walrus feed on benthic prey, and are therefore found on ice cover over the shallow continental shelf areas (Lowry et al. 1980, Sheffield et al. 2001). As sea ice declines these species feeding habitat would become limited to the areas within <100km of the shoreline where these species could haul out (Born et al 2003). Currently Pacific walrus give birth on the sea ice in the Bering Sea in the spring. If the sea ice in the Bering Sea disappears, Pacific walrus would most likely calve on the remaining sea ice in the Chukchi Sea or on land. Overall the reduction in sea ice is likely to result in a net reduction in abundance of ringed seals, bearded seals, and Pacific walrus (ACIA 2004).

Ringed seal young-of-the-year provide the majority of the polar bear diet, therefore, fluctuations in the productivity of ringed seal pups will likely be reflected immediately on polar bear reproduction and cub survival (Stirling and Lunn 1997). Stirling and Lunn (1997 p. 176) report that "the most critical factor affecting reproductive success, subsequent condition and probably survival of polar bears is the availability of ringed seal pups from about mid-April through to break-up sometime in July," and that this is especially so for females with cubs of the year. Moreover, high levels of polar bear predation sustained by ringed seal populations are only possible because a large proportion of seals taken are young of the year (Stirling and Lunn 1997). Predation by bears has modified the behaviors of northern hemisphere ice seals (Stirling 1977), has significantly affected some seal populations (Hammill and Smith 1991), and also may have modified the distribution of seals (Amstrup 2000).

Changes in prey availability may have especially large impacts on immature bears. Polar bears feed preferentially on blubber and adult bears often leave much of the meat (protein) behind. Younger bears, which are not believed to be as highly skilled hunters and not as efficient at taking seals, are known to utilize these kills to supplement their diet (Derocher et al. 2004). As prey availability decreases due to global warming, younger bears may be disproportionately impacted if there are fewer kills or greater consumption of kills resulting in less excess prey to scavenge (Derocher et al. 2004). Altered prey distribution would also likely lead to increased competition for prey between dominant and subordinate bears, resulting in subordinate or sub-adult bears reduced access to prey (Derocher et al. 2004). Polar bear populations will decline in response to declines in ringed seal abundance and availability.

4. Projected population specific effects and timing sequence

The populations that will be the most affected will be the Arctic Basin populations (CS, BA, SB and possibly the KA and LA populations) and those populations in which bears are required to fast for many months on land, because most or all of the sea ice melts during the summer (WH, SH, FB, DS, and BB). The Arctic Basin polar bear populations that occur in areas without significant land mass constraints or other open basin populations will be the most affected by large scale dramatic fluctuations in seasonal ice movements. The increased summer ice retreat into the polar basin, over deeper and less productive waters, will impact polar bears by altering distribution, increasing individual movements, reducing access to prey, increasing energetic demands, and correspondingly result in diminished physical body condition of bears. Prey species such as ringed seals will likely remain distributed in shallower more productive southerly areas characterized by vast expanses of open water. Secondary effects of diminished condition of polar bears, such as reduced reproductive rates, decreases in survival rates for cubs and possibly reduced survival rates for older age classes, have been demonstrated in the Western Hudson Bay (Stirling et al. 1999, Regehr et al., in prep.). For those populations where the sea ice occurs seasonally, the effects of an increased length of the open water season will be detected or observed earlier rather than later, similar to those that summer in the polar basin. The populations that will be affected last will be those associated with island archipelagos such as the Canadian Arctic Islands (Norwegian Bay, Lancaster Sound, M'Clintock Channel, Viscount-Melville, Kane Basin, and Gulf of Bothia).

Future Threats to Polar Bears from Global Climate Change

Table 4: Likely Impacts to the Polar Bear from Global Climate Change

Source: Adapted from Derocher et al. (2004).

Characteristic	Time Frame[1]	Projected Change
Body condition	Short	Decline, Increased variation
Movement patterns	Short	Alteration of existing patterns
Cub survival	Short	Decline, Increased variation
Reproductive rates	Short	Variable, Increased variation
Bear-human interactions	Variable	Increase
Den areas	Medium	Change in areas and substrates
Growth rates	Medium	Variable
Prey composition	Medium	Change in species, utilization, age of prey
Population boundaries	Medium	Mixing of adjacent populations
Population size	Medium	Variable

Intraspecific aggression	Variable	Increased
Cannibalism	Variable	Possible increase
Adult survival	Long	Decline, Increased variation

[1] Short = <10 years, Medium = 10-20 years, Long = >20 years. Time frame of impact will vary between populations and is dependent upon rate of change in a given population.

5. Conclusion

Worldwide, habitat loss is the primary cause of species extinction (Primack 2001). For polar bears, documented changes to habitat include seasonal retraction of sea ice in the fall, thinning and fragmentation of sea ice, and earlier spring breakup. While not all changes occur evenly throughout the Arctic, many changes are widespread. As the PBSG, the scientific advisory body to IUCN for polar bear, summarizes on their website, “[t]here is little doubt that polar bears and other ice-inhabiting marine mammals in the Arctic, are being, or will be, negatively affected by the effects of climate change via changes to their habitats” (Aars et al. 2006).

According to the ACIA, “the reduction in sea ice is very likely to have devastating consequences for polar bears, ice-dependent seals, and local people for whom these animals are a primary food source” (ACIA 2005). The ACIA concludes that “polar bears are unlikely to survive as a species if there is an almost complete loss of summer sea-ice cover, which is projected to occur before the end of this century by some climate models. The loss of polar bears is likely to have significant and rapid consequences for the ecosystems that they currently occupy.” (ACIA 2005).

Overall, polar bear scientists conclude that the “future persistence of polar bears is tenuous” (Derocher et al. 2004), reinforcing their earlier warnings that “ultimately, if sea ice disappeared altogether, polar bears would become extinct” (Stirling and Derocher 1993). The ACIA has also concluded that “polar bears are unlikely to survive as a species if there is an almost complete loss of summer sea-ice cover, which is projected to occur before the end of this century by some climate models.” (ACIA 2004). However, this opinion is not universal as other polar bear biologists believe that it is likely, even with the total loss of summer sea ice, that a small number of polar bears would survive semi-indefinitely provided there is still some ice cover during the winter and marine mammals continued to be available for capture or scavenging. Although this situation would be difficult for the bears they believe that the bears are unlikely to go extinct. As a species, polar bears have survived at least two warming periods, the Eem Interglacial period (140,000 - 115, 000 years BP), and the Holocene "climate optimum" (ca 8000 – 4000BP) (Dansgaard et al. 1993, Dahl-Jensen et al. 1998). Results from two ice-cores drilled in central Greenland revealed that the climate was much more variable in the past and some of the historical shifts between the warm and cold periods were relatively rapid suggesting that the recent relative climate stability seen during the Holocene may be an exception (Dansgaard et al. 1993). The impacts of these global warming periods on polar bears and the Arctic sea-ice habitat are unknown.

Observations of changes related to climate change are mounting on many fronts. As one recent report noted "If current trends continue, polar bears and other species that require a stable ice platform for survival could become extinct by the end of the century" (Rosentrater 2005).
A recent study of the Bering Sea, one of the most productive marine ecosystems on the planet, concluded that "[a] change from arctic to subarctic conditions is underway in the northern Bering Sea" (Grebmeier et al. 2006). This is being caused by warmer air and water temperatures, and less sea ice. Even bottom water temperatures are demonstrably increasing. The impacts include the decline of the prey base of benthic (bottom) feeding walrus, endangered sea ducks (i.e. spectacled eiders – *Somateria fischeri*), and gray whales (*Eschrichtius robustus*) (Grebmeier et al. 2006). Some pelagic (open sea) species like pollock (*Theragra chalcogramma*), on the other hand, are increasing their range (Grebmeier et al. 2006). "These observations support a continued trend toward more subarctic ecosystem conditions in the northern Bering Sea, which may have profound impacts on Arctic marine mammal and diving seabird populations as well as commercial and subsistence fisheries" (Grebmeier et al. 2006).

B. Overutilization for commercial, recreational, scientific, or educational purposes

The following section presents information relative to the harvest of polar bears. In the initial evaluation the use of polar bears for commercial, recreational, scientific, and education purposes was considered. The relative low level and highly regulated non-lethal use for scientific purposes was discounted as a threat to populations. Similarly, the regulated low level of use for educational purpose through placement of cubs or orphaned animals into zoos or public display facilities or through public viewing was also discounted as a serious threat to populations. Regarding sport harvested polar bears in Canada, which has both a commercial and recreational value, we have not distinguished between harvest uses for sport or subsistence purposes and we have incorporated these activities into the harvest section below.

1. Overview of Harvest

History of Polar Bear Hunting and Harvest Management

Other forms of removal including take associated with accidental mortality during scientific investigations, placement of orphaned cubs into public display facilities, defense of life, industrial takes, and illegal take have been considered within this section of the assessment. The levels of take from sources other than harvest have been determined to be insignificant and having no effect on the population and not warranting a detailed analysis herein. These sources of mortality are incorporated into consideration of harvest management regimes.

Polar bears have historically been and continue to be an important renewable resource for coastal communities throughout the Arctic. Polar bears and polar bear hunting were an important part of indigenous peoples' myths and legends and polar bear hunting is considered a source of pride, prestige, and accomplishment. Polar bears provide a source of meat and raw materials for handicrafts, including functional clothing such as mittens, boots (mukluks), parka ruffs, and pants.

Prior to the 1950s most hunting was done by indigenous people for subsistence purposes. However, population declines due to sport hunting became an increasing international concern during the 1950s and 1960s. As a result, in 1968, biologists from the 5 nations with polar bears in their respective jurisdictions met and formed the Polar Bear Specialist Group (PBSG) under the International Union for Conservation of Nature and Natural Resources (IUCN). The PBSG was largely responsible for the development and ratification of the *1973 International Agreement on the Conservation of Polar Bears (1973 Polar Bear Agreement),* which calls for cooperative international management of polar bear populations based on sound conservation practices. It prohibits polar bear hunting except by local people using traditional methods, calls for protection of females and denning bears, and bans use of aircraft and large motorized vessels to hunt polar bears (Prestrud and Stirling 1994). The *1973 Polar Bear Agreement* itself is not self-implementing and each signatory nation has its own national legislation to implement the *1973 Polar Bear Agreement's* terms, including individual harvest management practices. The PBSG meets every 3-5 years to review all aspects of polar bears science and management, including harvest management.

Principles of Harvest Management

Polar bears are a K-selected species: they are long-lived, take a relatively long time to mature, and have low reproductive rates and small litter sizes (DeMaster and Stirling 1981). Although this is compensated for with high adult survival rates, polar bear populations can be easily depleted through harvest (Taylor et al. 1987). To effectively manage polar bear populations using harvest management, scientists must know certain characteristics of the population, such as population size, and birth (recruitment), survival, and mortality rates. Generally, harvest management is based on the principle that, if recruitment and survival rates exceed mortality rates, the population will grow or remain stable.

Mortality can be separated into deaths from natural and unnatural (human) causes. Unnatural causes include accidental kills such as research mortalities or ingestion/exposure to toxins, or intentional kills such as for sport hunting, subsistence hunting, or defense of life. Hunting can be managed through establishment of limits (quotas) on the number of animals killed per year in relation to population sustainability.

Setting appropriate harvest quotas is dependent on accurate population estimates and age-specific survival and reproduction rates. With good population data, the total allowable harvest (TAH) can be used to adjust for population growth or decline. For example, if polar bear populations decline, a reduction in harvest quotas could be used to attempt to mitigate declines. Unfortunately, the cost and logistical challenges of conducting these studies has made obtaining reliable data difficult or impossible for many populations.

The MMPA requires the Service to calculate the allowable level of human-caused mortality, or potential biological removal (PBR) level, for polar bear populations (also referred to as "stocks") in the U.S. by using a minimum population size estimate (N min) multiplied by ½ of the maximum net productivity or rate (R max) of the population. The PBR is an estimate of the number of animals that can be taken without causing the population to decline below its optimum sustainable population (OSP), or that will allow a population already below OSP to increase to that level. If the population is known to be reduced or declining a recovery factor (Fr), can be used to reduce PBR.

Nunavut uses flexible harvest quotas, the RISKMAN computer model, and MOUs with the local Hunting and Trapping Organizations and the wildlife officers for its harvest management. This management is not used by the NWT or any of the provinces. In the past, a key argument for sport hunting was that, because not all sport hunters were successful and unused tags could not be reused by local hunters, sport hunting actually reduced the total harvest. Although this is still the practice in the NWT, the policy was reversed in Nunavut so that all the unused tags go back to local Hunters and Trappers Organization for re-issue.

The TAH is determined using the "RISKMAN" computer model that incorporates population data such as survival rates, age of first reproduction, age-specific litter production rates for females available to have cubs, litter size, sex ratio of cubs, sex, age, and family status distribution of harvest, and population size (Taylor et al. 2000, Taylor et al. 2001a). The model also incorporates uncertainty due to sampling error and environmental variation. Although modeling indicated that a 2:1 (male/female) sex ratio in the harvest is sustainable, the adult sex ratio is usually 1:1. As a consequence of sex-selective harvesting, the sex ratio in some populations (e.g. Western Hudson Bay) is now permanently skewed towards females. This change in the sex ratio is due in part from the focus of sport hunters on larger males. The significance of the skewed sex ratios or sex-selective harvesting over the longer term is unknown.

As a result of the unknown long-term effects of sex-selective harvesting and the rapidly changing sea ice environments in response to climatic warming, the PBSG passed a resolution in support of the precautionary principle with respect to managing polar bear harvests.

Another approach (Taylor et al. 1987) calculates sustainable harvest based on a population size estimate (N), estimated rates of birth and death, and harvest sex ratios where:

$$\text{Sustainable harvest} = \frac{N \times 0.015}{\text{Proportion of harvest that was female}}$$

Both the RISKMAN and Taylor et al.(1987) approach project current life history demographic parameters into the future and ascribe a sustainable harvest level based on population parameters previously documented through capture research. The underlying assumption is that the populations will remain stable or increase during intervening years. Since there generally is a lengthy period between population inventory cycles, this approach has limitations for populations experiencing changes in survival or recruitment.

2. Harvest Management by Nation

Canada

Canada manages (or shares management responsibility for) 13 of the world's 19 polar bear populations. Wildlife management is the responsibility of the provincial and territorial governments. The federal government (Canadian Wildlife Service) has an ongoing research program and is involved in management of wildlife populations shared with other jurisdictions, especially ones with other nations. Canada has formed the Federal Provincial Technical and Administrative Committees for Polar Bear Research and Management (PBTC and PBAC, respectively) to ensure coordinated management. The committees include provincial, territorial, and federal representatives who meet annually to review research and management activities.

Human-caused mortality such as hunting, defense of life, and incidental kills are all included in TAH. Hunting is allowed by Inuit people of communities in Nunavut, NWT, Manitoba, Labrador, Newfoundland, and Quebec. In Ontario the Cree as well as the Inuit can harvest polar bears. In Nunavut and NWT, each community obtains an annual harvest quota which is based on the best available scientific information and monitored through distribution of harvest tags to local hunter groups, who work with scientists to help set quotas. Some communities may hold tags for several separate polar bear populations. Native hunters may use their harvest tags to guide sport hunts from approved populations and sport hunts must occur using traditional methods, e.g. dog teams. Local Hunter and Trapper Organizations (HTO) determine how many tags shall be allocated to sport hunts, and monitor, regulate, and enforce hunting regulations. A flexible quota system is used in all but the DS populations hunted by Nunavut. Quebec and Ontario do not set quotas but do monitor and report harvest.

In April 1999, the Nunavut Territory, formerly part of the NWT, officially joined the Federation of Canada. Nunavut now has primary management responsibility for 12 of the 13 Canadian polar bear populations and has committed to conducting 15-year population inventory cycles for each population. Their harvest approach consists of two phases: 1) conservative harvest rate, which begins after a scientific population inventory is completed, and continues for the next 7 years. Harvest is limited to “the number of bears that can be taken per year with not more than 10% risk of a population decline that would require more than 5 years of harvest moratorium to recover to the current numbers”. This is thought to allow for slight population growth; and 2) guided harvest rate, which means “the number of bears that can be taken without reducing the population below the target number, which takes into account that scientific data is becoming increasingly dated and allows for Inuit ecological knowledge (IQ) to increase or decrease the harvest rate. RISKMAN modeling is used to identify sustainable harvest levels. Harvest is based on the assumption that providing protection to reproductive females by setting a sex-selected harvest of 2:1 males: females increase the potentially allowable harvest by 50% (Testa 1997, Taylor et al. 2001a). If the quota for female polar bears is inadvertently exceeded, it results in an automatic reduction in next year’s quota, so the average take of females over a two year period cannot exceed the sustainable rate (Testa 1997, Taylor et al. 2001a).

The Canadian system has resulted in tight controls on the size of harvest and high quality harvest reporting. It allows reduction of quotas in response to population declines resulting from over-hunting (PBSG 1995). In 2004, the existing polar bear harvest practices became more controversial when Nunavut identified quota increases for 8 populations, 5 of which are shared with other jurisdictions (Lunn et al. 2005, Aars et al. 2006). Quota increases were largely based on IQ and the perception that some populations are increasing from historic levels; it was also done without input from jurisdictions with shared management responsibility. This action resulted in an overall increase from the 2003/2004 quota of 398 bears to 507 bears in 2004/2005 (Lunn et al. 2005, Aars et al. 2006). Concern has been expressed by PBSG and PBTC members whether raising harvest quotas based on IQ constitutes a sound conservation practice based on the best scientific data, as called for in the *1973 Polar Bear Agreement* (Wiig 2005, Aars et al. 2006). In Western Hudson Bay, the scientific information was used and the quotas were not reduced which would seem to directly contradict guidelines set forth by the *1973 Polar Bear Agreement*.

The Service, in its overall evaluation of the Canadian management program relative to approving specific populations for importation of polar bear trophies by U.S. hunters, found three key characteristics of the calculation of sustainable harvest from the population estimates. These are: (a) assumption of no density effects; (b) emphasis on conservation of female bears through hunting at a ratio of 2 males to 1 female; and (c) use of pooled best estimates for vital rates (e.g. rates of birth and death) for all Canadian polar bear populations, with the exception of Viscount Melville Sound (USFWS 1997). In his review and evaluation of the procedures used to estimate sustainable harvests, Testa (1997) tested the polar bear parameters provided by Taylor et al. (1987) with a general population model. He concluded that a 3 % harvest of the female segment of the polar bear population is sustainable and probably conservative, and that the assumptions made for calculation of the sustainable harvest are reasonable. Additionally, he noted that these low rates of harvest, even if somewhat greater than 3 %, are unlikely to result in irreversible reductions of bear numbers on the time scale of Canada's research and management actions. Harvests of 4 to 6 % of the original population would take from 9 to 23 years to reduce the female population by 30 %. In this context overharvest is possible, but reversible in the same or shorter time span by regulating or eliminating quotas, particularly if density dependent effects come into play (Testa 1997, USFWS 1999). It should be noted that reliance of density dependent effects for management of polar bears may not be warranted based on previous research with grizzly bears (Derocher and Taylor 1994, Wielgus and Bunnell 2000). Assuming the Maximum Sustainable Yield (MSY) is close to the carrying capacity, Taylor (1994) recommended that managers assume that there will be no increases in reproduction or decreases in the rates of natural mortality as a result of a reduction in population numbers, at least until the density dependent mechanisms for population regulation in bears have been documented.

Regarding the harvest of polar bears, the PBSG recently expressed concerns for the application of IQ by the Government of Nunavut in determining harvest rates in the absence of supportive scientific data. The PBSG advocated that a precautionary approach be instituted when setting future harvest levels in a warming Arctic. The group noted that during recent decades the area of the sea ice in the Arctic has declined significantly, and that ice break-up in many areas is occurring earlier and freeze-up later; these patterns are predicted to continue to effect survival and abundance of polar bears in Western Hudson Bay. The group recognized that both local hunters and scientists have observed an increased occurrence of polar bears near settlements and outposts and on near-shore sea ice in recent years, but that this may not reflect an increased population size, and that some quotas had been increased based on local and traditional knowledge or, in the case of Greenland, based on increased nearshore availability. The group was concerned that the combined effect of habitat loss and increased harvest could threaten populations and recommended that harvest levels be increased only when supported by scientific information. The group noted the recent analysis (Aars et al. 2005) indicating population declines and recommended that management action be taken (reduced quotas) without delay.

Sport hunting is allowable by communities in Canada (Nunavut and NWT) and Greenland and as part of the TAH. Because sport hunters tend to seek out large adult "trophy" bears, sport hunting tends to decrease the proportion of the harvest. The majority of sport hunters in Canada are American citizens, and in 1994 a provision was made in the MMPA to allow these hunters to import their trophies into the U.S. if the bears had been taken in a legal manner from approved populations (see "United States" section). The propotion of the TAH comprised of sport hunting has increased dramatically from around 1% to 15% since the 1970s (Freeman and Wenzel 2006). Import of sport-hunted polar bears into the U.S. is currently allowed from the Southern Beaufort Sea, Northern Beaufort Sea, Viscount Melville Sound, Lancaster Sound, Norwegian Bay and Western Hudson Bay populations. Gulf of Boothia and Western Hudson Bay are currently being reviewed for status change (PBTC 2006).

Greenland

Greenland was governed by Denmark until attaining Home Rule in May 1979. Greenland's Home Rule Government now manages harvest through a system introduced in 1993 that allows only full-time hunters living a subsistence lifestyle to hunt polar bears. Licenses are issued annually for a small fee, contingent upon reporting of harvest during the prior 12 months. Until 2006, no quotas were in place but harvest statistics were collected through Piniarneq, a local reporting program. In January 2006, a new harvest monitoring and quota system was implemented. Annual quotas are determined in consideration of international agreements, biological advice, user knowledge, and consultation with the Hunting Council. Part of the quota may be used for sport hunting and quotas may be divided into smaller quotas for certain areas. Quotas are distributed among local authorities who administer permit issuance and distribution and establish controls to ensure that the allocated quota is not exceeded. Hunting is allowed only between 1 September and 30 June, except in two areas where hunting is allowed between 1 October and 31 July.

Greenland harvests bears from the Kane Basin, BB, Davis Strait, and Eastern Greenland populations (Born and Sonne 2005). A current concern is that the total harvest of polar bears in Greenland increased significantly during 1993-2003, due to an increase in the catch from the BB population (Born and Sonne 2005), which is shared with Canada.

Norway

Norway and Russia share jurisdiction over the BS population of polar bears. Management in Norway is the responsibility of the Ministry of the Environment. All hunting has been banned since 1973, in response to the *1973 Polar Bear Agreement* that calls for hunting by Natives only. Because no Native people live in Norway, no indigenous hunting is allowed. Bears may only be killed in self-defense, protection of property, and "mercy" kills.

A rapid increase in tourism in Svalbard has led to an increase in the numbers of polar bears killed in defense of life and property; 9 bears were killed in Svalbard in 1997-2000 (PBSG 2002). The actual annual kill is, however, relatively low.

Russia

Russia is responsible for management of polar bears occurring in the BA, CS, KS, and LS populations through the Ministry of Natural Resources. Management of the BA and KS populations is shared with Norway, and management agreements for them have been in place since 1988 (PBSG 2002).

Polar bear hunting in Russia has been banned since 1956; some animals are killed in defense of life, and a few cubs are taken annually for zoos. Illegal harvest is occurring in the Chukchi Sea region with limited ability for monitoring or enforcement (PBSG 1995), and there is significant interest in re-opening a hunt by Russian indigenous peoples. Over-harvest of the CS population resulting from illegal hunting in Russia, combined with legal subsistence harvest in Alaska, is a conservation concern.

In 2000, The *Agreement on the Conservation and Management of the Alaska-Chukotka Polar Bear Population* (*Bilateral Agreement)* was signed in partnership with the U.S. It establishes a conservation program for the CS population of polar bears that would allow for hunting by Native people under a quota system, along with harvest monitoring and enforcement. The Chukotka Union of Marine Mammal Hunters and the Alaska Nanuuq Commission represent indigenous hunters in Russia and the U.S., and they are developing a Native-to-Native agreement to help implement the terms of the *Bilateral Agreement*. On December 8, 2006, the U.S. Congress passed legislation to implement the *Bilateral Agreement* and the Service anticpates working with our Russian partners towards full implentation of the provisions of the *Bilateral Agreement.*

The PBSG (Aars et al. 2006) recognized the immediate need to coordinate and regulate harvest of the shared CS population of polar bears. The lack of a valid population estimate and concern for unsustainable levels of harvest, as well as the need to coordinate and conduct research, led the PBSG to recommend that the U.S. and Russia immediately enact and enforce the terms of the *Bilateral Agreement*.

United States

Prior to the 1950s the vast majority of polar bear hunting was done by Alaska Natives for subsistence purposes. Economically, polar bear hunting and the commercial sale of skins became increasingly important to Alaskan Natives when whaling began in the 1850s. Trophy hunting using aircraft began in the late 1940s. In the 1960s State of Alaska hunting regulations became more restrictive and in 1972, aircraft-assisted hunting was stopped altogether. Between 1954 and 1972, an average of 222 polar bears was harvested per year, resulting in a decline in polar bear populations in Alaska (Amstrup et al. 1986).

In 1972, the MMPA was passed which ended all polar bear hunting, except by coastal dwelling Alaska Natives for subsistence and handicraft purposes. The MMPA also prohibits the commercial sale of any marine mammal parts except when they have been significantly altered into handicrafts by Alaska Natives. No sport hunting is allowed.

In the U.S. polar bears occur only in Alaska and are delineated as the CS and SB polar bear populations (Paetkau et al. 1999, Amstrup et al 2000, Amstrup et al. 2005, Cronin et al. 2006). The Service is responsible for polar bear management and implementation of the MMPA. Under the MMPA, non-wasteful subsistence harvest by Alaska Natives cannot be restricted unless a population is designated as depleted (it is below its OSP level). The Service is engaged in cooperative management of polar bears with the Alaska Nanuuq Commission, a non-profit organization that represents interests of Alaska Native polar bear users.

For the SB population, hunting is regulated voluntarily through an agreement between the Inuvialuit of Canada and the Inupiat of Alaska. The *North Slope Borough/Inuvialuit Game Council Agreement of 1988* established a Joint Commission and Technical Advisory Committee to oversee polar bear management of the SB population, and calls for management based on sustainable yield. It also calls for protection of females with cubs and denning bears, prohibits hunting using aircraft or large motorized vessels, and establishes (annually reviewed) harvest quotas and hunting seasons. Since development of this agreement, the harvest has generally remained below MSY (Brower et al. 2002). A similar agreement is being worked on for the CS population (the *Bilateral Agreement*) shared with Russia, which will include implementation of a quota system.

The MMPA was amended in 1994 to provide for the import of sport-hunted polar bear trophies legally taken by the importer from Canada. Prior to issuing a permit for import of such trophies, the Service must make specific determinations regarding the status and management of polar bears population in Canada. In 1997, the SB, NB, MC, VM, and WH populations approved for import of polar bears trophies. In 1999, LS and NW were added; in 2001 MC was removed from the list in light of new information indicating that the population was severely depleted. At present (2006), the Service is considering removing WH from the list.

3. Harvest by Population

For harvest management purposes, the world's polar bears are divided into 19 populations, or stocks, based primarily on geographic core areas of use. Their status is presented in Table 1. Additional harvest information for each population is described below and included in Table 1.

a. East Greenland

The current size of the EG population is unknown; a population estimate of 2,000 polar bears has been proposed (Lunn et al. 2000 in PBSG 2005 Greenland Research Report p.2).

The population is hunted by residents of eastern and southwestern Greenland. From 1979-1998, the annual harvest averaged 77 bears (PBSG 2002 p.21). During 1999-2003 harvests averaged 70 bears per year (Born and Sonne 2005 Greenland Research Report to PBSG, p.7). No significant trend in the annual harvest was noted in 1993-2003 (Born and Sonne 2005, Greenland Research Report to PBSG, p.7).

b. Barents Sea (BA)

The current size of the BA population is estimated at 3,000 animals based on a 2004 aerial survey (Aars et al. 2005, Norway Management and Research Report to PBSG, p. 6). Historically the population was believed to be depleted by over-harvest until a total ban on hunting in 1956 in Russia and in 1973 in Norway allowed the population to increase (Prestrud and Stirling 1994, Derocher 2005). The population is not currently harvested except for some polar bears taken in defense of life and property (Gjertz and Persen 1987, Gjertz et al. 1993, 1995 in PBSG 2001 p. 23). Since 2001 through April 2005 a total of 15 bears were killed in defense and one illegal kill (Aars et al. 2006).

c. Kara Sea (KS)

The size of the KS is unknown. Harvest is limited to defense of life kills and some illegal harvest that is not thought to be having a population-level effect (PBSG 2002 p.24).

d. Laptev Sea (LA)

The size of the LA population is unknown but has been estimated to be 800-1,200 polar bears (PBSG 2001 p.22). Known harvest is limited to defense-of-life kills and some illegal harvest not thought to be having a population-level effect (PBSG 2001 p.24).

e. Chukchi Sea

The current size of the CS population is unkown; the best available information indicates it may be comprised of approximately 2,000 animals (PBSG 2001 p.22). The Chukchi population is hunted by Yupik and Inupiat Natives in Alaska as hunting is illegal in Russia. No harvest quota has been set in Alaska and an unquantified level of illegal harvest is occurring in Russia although a minimum of 100 bears are estimated to be harvested and in some years the estimates have exceeded 200 animals. Between the 1980s and 1990s the Alaska harvest declined by 50% (Schliebe et al.1998 in PBSG 2001 p.24). In 2004/2005, 32 bears were harvested in Alaska from this sub-population (Schliebe et al. 2006, Alaska PBTC report, p. 2.). The combined Alaska-Chukotka harvest is believed to exceed sustainable levels.

f. Southern Beaufort Sea (SB)

Amstrup et al. (1986) estimated the SB population size to be 1,800 animals in 1986. Recent analysis (Amstrup et al. in prep.) of a 5-year capture and recapture study completed in 2006 indicates that this population has declined to about 1,500. Although it appears that harvest levels were sustainable in the past, primarily because hunters harvested fewer animals than the quota allowed, adjustments in the harvest level may be necessary in the future.

The harvest quota for the SB is 80 animals (40 for Alaska and 40 for NWT) and this population is harvested by Native subsistence hunters from Alaska and NWT. In 2004/2005, the harvest in Alaska and NWT was 27 bears (Schliebe et al. 2006, NSB-IGC Report) and 19 bears respectively (Branigan and Stirling 2006, NSB-IGC Report p. 2). A joint users-group agreement sets harvest quotas and includes provisions to protect bears in dens and females with cubs. Hunters and scientists meet annually to review harvest levels.

g. Northern Beaufort Sea (NB)

The size of the NB population was estimate as 1,200 animals in 1986 and the harvest was thought to be occurring at a sustainable level (PBSG 2001 p. 25). In 2003 mark-recapture work was begun to reassess population size and this work is ongoing.

The NB sub-population is harvested by hunters from Nunavut and NWT. The harvest quota is 6 bears for Nunavut and 65 from NWT (Dyck et al. 2005, Nunavut Report to PBTC p.14, NWT Report to PBTC, 2005 p.3). The 2004-2005 harvest was four bears from Nunavut and 32 bears from NWT (PBTC 2005).

h. Viscount Melville Sound (VM)

The current size of the VM population was estimated to be 161 animals in 1992 (Aars et al. 2006).

This population is harvested by hunters from NWT and Nunavut. In February 2004, the NWT portion of the VM quota was increased to 4 bears annually (PBSG 2005 Canadian Management Report P. 2). An increase of 1 bear (from 2 to 3) was implemented for Nunavut in the 2004/2005 season (Dyck et al. 2005, Nunavut Report to PBTC p.14). The 2004-2005 harvest was 3 bears by NWT and 2 bears by Nunavut hunters (PBTC 2005). In 2004, the Wildlife Management Advisory Council (NWT) and the Inuvialuit Game Council (Nunavut) initiated discussions to develop an inter-jurisdictional user agreement between NWT and Nunavut hunters (PBSG 2005 Canadian Management Report, p. 2) because both groups hunt from the NB and VM polar bear sub-populations.

i. Norwegian Bay (NW)

The size of the NW population was estimated at 190 animals in 1998 (M. Taylor unpubl. data in PBSG 2002 p.26, Aars et al. 2006). This population's low numbers and low reproductive rate make it susceptible to any increase in harvest or mortality. This population is harvested by hunters from Nunavut,with the harvest quota set at four animals. The 2004-2005 harvest was four bears (PBTC 2005).

j. Lancaster Sound (LS)

The size of the LS population was estimated at 1,700 bears in 2002 (PBSG 2002 p. 26).
The population is harvested by Nunavut hunters. A quota increase of 7 bears (from 78 to 85) for Nunavut was implemented in 2004/2005 (Dyck et al. 2005, Nunavut Report to PBTC p.14). The 2004-2005 harvest was 87 bears (PBTC 2005).

k. M'Clintock Channel (MC)

The size of the MC population is estimated at 284 bears (PBSG 2005 Canadian Research Report p.2). The population is harvested by Nunavut hunters. The harvest quota is set at 3 bears (PBSG 2005 Canadian Research Report p.2). Recent modeling indicates that this sub-population may have been historically harvested at a level resulting in gradual depletion over a long time (> 30 years) (PBSG 2005 Canadian Research Report p.2). The population is estimated to have declined by approximately 2/3 of its original size. Local hunters suggest that declining environmental conditions or disturbance may also be factors causing a reduction in population numbers. A long period of reduced harvest is needed if the MC sub-population is to recover to its former numbers.

l. Gulf of Boothia (GB)

The population was estimated at 1,523 bears, based on a 1998-2000 mark/recapture study (PBSG 2005 Canadian Research Report p.2). The population is harvested by Nunavut hunters. A quota increase of 33 bears (from 41 to 74) for Nunavut was implemented in 2004/2005 (Dyck et al. 2005, Nunavut Report to PBTC p.14).

m. Foxe Basin (FB)

The FB population was estimated to consist of approximately 2,300 animals in 1996 (M. Taylor, unpublished data in PBSG 2002 p.27). The method used to estimate the population size utilized tetracycline marking (Taylor and Lee 1994) and recovery of marked animals through the harvest. No published report of the results is available. Polar bears are harvested by Nunavut, Quebec, and Ontario hunters. Nunavut hunters take the majority of bears from this sub-population. A quota increase of 9 bears (from 97 to 106) for Nunavut was implemented in 2004/2005 (Dyck et al. 2005, Nunavut Report to PBTC p.14). No harvest quotas exist for Quebec and Ontario hunters. Neither Quebec nor Ontario reported harvests from this population in 2003-2005 (PBTC 2004, 2005). In the past, the Service was concerned that no restrictions on hunting cubs, females with cubs, and denning bears were in place in Quebec and Ontario, however, all parties are monitoring their respective harvests and sharing data (Testa 1997 p. 6). A formal harvest agreement among jurisdictions is needed.

n. Western Hudson Bay (WH)

The size of the WH population was estimated at 977 animals in 2003 with a declining trend (Regehr et al. in prep., and unpublished data in PBSG 2005 Canadian Research Report p.3).

A quota increase of 9 bears (from 47 to 56) was implemented for Nunavut in 2004/2005 season (Dyck et al. 2005, Nunavut Report to PBTC p.14), based on Native residents' reports that more polar bears are being observed along the coast in recent years, which they interpret as evidence that the sub-population is increasing (PBSG 2005 Canadian Research Report p.3). This finding was discussed by PBSG members in the 2005 IUCN PBSG meeting, who questioned whether this population continues to be managed on the best available scientific data, as called for in the *1973 Agreement*.

This population is harvested by Nunavut hunters. Manitoba has a quota of 8 that is used for the Polar Bear Control Program if bears become a threat to public safety. The 2004/2005 harvest was 41 bears by Nunavut and 2 bears by Manitoba hunters (PBTC 2005).

o. Southern Hudson Bay (SH)

The estimated size of the SH population size in 1988 was 1,000 animals (PBSG 2001 p. 27). The sub-population is harvested by hunters from Nunavut, Quebec, and Ontario (Manitoba shares management responsibility but does not hunt this sub-population). The 2004-2005 harvest was 25 bears by Nunavut and 2 bears by Ontario hunters (PBTC 2005).

p. Kane Basin (KB)

The current size of the KB population is estimated at approximately 165 bears based on 1993-1997 data, (M. Taylor, unpublished data in PBSG 2005 Greenland Research Report p.2

Greenland hunters harvested an average of 10 per year from this sub-population from 1999-2003 (Born and Sonne 2005, Greenland Research Report to PBSG p. 5). Prior to 1997, this sub-population was harvested only by Greenland hunters, but since 1997, Nunavut hunters from Grise Fjord have also harvested bears from KB (PBSG 2001 p. 28). The combined harvest of 10-15 bears per year from Greenland and Nunavut is believed to be unsustainable (PBSG 2002 p. 28). The current quota in Nunavut is set at 5 bears per year (Dyck et al. 2005, Nunavut Report to PBTC p.14). Greenland and Canada are continuing to hold co-management discussions for this population (PBSG 2002 p. 28).

q. Baffin Bay (BB)

The current size for the BB population based on 1994-1997 data, is 2,074 bears (PBSG 2005, Greenland Research Report, p.2). Harvest levels in 1999-2003 averaged 115 polar bears annually from the Greenland side (PBSG 2005 Greenland Research Report p.6) and 64 in Nunavut (Aars et al. 2006). During the last 3 years (2001-2003) an average of 137 bears/year were taken in Greenland (Aars et al. 2006) A quota increase of 41 bears (from 64 to 105) was implemented by Nunavut in 2004/2005 (Dyck et al. 2005, Nunavut Report to PBTC p.14).

Greenland's harvest levels of polar bears in Baffin Bay have increased significantly since 1993 and were particularly high during 2002-2004. It is unknown whether this is related to an increase in hunting effort, increased efficiency of reporting, or because sea ice cover in eastern Baffin Bay has decreased, forcing an increased number of bears on to the shore. Canada and Greenland are holding co-management discussions to address the severe over-harvest of this population.

r. Davis Strait (DS)

The current size of the DS population size is unknown. In 1993 a population estimate of 1,400 animals was proposed because that was the minimum number of animals required to sustain the existing level of harvest (PBSG 2001 p.29). Nunavut currently uses a population estimate of 1,650 bears for harvest management purposes. A three-year population survey was initiated in 2005.

The DS sub-population is hunted by both Greenland hunters and Canadian hunters from Nunavut, Labrador, and Quebec. While quotas are in place for Nunavut and Labrador, Quebec does not manage with a quota system and the harvest there is unregulated. Quebec reported a harvest of 19 bears and Labrador 8 bears in 2003-2004 (PBTC report). Greenland hunters had an average catch of 1 polar bear per year during 1999-2003 (Born and Sonne 2005, Greenland Research Report to PBSG, p.6). In Nunavut, a harvest quota increase of 12 bears (from 34 to 46) was implemented in 2004/2005 (Dyck et al. 2005, Nunavut Report to PBTC p.14), based on Inuit reports that the sub-population has increased since 1996. Nunavut harvested 43 bears in 2004-2005 (PBTC 2005). Co-management discussions between Greenland and Canada are on-going.

s. Arctic Basin (AB)

Polar bear densities are believed to be low; no population surveys have been done of the AB population, and a rough population estimate is perhaps 200 animals (PBSG 2005, Canadian Management Report p.2). No harvest quota has been set, and there is no known harvest, except for an occasional defense kill (PBSG 2005, Canadian Management Report p.2)

Summary

At present, concern exists for potential over-harvest of the BB, CS, KB, and WH populations of polar bears. In other populations like East Greenland and Davis Strait, a high number of polar bears are taken annually despite lack of scientific information about population size. Considerable debate has occurred regarding the recent changes in population estimates and quota increases for some populations in Nunavut (Aars et al. 2006). The question arises whether increasing quotas based on IQ (and the perception that the populations were increasing because hunters were seeing more bears along the coast) constitutes a “sound conservation practice” and is “based on best scientific data”. Most scientists indicated that increased numbers of bear along the coastline could be related to changes in bear distribution (lack of suitable ice habitat) rather than an increase in the population size, and until additional inventories are done, a precautionary approach should be used when setting polar bear harvest limits (Aars et al. 2006). Recent computer simulations indicate that harvesting polar bear populations at or near MSY involves more risk (e.g. the probability that harvest will result in population decline) than previously believed (PBSG 2002). Also, managers must consider the cumulative effects of harvest in combination with other stressors such as diminishing ice habitat, high level of pollutants in some populations, increased bear-human interactions, and the overall lack of current data regarding polar bears and their habitat.

On the other hand, for most of the world's harvested polar bear populations, the economic and cultural value associated with both subsistence and sport hunting of polar bears is an important consideration in polar bear conservation (Freeman and Wenzel 2006). One concern is that if polar bears are listed as "threatened" and that action results in a ban on polar bear hunting or import of sport hunted trophies into other countries, a serious economic effect may occur in small hunting communities in Nunavut, and local hunters may see less value in conserving bears and abiding by the harvest management practices that are currently in place, and therefore, an increase in nuisance or defense kills may occur. Regardless of what the U.S. decides regarding listing polar bearsunder the ESA, other jurisdictions have a right and obligation to manage their polar bear populations. In instances of cooperative management of shared stocks (e.g. Canada and Greenland, U.S. and Russia) a decision to list the species may have indirect or direct implications.

C. Disease and Predation

1. Disease

Except for the presence of *Trichinella* larvae, the occurrence of diseases and parasites in polar bears is relatively rare compared to other bears. Polar bears feed primarily on fat which is relatively free of parasites, except for *Trichinella* (Rogers and Rogers 1976, Forbes 2000). Lentfer (1976) reported that 64% of the polar bears tested from Alaska had *Trichinella* larvae in the masseter muscle tissue. Rogers and Rogers (1976) found that of the 7 endoparasites found in captive polar bears, only *Trichinella* had been observed in wild animals. *Trichinella* has been documented in polar bears throughout their range and although infestations can be quite high they are normally not fatal (Rausch 1970, Dick and Belosevic 1978, Larsen and Kjos-Hannssen 1983, Taylor et al. 1985, Forbes 2000). Although rabies is commonly found in Arctic foxes, there has been only one confirmed instance of rabies in polar bears (Taylor et al. 1991). In a recent study in Svalbard, Norway, antibodies to the rabies virus were not detected (Tryland et al. 2005). Follmann et al. (1996) initially reported the presence of morbilllivirus in polar bears from Alaska and Russia and four morbilliviruses, canine distemper (CDV), dolphin morbillivirus (DMV), phocine distemper (PDV), and porpoise morbillivirus (PMV), were later identified (Garner et al. 2000). More recently, the presence of CDV, DMV, PDV, and PMV was detected in 48% of the Alaskan polar bears tested (n=64) (Kirk, pers. comm.). Epizootics including mass mortalities in marine mammals, particularly seals, have been attributed to this group of morbilliviruses (Duignan et al. 1994, Duignan et al. 1995, Mamaev et al.1996, Visser et al. 1993, Kennedy 1998, Duignan et al. 1997, Garner et al. 2000). The bears that were positive for DMV, PDV, or PMV had higher titers for CDV (Kirk, pers. comm.), which suggests that that the source is likely from a terrestrial origin (Garner et al. 2000).

Antibodies to the protozoan parasite, *Toxoplasma gondii,* were found in 13% of serum samples from Alaskan polar bears (n=64) (Kirk, pers. comm.). Toxoplasmosis has been suspected as a risk factor increasing the susceptibility of southern sea otters (*Enhydra lutris*) to infection (Miller et al. 2002, Krueder et al. 2003). It is currently unknown whether or not the presence of *Toxoplasma gondii* is a health concern for polar bears.

It is unknown whether polar bears are more susceptible to new pathogens due to their lack of previous exposure to diseases and parasites. Many different pathogens and viruses have been found in seal species that are polar bear prey (Duignan et al. 1997, Measures and Olson 1999, Dubey et al. 2003, Hughes-Hanks et al. 2005), so the potential exists for transmission of these diseases to polar bears. As polar bears become more stressed they may eat more of the intestines and internal organs than they do presently, thus increasing their potential exposure to parasites and viruses (Derocher et al. 2004, Amstrup et al. 2006b). It has also been well documented that populations or individuals that are stressed are more susceptible to effects of disease. There is also the potential for pathogens to expand their range northward from more southerly areas as areas in the Arctic get progressively warmer (Harvell et al. 2002). For example, *Echinococcus multilocularis* was recently found in brown lemmings (*Lemmus trimucronatus*) along the Arctic coast in Barrow, Alaska, which represents a northern expansion of this disease vector (Holt et al. 2005). *Ecninococcus granulosis* is the wolf-ungulate version and may be more of threat to polar bears scavenging caribou (*Rangifer tarandus*) since scavenging these carcasses has been documented on Svalbard (Derocher et al. 2000a) and Wrangel Island (Belikov 1976).

2. Intraspecific Predation

Intraspecific killing has been reported among all North American bear species. Reasons for intraspecific predation in bears species is poorly understood but thought to include population regulation, nutrition, and enhanced breeding opportunities in the case of predation of cubs. Although infanticide by male polar bears has been well documented (Hannsson and Thomassen 1983, Larsen 1985, Taylor et al. 1985, Derocher and Wiig 1999), it is thought that this activity does not account for large percentage of the cub mortality. By killing cubs sired by other males the adult male eliminates potential competition with their own offspring and may also create an opportunity to breed with the female whose cubs he killed, thus producing his own cubs Swenson et al. 1997). It is thought that this behavior increases the male's relative fitness in the population. However, for this to be successful a male has to recognize his own cubs and have a reasonable opportunity to breed with a female whose cubs he kills when she comes back into estrus. Another potential reason for infanticide relates to density dependent mechanisms of population control as this behavior seems to occur more frequently with increasing population size (Derocher and Wiig 1999).

Cannibalism has also been documented in polar bears (Derocher and Wiig 1999, Amstrup et al. 2006b). Amstrup et al. (2006b) observed three instances of intraspecific predation and cannibalism in the southern Beaufort Sea during the spring of 2004. The first was the first documented predation of an adult female in a den, the second was of a female and newly emerged cub from a den, and the third involved a yearling male. In a combined 58 years of research by the senior investigators similar observations had not taken place. Active stalking or hunting preceded the attacks and both of the killed bears were eaten. Adult males were believed to be the predator in the attacks. Amstrup et al. (2006b) indicated that in general a greater portion of polar bears in the area where the predation occurred were in poor physical condition compared to other years. The authors hypothesized that adult males may be the first to show the effects of nutritional stress caused by significant ice retreat in this area (Skinner et al. 1998, Comiso and Parkinson 2004, Stroeve et al. 2005) because they feed less during the spring mating season and enter the summer in poorer condition than other sex/age classes. Derocher and Wiig (1999) documented a similar intraspecific killing and consumption of another polar bear in Svalbard, Norway, which was attributed to relatively high population densities and food shortages. Taylor et al. (1985) documented that a malnourished female killed and consumed her own cubs, and Lunn and Stenhouse (1985) found an emaciated male consuming an adult female polar bear.

The potential importance of cannibalism and infanticide for population regulation is unknown. Given our current knowledge of disease and predation, we do not believe that these factors currently are having any major population level effects. However, increased cannibalism in polar bears was postulated and thought to be a result nutritional stress brought on by climate change (Derocher et al. 2004).

D. Adequacy of existing regulatory mechanisms

1. Description of International Agreements and Oversight

a. International Agreement on the Conservation of Polar Bears

Canada, Denmark on behalf of Greenland, Norway, the Union of Soviet Socialist Republics, and the U.S. signed the *Agreement on the Conservation of Polar Bears* (*1973 Polar Bear Agreement*) in 1973 (Appendix 1). The *1973 Polar Bear Agreement* requires signatories to protect the ecosystems and habitats used by polar bears and to promote polar bear protection efforts through coordinated national measures. The *1973 Polar Bear Agreement* represented the first effort by five circumpolar nations to address a circumpolar conservation issue (Prestrud and Stirling 1994, Stirling 1988).

In 1976, the U.S. Senate unanimously provided its advice and consent to the Polar Bear Agreement and by 1978 all five parties had ratified the Polar Bear Agreement. The Polar Bear Agreement, initially in force for five years, became permanent upon agreement by the five parties in 1981. Article II of the Polar Bear Agreement requires each country to “take appropriate action to protect the ecosystem of which polar bears are a part, with special attention to habitat components such as denning and feeding sites and migration patterns,” and to “manage polar bear populations in accordance with sound conservation practices based on the best available scientific data.” Article VI of the Polar Bear Agreement requires each country to “enact and enforce such legislation and other measures as may be necessary” to implement the Polar Bear Agreement. Each party must enact implementing legislation where necessary. The Agreement. relies on the efforts of each jurisdiction to implement conservation programs, and does not preclude a party from establishing additional controls.

The Marine Mammal Protection Act of 1972 (MMPA, 16 U.S.C. § 1361 *et seq*.), as amended, is the primary legislation through which the U.S. meets the obligations of the Polar Bear Agreement. The MMPA addresses domestic conservation of polar bears and other marine mammals under the jurisdiction of the U.S.

The initial impetus for the *1973 Polar Bear Agreement* was a concern that over-harvest of polar bears was negatively impacting the species. The *1973 Polar Bear Agreement* is widely viewed as a success in that polar bear populations recovered from excessive harvests and severe population reductions in many areas. However, implementation of the terms of the *1973 Polar Bear Agreement* varied throughout the Arctic and some populations and locales require improvements to current harvest management practices, such as restricting harvest of females and cubs, establishing sustainable harvest limits, and controlling illegal harvests, have been identified for some populations or locales (PBSG 1998). The lack of protection of critical habitats by the Parties, with few notable exceptions for some denning areas, is a weakness of the Agreement (Prestrud and Stirling 1994). Further, the Parties acknowledged that additional efforts were necessary to protect habitat and emphasized national efforts to identify important denning and feeding habitats (Baur 1996).

b. IUCN/SSC Polar Bear Specialist Group

The Polar Bear Specialist Group (PBSG) operates under the IUCN Species Survival Commission. The PBSG was formed in 1968 in response to polar bear conservation needs identified at a September 1965 scientific meeting arranged by the University of Alaska in Fairbanks (Anonymous 1966). This was one of the first major scientific gatherings with the primary task to discuss international conservation measures regarding a single species, the polar bear. Subsequent to its formation, the PBSG contributed to the negotiation and development of the *1973 Polar Bear Agreement*.

The PBSG meets periodically at 3 to 5 year intervals so as to comply with Article VII of the *1973 Polar Bear Agreement*, which instructs the Contracting Parties to "conduct national research programs on polar bears, particularly research relating to the conservation and management of the species. They shall as appropriate coordinate such research with the research carried out by other Parties, consult with other Parties on management of migrating polar bear populations, and exchange information on research and management programs, research results, and data on bears taken." The PBSG held their 14th working group meeting in Seattle, Washington, U.S., in June 2005.

The PBSG first evaluated the status of all polar bear populations in 1980. In 1993, 1997, and 2001 the PBSG conducted circumpolar status assessments, the results of which were published as part of the proceedings of each meeting.

The PBSG also evaluates the status of this species under the IUCN Red List criteria. Previously, under the IUCN Red List program polar bears were classified as "Less rare but believed to be threatened-requires watching" (1965), "Vulnerable" (1982, 1986, 1988, 1990, 1994), and "Lower Risk/Conservation Dependent" (1996). During the 14th working group meeting, the PBSG re-evaluated the status of polar bears and based on climate change analysis and projected changes in sea ice, effects of climatic change on the distribution of polar bears, and the condition of polar bears including effects on reproduction and survival associated with climate change, the group agreed unanimously that a status designation of "Vulnerable" was warranted.

c. *Inupiat-Inuvialuit Agreement for the Management of Polar Bears of the Southern Beaufort Sea*

Telemetry research on polar bears in the 1980s suggested that Alaskan and Canadian polar bear hunters were harvesting from the same southern Beaufort Sea population that ranged between Icy Cape in Alaska and Pearce Point, to the east of Paulatuk in Canada (Amstrup et al.1986, Stirling et al.1988). Because harvests in Canada and Alaska were being managed differently and independently, recognition that the population was shared raised conservation concerns by the users and managers from each jurisdiction.

The Inuvialuit and the Inupiat recognized the shared responsibility for conservation and need to coordinate harvest practices (Stirling 1988, Treseder and Carpenter 1989, Nageak et al. 1991). The user group management agreement for polar bears of the southern Beaufort Sea was signed in Inuvik, NWT in January 1988, following two years of technical discussions and community consultations

Provisions of the Agreement included: annual quotas (which may include problem kills), hunting seasons; protection of bears in or constructing dens and of females accompanied by cubs and yearlings; collection of specimens from killed bears to facilitate monitoring of the sex and age composition of the harvest; agreement to meet annually to exchange information on research and management, to set priorities, and to agree on quotas for the coming year; and, prohibition of hunting with aircraft or large motorized vessels and of trade in products taken in violation of the Agreement. To facilitate implementation, a Joint Commission was formed, comprised of two Commissioners appointed by each party, as well as a Technical Advisory Committee, appointed by the Joint Commission, made up of biologists from government agencies in both countries who were actively involved in collecting research and management data. These two groups meet annually at the same time and place, and decisions are made by consensus. In Canada, recommendations and decisions from the Commissioners are then implemented through Community Polar Bear Management Agreements, Inuvialuit Settlement Region Community Bylaws, and NWT Big Game Regulations; in the United States this agreement is implemented at the local level. There are no Federal, states, or local regulations that limit the number or type (male, female, cub) of polar bear that may be taken. Adherence to the agreement's terms in Alaska is voluntary, and levels of compliance may vary. However, Brower et al. (2002) analyzed the overall effectiveness of this agreement and found that it had been successful in maintaining the total harvest and the proportion of females in the harvest within sustainable levels. The authors noted the need to improve harvest monitoring in Alaska and increase awareness of the need to prevent overharvest of females for both countries.

d. Agreement between the United States of America and the Russian Federation on the Conservation and Management of the Alaska-Chukotka Polar Bear Population

On October 16, 2000, the U.S. and Russia signed a bilateral agreement for the conservation and management of polar bear populations shared between the two countries. The *Agreement between the United States of America and the Russian Federation on the Conservation and Management of the Alaska-Chukotka Polar Bear Population* (*Bilateral Agreement*) represents a significant effort by the U.S. and Russia to expand upon the progress made through the multi-lateral *1973 Polar Bear Agreement* and to implement unified conservation programs for this shared population. The Bilateral Agreement reiterates requirements of the *1973 Polar Bear*

Agreement and includes restrictions on harvesting denning bears, females with cubs or cubs less than one year old, and prohibitions on the use of aircraft, large motorized vessels, and snares or poison for hunting polar bears. The Bilateral Agreement does not allow hunting for commercial purposes or commercial uses of polar bears or their parts. It also commits the Parties to the conservation of ecosystems and important habitats, with a focus on conserving polar bear habitats such as feeding, congregating and denning areas. The U.S. passed legislation on December 9, 2006 to enable full implemention of the Bilateral Agreement.

e. The Convention on the International Trade in Endangered Species of Wild Fauna and Flora

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is a treaty aimed at protecting species at risk from international trade. CITES regulates international trade in animals and plants by listing species on one of its three appendices. The level of monitoring and control to which an animal or plant species is subject depends on which of the three appendices the species is listed. Appendix I includes species threatened with extinction, and their trade is only allowed in exceptional circumstances. Appendix II includes species not necessarily threatened with extinction, but for which trade must be controlled in order to avoid utilization incompatible with their survival. Appendix III includes species that are protected in at least one country, and for which that country has asked other CITES Party countries for assistance in controlling and monitoring international trade in that species.

For species to be added or removed from Appendices I or II, a vote is required at a CITES Conference of the Parties, which is held every 2-3 years, but any CITES Party may add a native species to Appendix III unilaterally provided that the Party has domestic laws to protect the species.

Polar bears are currently listed as an Appendix II species under CITES. As such, member countries to CITES must determine, amongst other things, that any polar bear, polar bear part, or product made from polar bear was legally obtained and that the export will not be detrimental to the survival of the species, prior to issuing a permit authorizing the export of the animal, part or product.

f. Mechanisms to regulate climate change

Regulatory mechanisms to comprehensively address the causes of climate change are still under development. Efforts to address climate change globally began with the United Nations Framework Convention on Climate Change ("UNFCCC"), which was adopted in May 1992. The stated objective of the UNFCCC is the stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Due to the complexity of climate issues and the widely divergent political positions of the world's nation states, the UNFCCC itself was unable to set emissions targets or limitations, but instead created a framework that set the stage for subsequent actions (UNFCCC 2004). The UNFCCC covers greenhouse gases not otherwise controlled by the Montreal Protocol on ozone-depleting substances (UNFCCC 2004). A key feature of the Framework is the designation of different levels of responsibility to the parties of the convention, based on their differing levels of economic development (UNFCCC 2004). To date, the goals set by the Framework have not been met (International Climate Change Taskforce 2005).

The Kyoto Protocol, negotiated in 1997, became the first additional agreement added to the UNFCCC to set emissions targets. The Kyoto Protocol set goals for developed countries to reduce their emissions to at least 5% below their 1990 levels (UNFCCC 2004). Implementation of the Kyoto Protocol would slightly reduce the rate of growth of emissions and would only make a small contribution to stabilizing the level of emissions in the atmosphere (Williams 2002). Additionally, mechanisms for enforcement of emission reductions have not yet been tested and there are no financial penalties or automatic consequences for failing to meet Kyoto targets (UNFCCC 2004). Climate responds to changes in greenhouse gas concentrations with a time lag therefore, past emissions have initiated processes that lead to a certain degree of warming and climate change (IPCC 2001, Williams 2002, ACIA 2004).

Domestic efforts relative to climate change focus on continued studies programs, support for developing new technologies and use of incentives for supporting reductions in emissions. A strategic plan for the U.S. Climate Change Science Program released by the Departments of Energy and Commerce and the White House Office of Science Technology and Policy is available (http://climatescience.gov/). The strategy is for developing knowledge of variability and change in climate and related environmental and human systems and for encouraging the application of this knowledge. The strategic goal of emissions reductions is measured by emissions intensity, the amount of emissions per unit of economic activity (http://state.gov/g/oes/climate/). This measure differs from an absolute measure of output and while the emissions intensity could decrease the total emissions would still increase (GAO 2003).

2. International Classification Systems

a. NatureServe List

NatureServe is a non-profit conservation organization that provides the scientific information and tools needed to help guide effective conservation action. NatureServe and its network of natural heritage programs are a major source for information about rare and endangered species and threatened ecosystems.

NatureServe represents an international network of biological inventories—known as natural heritage programs or conservation data centers—operating in all 50 U.S. states, Canada, Latin America and the Caribbean. The organization collects and manages detailed local information on plants, animals, and ecosystems, and develops information products, data management tools, and conservation services to help meet local, national, and global conservation needs. The scientific information about species and ecosystems developed by NatureServe is used by a variety of government and private sectors to make informed decisions about managing our natural resources.

On October 3, 2005 NatureServe revised its global status rank for polar bears to G3, the equivalent of "Vulnerable," from the previous classification of G4, "apparently secure." The term vulnerable is defined as one that is at moderate risk of extinction due to a restricted range, relatively few populations, recent and widespread declines, or other factors. Polar bears fit this classification as the population is restricted to high northern latitudes with a relatively small total population of 21,500-25,000 individuals located in about 20 relatively discrete major populations. Potential negative impacts from various human activities were cited (e.g. oil and gas exploration and development, harvest, environmental contaminants) as increasing or not well regulated in some areas. Global warming effects on sea ice could result in major declines in polar bear distribution and abundance. Details regarding NaturServe and the polar bear status assessment can be found at the following web site: http://www.natureserve.org and Appendix 2.

b. IUCN Red List

The IUCN World Conservation Union) through its Red List program assesses the conservation status of species, subspecies, varieties and selected subpopulations to identify taxa threatened with extinction in order to promote their conservation. The program goal is to provide the world with the most objective, scientifically-based information on the current status of globally threatened biodiversity. The IUCN Red List of Threatened Species provides taxonomic, conservation status and distribution information on taxa that have been evaluated using the IUCN Red List Categories and Criteria.

De Grammont and Cuarón (2006) conducted an evaluation of categorization systems that assess the risk of species extinction to evaluate the objectivity and accuracy of threatened or endangered classification systems. Twenty-five categorization systems from 20 countries were evaluated. These included examples of international lists, most national systems used in the American continent, and some systems independently proposed by academics. Fifteen characteristics that should be included in the categorization were assessed. They concluded that of all evaluated systems, the current World Conservation Union system (IUCN) is the most suitable for assessing species extinction risk. On May 4, 2006, the IUCN/SSC Red List of Threatened Species was updated to include the "Vulnerable" classification of polar bears developed by the PBSG as discussed above.

The assessment was based on an assumed population reduction of greater then 30% within 3 generations (defined as age of sexual maturity, i.e., 5 years, plus 50% of the length of the life time reproductive period, i.e. 20 years, or 45 years) that would result from a decline in area of occupancy, extent of occurrence, and habitat quality. The assessment, conducted by the Polar Bears Specialist Group, uses the 2001 IUCN criteria (Appendix 4) and found the following (Aars et al. 2005):

> "Polar bears rely almost entirely on the marine sea ice environment for their survival so that large scale changes in their habitat will impact the population (Derocher et al. 2004). Global climate change poses a substantial threat to the habitat of polar bears. Recent modeling of the trends for sea ice extent, thickness, and timing of coverage predicts dramatic reductions in sea ice coverage over the next 50-100 years (Hassol 2004). Sea ice has declined considerably over the past half century. Additional declines of roughly 10 - 50% of annual sea ice are predicted by 2100. The summer sea ice is projected to decrease by 50 – 100% during the same period. In addition the quality of the remaining ice will decline. This change may also have a negative effect on the population size (Derocher et al. 2004). The effects of sea ice change are likely to show large difference and variability by geographic location and periods of time, although the long term trends clearly reveal substantial global reductions of the extent of ice coverage in the Arctic and the annual time frames when ice is present.
>
> While all bear species have shown adaptability in coping with their surroundings and environment, polar bears are highly specialized for life in the Arctic marine environment. Polar bears exhibit low reproductive rates with long generational spans. These factors make facultative adaptation by polar bears to significantly reduced ice coverage scenarios unlikely. The effects of the Eemian or Sangamon interglacial period (warming period) around 131,000BP on the Arctic marine ecosystem and polar bears are unknown. Due to

their long generation time and the current greater speed of global warming, it seems unlikely that polar bear will be able to adapt to the current warming trend in the Arctic. If climatic trends continue polar bears may become extirpated from most of their range within 100 years.

There is little doubt that in the future polar bears will have access to less sea ice for a shorter time period. Also the location of ice that remains may be in areas of lower biological productivity. However, only in Western Hudson Bay are data presently available to link these ice features with the abundance of polar bears. While some have speculated that polar bears might become extinct by the end of the 21st century, which would indicate a population decrease of > 50% in 45 years. Based on a precautious attitude to the uncertainty in data a more realistic attitude to the risk involved in the assessment make it fair to suspect population reduction of > 30%.

Other population stress factors that may also operate to impact recruitment or survival include toxic contaminants, shipping, recreational viewing, oil and gas exploration and development. In addition to this comes a potential risk of over-harvest due to increased quotas or no quotas in Canada and Greenland and poaching in Russia."

3. Description of Domestic Management Structures

a. United States

Marine Mammal Protection Act of 1972, as amended

The MMPA was enacted in response to growing concerns among scientists and the general public that certain species and populations of marine mammals were in danger of extinction or depletion as a result of human activities. The goal of the MMPA is to protect and conserve marine mammals so that they continue to be significant functioning elements of the ecosystem of which they are a part. The MMPA set forth a national policy to prevent marine mammal species or population stocks from diminishing to the point where they are no longer a significant functioning element of the ecosystems.

The MMPA places an emphasis on habitat and ecosystem protection. The habitat and ecosystem goals set forth in the MMPA include: (1) management of marine mammals to ensure they do not cease to be a significant element of the ecosystem to which they are a part; (2) protection of essential habitats, including rookeries, mating grounds, and areas of similar significance "from the adverse effects of man's action;" (3) recognition that marine mammals "affect the balance of marine ecosystems in a manner that is important to other animals and animal products" and that marine mammals and their habitats should therefore be protected and conserved; and (4) directing that the primary objective of marine mammal management is to maintain "the health and stability of the marine ecosystem." Congressional intent to protect marine mammal habitat is also reflected in the definition of terms set out in section of the MMPA. The terms "conservation" and "management" of marine mammals are specifically defined to include habitat acquisition and improvement.

The Act includes a general moratorium on the taking and importing of marine mammals, which is subject to a number of exceptions. Some of these exceptions include take for scientific purposes, for purpose of public display, subsistence use by Alaska Natives, and unintentional incidental take coincident with conducting lawful activities.

Take is defined to include the "harassment" of marine mammals. "Harassment" includes any act of pursuit, torment, or annoyance which "has the potential to injure a marine mammal or marine mammal stock in the wild" (Level A harassment), or "has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering" (Level B harassment).

The Secretaries of Commerce and the Interior have primary responsibility for implementing the MMPA. The Department of Commerce, through the National Oceanic and Atmospheric

Administration (NOAA) has authority with respect to whales, porpoises, seals, and sea lions. The remaining marine mammals, including polar bears, walruses, and sea otters, manatees and marine otters are managed by the Department of the Interior through the Service. Both agencies are " . . . responsible for the promulgation of regulations, the issuance of permits, the conduct of scientific research, and enforcement as necessary to carry out the purposes of [the MMPA]".

U.S. citizens who engage in a specified activity other than commercial fishing within a specified geographical region may petition the Secretary of the Interior to authorize the incidental, but not intentional, taking of small numbers of marine mammals within that region for a period of not more than five consecutive years. 16 U.S.C. § 1371(a)(5)(A). The Secretary "shall allow" the incidental taking if the Secretary finds that "the total of such taking during each five-year (or less) period concerned will have a negligible impact on such species or stock and will not have an unmitigable adverse impact on the availability of such species or stock for taking for subsistence uses…" If the Secretary allows the incidental taking, the Secretary must also prescribe regulations that specify (1) permissible methods of taking, (2) means of affecting the least practicable adverse impact on the species, their habitat, and their availability for subsistence uses, and (3) requirements for monitoring and reporting. The regulations promulgated do not authorize the activities themselves, but authorize the incidental take of polar bears in conjunction with otherwise legal activities described within the regulations.

National Environmental Policy Act

The purpose of the National Environmental Policy Act (NEPA) is to consider every significant aspect of the environmental impact of programs and actions of the federal government and to inform the public that the agency did indeed consider the environmental concerns in its decision-making process. An EIS is required for all significant federal actions that could affect the environment. For example, the Service's Office of Marine Mammals Management prepares Environmental Assessments when promulgating Incidental Take Regulations and Incidental Harassment Authorizations in regard to the incidental taking of small numbers of polar bears during oil and gas operations on the North Slope of Alaska. Through these efforts, the Service seeks to ensure that impacts to fish and wildlife resources are adequately described and that mitigation needs are met.

Outer Continental Shelf Lands Act

The Outer Continental Shelf Lands Act (OCSLA) established federal jurisdiction over submerged lands on the Outer Continental Shelf (OCS) seaward of the State boundaries (3-mile limit) in order to expedite exploration and development of oil/gas resources on the OCS.

Implementation of OCSLA is delegated to the Minerals Management Service (MMS) of the Department of the Interior. OCS projects which could adversely impact the Coastal Zone are subject to federal consistency requirements under terms of the CZMA, as noted below. OCSLA also mandates that orderly development of OCS energy resources be balanced with protection of human, marine and coastal environments.

Coastal Zone Management Act

The Coastal Zone Management Act (CZMA) was enacted to "preserve, protect, develop, and where possible, to restore or enhance the resources of the Nation's coastal zone." This is a State program subject to federal approval. The CZMA requires that federal actions be conducted in a manner consistent with the State's CZM plan to the maximum extent practicable. Federal agencies planning or authorizing an activity that affects any land or water use or natural resource of the coastal zone must provide a consistency determination to the appropriate State agency. The CZMA applies to areas on the northern and western coasts of Alaska which occur in polar bear habitat. The North Slope Borough and Alaska Coastal Management Programs through their project review processes have operated effectively to assist in protection of polar bear habitat in recent times.

Alaska National Interest Lands Conservation Act

The Alaska National Interest Lands Conservation Act (ANILCA) created or expanded National Parks and Refuges in Alaska, including the Arctic National Wildlife Refuge (NWR). One of the establishing purposes of the Arctic NWR is to conserve polar bears. Most of the Arctic National Wildlife Refuge is designated Wilderness and is therefore off limits to oil and gas development. The coastal plain of Arctic NWR (Section 1002 designated lands), which provides important polar bear denning habitat, does not have Wilderness status, however, and could be opened for development by an Act of Congress.

Marine Protection, Research and Sanctuaries Act

The Marine Protection, Research and Sanctuaries Act was enacted in part to "prevent or strictly limit the dumping into ocean waters of any material that would adversely affect human health, welfare, or amenities, or the marine environment, ecological systems, or economic potentialities."

b. Canada

The constitutional arrangement in Canada specifies that the Provinces and Territories have the authority to manage terrestrial wildlife which includes polar bears as they are not defined as a marine mammal in Canada. The federal government is responsible for CITES related programs and has continued to provide both technical (long-term demographic, ecosystem, and inventory research) and administrative (Federal/Provincial Polar Bear Technical Committee, Federal/Provincial Polar Bear Administrative Committee, and the National Database) support to the Provinces and Territories. The Provinces and Territories have the ultimate authority for management, although in several areas, the decision-making process is shared with aboriginal groups as part of the settlement of land claims. Hunting by aboriginal people is permissible. Harvest quotas or guidelines, in the instance where treaty interest rights are in effect, are based on principles of sustainable use (Derocher et al. 1998).

In Canada, much of the denning areas in Manitoba have been protected by inclusion within the boundaries of Wapusk National Park. In Ontario, some denning habitat and coastal summer sanctuary habitat are included in Polar Bear Provincial Park. Some polar bear habitat is included coincidentally in some of the National Parks and National Park Reserves and territorial parks in the NWT, Nunavut and Yukon Territory (e.g. Herschel Island). Offshore areas which may be important habitat have variable levels of protection. Additional habitat protection measures include restrictions on harassment and approaching dens and denning bears, and a land use permit review that considers potential impacts of land use activities on wildlife (Derocher et al. 1998).

Canada's Species at Risk Act

Canada's Species at Risk Act (SARA) became law on December 12, 2002, and went into effect on June 1, 2004 (Walton 2004). Prior to SARA, Canada's overview of species at risk was through the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and the Minister of Environment, which continued to function under SARA following passage of SARA. The Committee evaluates species status and provides recommendations to the Minister of the Environment, who makes the final listing decision and identifies species specific management actions. SARA provides a number of protections for wildlife species designated to the List of Wildlife Species at Risk, or "Schedule 1" (SARA Registry 2005).

SARA promotes species conservation through a number of mechanisms, including prohibitions on killing listed species and destroying critical habitat, and the implementation of recovery strategies. Those prohibitions apply only on federal lands, such as national parks (Walton 2004), however, SARA includes an exception for species like the polar bear. In such cases, the Federal Cabinet, based on recommendation of the Minister of the Environment, may apply restriction to non-federal lands in a Province or Territory (Walton 2004). This provision has not been tested by the courts (Walton 2004).

The listing criteria used by COSEWIC are based on the 2001 IUCN Red List assessment criteria (Appendix 3). Currently, the polar bear is designated as a Schedule 3 species, "Species of Special Concern," awaiting re-assessment and public consultation for possible addition to Schedule 1 (Environment Canada 2005). The Minister of the Environment did not add the polar bear to the List of Wildlife Species at Risk under SARA at the request of Nunavut which wanted additional consultation. The Minister recognized that there was new knowledge available and a greater need to incorporate TEK and IQ (Dowsley 2005) in the assessment. There is an ongoing re-assessment through COSEWIC on the status of polar bears in Canada.

Intra-jurisdiction polar bear agreements within Canada

Polar bears occur in Canada in the NWT, Nunavut, Yukon Territory, and in the provinces of Manitoba, Ontario, Quebec, and Newfoundland and Labrador (Map 1). All 12 Canadian polar bear populations lie within or are shared with the NWT and Nunavut. The NWT and Nunavut geographical boundaries include all Canadian lands and marine environment north of the 60th parallel (except the Yukon Territory) and all islands and waters in Hudson Bay and Hudson Strait up to the low water mark of Manitoba, Ontario, and Quebec. The offshore marine areas along the coast of Newfoundland and Labrador are under federal jurisdiction (GNWT). Although Canada manages each of the 12 populations of polar bear as separate units, there is a complex sharing of responsibilities. While wildlife management has been delegated to the provincial and territorial governments, the federal government (Environment Canada's CWS) has an active research program and is involved in management of wildlife populations shared with other jurisdictions, especially ones with other nations. In the NWT, native land claims resulted in co-management boards for most of Canada's polar bear populations. Canada formed the Federal-Provincial Technical and Administrative Committees for Polar Bear Research and Management (PBTC and PBAC, respectively) to ensure a coordinated management process consistent with internal and international management structures and the International Agreement. The committees meet annually to review research and management of polar bears in Canada and have representation from all the provincial and territorial jurisdictions with polar bear populations and the federal government. Beginning in 1984, the Service has attended meetings of the PBTC and biologists from Norway and Denmark have attended a number of meetings as well. Although in recent years, the PBAC meetings have invited the participation of nongovernment groups, such as the Inuvialuit Game Council and the Labrador Inuit Association, for their input at the management level, they have for the most part not attended. The annual meetings of the PBTC provide for continuing cooperation between jurisdictions and for recommending management actions to the PBAC (Calvert et al. 1995). The NWT Polar Bear Management Program (GNWT) manages polar bears under the Northwest Territories Act (Canada). The 1960 "Order-in-Council" granted authority to the Commissioner in Council (NWT) to pass ordinances that are applicable to all people to protect polar bear, including the establishment of a quota system. The Wildlife Act, 1988, and Big Game Hunting Regulations provide supporting legislation which addresses each polar bear population. The Inuvialuit and Nunavut Land Claim Agreements supersede the Northwest Territories Act (Canada) and the Wildlife Act. The Government of Nunavut passed a new Wildlife Act two years ago and has management and enforcement authority for polar bears in their jurisdiction. Under the umbrella of this authority, polar bears are now comanaged through wildlife management boards made up of land claim beneficiaries and territorial and federal representatives. One of the strongest aspects of the program is that the management decision process is integrated between jurisdictions and with local hunters and management boards. A main feature of this approach is the development of Local Management Agreements between the communities that share a population of polar bears. Management agreements are in place for all Nunavut populations. The MOUs are signed between the communities, regional wildlife organiztions, and the Government of Nunavut (Department of Environment) but not by the Nunavut Wildlife Management Board (NWMB). Consequently these MOUS are not binding on the NWMB and as such the NWMB are not bound to them and can step outside the management agreements. For example a moratorium might be in the MOUs but it could be over-ruled by the NWMB. In the case of populations that Nunavut shares with Quebec and Ontario (neither of which is approved under the criteria specified in this rule), the management agreement is not binding upon residents of communities outside of Nunavut jurisdiction. The GNWT uses these agreements to develop regulations that implement the agreements. In addition to regulations to enforce the agreements, there is strong incentive to comply with the management agreements since they are developed co-operatively between the government and the resource users who directly benefit from the commitment to long-term maintenance of the population. The interest and willingness of members of the community to conform their activities to observe the law, reinforces other law enforcement measures. Regulations specify who can hunt, season timing and length, age and sex classes that can be hunted, and the total allowable harvest for a given population in Polar Bear Management Areas. The Department of Environment in Nunavut and the Department of Environment and Natural Resources in the NWT has officers to enforce the regulations in most communities of the NWT. The officers investigate and prosecute incidents of violation of regulations, kills in defense of life, or exceeding a quota (USFWS 1997).

c. Russia

Polar bears are listed in the second issue of the Red Data Book of the Russian Federation (2001). The Red Data Book establishes official policy for protection and restoration of rare and endangered species in Russia. Polar bear populations inhabiting the Barents Sea and part of the Kara Sea (Barents-Kara population) are designated as Category IV (uncertain status); polar bears in the eastern Kara Sea, Laptev Sea and the western East-Siberian Sea (Laptev population) are listed as Category III (rare); and polar bears inhabiting the eastern part of the East-Siberian Sea, Chukchi Sea, and the northern portion of the Bering Sea (CS population) are listed as Category V (restoring). The main government body responsible for management of species listed in the Red Data Book is the Department of Envoronment Protection and Ecological Safety in the Ministry of Natural Resources of the Russian Federation. Russia Regional Committees of Natural Resources are responsible for managing polar bear populations consistent with federal legislation (Belikov et al. 2002).

Polar bear hunting has been totally prohibited in the Russian Arctic since 1956 (Belikov et al. 2002). The only permitted take of polar bears is catching cubs for public zoos and circuses. CITES Appendix II regulations are followed for polar bear. There are no data on illegal trade of polar bears, and parts and products derived from them, although considerable concern persists for unquantified levels of illegal harvest that is occurring In the Russian Arctic, Natural Protected Areas (NPAs) have been established that protect marine and associated terrestrial ecosystems including polar bear habitats. In the Russian Arctic, Wrangel and Herald Islands have special conservation status as places with high concentrations of maternity dens and/or polar bears. Wrangel and Herald Islands were included in the Wrangel Island State Nature Reserve (zapovednik) in 1976. Also a decree of Russian Federation Government in 1997 established a 12-nm marine zone was added to the Wrangel Island State Nature Reserve which was extended to 24-nm marine protected zone in 1999 by a decree from the Governor of Chukotsk Autonomous Okruga (Belikov et al. 2002). The Franz Josef Land State Nature Refuge was established in 1994. Special protected areas are proposed in the Russian High Arctic: the Novosibirsk Islands, Severnaya Zemlya, and Novaya Zemlya. Within these protected areas, conservation and restoration of terrestrial and marine ecosystems, and plant and animal species (including the polar bear), are the main goals. In 2001the Nenetskiy State Reserve, which covers 313,400ha and includes the mouth of the Pechora River and adjacent waters of the Barents Sea, was established. In May 2001 the federal law "Concerning territories of traditional use of nature by small indigenous peoples of North, Siberia, and Far East of the Russian Federation" was passed. This law established areas for traditional use of nature (TTUN) within NPAs of federal, regional, and local levels to support traditional life styles and traditional subsistence use of nature resources for indigenous peoples. This law and the Law "Concerning natural protected territories" (1995) regulate protection of plants and animals on the TTUNs. The latter also regulates organization, protection and use of other types of NPAs: State Nature Reserves (including Biosphere Reserves), National Parks, Natural Parks, and State Nature Refuges. Special measures on protection of polar bears or other resources may be governed by specific regulations of certain NPAs. Outside NPAs protection and use of marine renewable natural resources are regulated by federal legislation, Acts of the President of the Russian Federation, regulations of State Duma, Government, and Federal Senate of the Russian Federation, and through regulations issued by appropriate governmental departments. The most important federal laws for nature protection are: "About environment protection" (1991), "About animal world" (1995), "About continental shelf of the Russian Federation" (1995), "About exclusive economical zone of the Russian Federation" (1998), and "About internal sea waters, territorial sea, and adjacent zone of the Russian Federation" (1998). All these laws protect important polar bear denning and feeding habitat.

d. Norway

According to the Svalbard Treaty of February 9, 1920, Norway exercises full and unlimited sovereignty over the Svalbard Archipelago. The Svalbard Treaty applies to all the islands situated between 10^{o} and 35^{o} East of Greenwich and between 74^{o} and 81^{o} latitude North and includes the waters up to four nautical miles offshore. Beyond this zone, Norway claims an economic zone to the continental shelf areas to which Norweigian Law applies. Therefore under Norweigian Game Law, all game, including polar bears, are protected unless otherwise stated (Derocher et al. 2002b). The main responsibility for the administration of Svalbard lies with the Norwegian Ministry of Justice. Norwegian civil and penal laws and various other regulations are applicable to Svalbard as well. The Ministry of Environment deals with matters concerning the environment and nature conservation. The Governor of Svalbard (Sysselmannen), which has management responsibilities for freshwater-fish and wildlife, pollution and oil spill protection, environmental monitoring, and is is the cultural and environmental protection authority in Svalbard (Derocher et al. 2002b). Polar bears have complete protection from harvest under the Svalbard Treaty (Derocher et al. 2002b).

Approximately 65% of the land area of Svalbard is totally protected, including all major regions of denning by female bears; however, protection of habitat is only on land and to 4 nautical miles offshore. Marine protection was increased in 2004 when the territorial border of the existing protected areas was increased to 12 nautical miles (Aars et al. 2006). Norway claims control of waters out to 200 nautical miles and regard polar bears as protected within this area.

In 2001, the Norwegian Parliament passed a new Environmental Act for Svalbard which went into effect in July 2002. This Act was designed to ensure that wildlife is protected, with exceptions made for hunting. The regulations included specific provisions on harvesting, motorized traffic, remote camps and camping, mandatory leashing of dogs, environmental pollutants and on environmental impact assessments in connection with planning development or activities in or near settlements. Some of these regulations were specific to the protection of polar bears e.g. through enforcing temporal and spatial restrictions on motorized traffic and through giving provisions on how and where to camp, and to ensure adequate security concerning polar bears in the area (Aars et al. 2006).

In 2003 Svalbard designated six new protected areas, two nature reserves, three national parks and one "biotope protection area". The new protected areas are mostly located around Isfjord, the most populated fjord on the west side of the archipelago. Another protected area, Hopen, has special importance for denning bears and is an important denning area on Svalbard (Aars et al. 2006). Kong Karls Land is the main denning area and has the highest level of protection under the Norwegian land management system. These new protected areas cover 4449 km^2, which is 8% of the Archipelago's total area, and increase the total area under protection to 65% of the total land area in all protected areas (http://www.norway.org/News/archive/2003 /200304svalbard.htm).

e. Denmark/Greenland

Under terms of the Greenland Home Rule (1979) the government of Greenland is responsible for management of all renewable resources including polar bears. Greenland is also responsible for providing scientific data for sound management of polar bear populations and for compliance with terms of the *1973 Polar Bear Agreement*. Regulations for the management and protection of polar bears in Greenland that were introduced in 1994 have been amended several times (Jensen 2002). Hunting and reporting regulations include who can hunt polar bears, protection of family groups with cubs of the year from trophy hunting, mandatory reporting requirements, and regulations on the permissible firearms and means of transportation (Jensen 2002). In addition there are specific regulations which apply to the traditional take within the National Park of North and East Greenland and the Melville Bay Nature Reserve. A large amount of polar bear habitat occurs within the National Park of North and East Greenland. During the fall of 2000, the Greenland Home Rule Government signed a MOU with Governement of Nunavut concerning shared populations. Greenland introduced a quota system taking effect on 1 January 2006 (Lønstrup 2005).

E. Other natural or manmade factors affecting the continued existence: contaminants, development, human interactions/tourism.

1. Contaminants

Understanding the potential effects of contaminants on polar bears in the Arctic is confounded by the wide range of contaminants present, each with different chemical properties and biological effects, and the differing geographic, temporal, and ecological exposure regimes impacting each of the 19 polar bear populations. Further, contaminant concentrations differ with age, sex, reproductive status, and other factors. Contaminant sources and transport, geographical, temporal patterns and trends, and biological effects are detailed in several recent publications (AMAP 1998, AMAP 2004, AMAP 2005). Three main groups of contaminants in the Arctic are thought to present the greatest potential threat to polar bears and other marine mammals: petroleum hydrocarbons, persistent organic pollutants (POPSs), and heavy metals.

a. Petroleum Hydrocarbons

The principal petroleum hydrocarbons include crude oil, refined oil products, polynuclear aromatic hydrocarbons (PAHs), and natural gas and condensates (AMAP 1998). Petroleum hydrocarbons come from both natural and anthropogenic sources. The primary natural source is oil seeps. Anthropogenic sources include activities associated with exploration, development, and production (well blow outs, operational discharges), ship and land based transportation (oil spills from pipelines, accidents, leaks, and ballast washings), discharges from refineries and municipal waste water, and combustion of wood and fossil fuels. In addition to direct contamination, petroleum hydrocarbons are transported from more southerly areas to the Arctic via long range atmospheric and oceanic transport, as well as by north-flowing rivers (AMAP 1998).

The most direct exposure of polar bears to petroleum hydrocarbons comes from direct contact with and ingestion of oil from acute and chronic oil spills. Polar bear range overlaps with many active and planned oil and gas operations within 25 miles of the coast or offshore. To date, no major oil spills have occurred in the marine environment within the range of polar bears. However spills associated with terrestrial pipelines have occurred in the vicinity of polar bear habitat and denning areas (e.g. Russia, Komi Republic, 1994 oil spill, http://www.american.edu/ted/KOMI.HTM). Despite numerous safeguards to prevent spills, smaller spills do occur. Minerals Management Service (2004) estimated an 11% chance of a marine spill greater than 1000 barrels in the Beaufort Sea from the Beaufort Sea Multiple Lease Sale in Alaska. An average of 70 oil and 234 waste product spills per year occurred between 1977 and 1999 in the North Slope oil fields (USFWS 2006c). The largest oil spill (estimated volume of approximately 201,000 gallons) from the North Slope Oil fields in Alaska to date occurred on land in March 2006, resulting from an undetected leak in a corroded pipeline. Similar situations are possible from underwater pipelines. Spills during the fall or spring during the formation or breakup of ice present a greater risk because of difficulties associated with clean up during these periods and the presence of bears in the prime feeding areas over the continental shelf. Amstrup et al. (2000a) concluded that the release of oil trapped under the ice from an underwater spill during the winter could be catastrophic during spring break-up. During the autumn freeze-up and spring break-up periods it is expected that any spilled oil in the marine environment would concentrate and accumulate in open leads and polynyas, areas of high activity for both polar bears and seals (Neff 1990), resulting in oiling of both polar bears and seals (Neff 1990, Amstrup et al. 2000a, Amstrup et al. 2006a). Increases in Arctic oil and gas development coupled with increases in shipping and/or development of offshore and land-based pipelines increase the potential for an oil spill to negatively affect polar bears and/or their habitat. Any future declines in the Arctic sea ice may result in increased tanker traffic in high bear use areas (Frantzen and Bambulyak 2003) which would increase the chances of an oil spill from a tanker accidents, ballast discharge, or discharges during the loading and unloading the oil at the ports.

Biological Effects of Petroleum Hydrocarbons

Polar bears are most likely to come in contact with oil either directly at preferred feeding areas or through ingesting contaminated prey (Neff 1990). Polar bears groom themselves regularly as a means to maintain the insulating properties of their fur, so oil ingestion would likely be by this means (Neff 1990). Most direct information comes from an experimental study (St. Aubin 1990) in which two polar bears were involuntarily forced into a pool of oil for 15 minutes and then observed. The animals immediately attempted to clean the oil from their paws and forelegs by licking, and continued grooming trying to clean their fur for five days. After 26 days one bear died of liver and kidney failure and the other bear was euthanized at day 29. Gastrointestinal fungus-containing ulcers, degenerated kidney tubules, low-grade liver lesions, and depressed lymphoid activity were found during necropsy (St. Aubin 1990). Other effects included loss of hair (Derocher and Stirling 1991), anemia, anorexia, and stress (St. Aubin 1990). The results of an earlier study on thermoregulation (Øritisland et al. 1981), as well as this study, suggest that polar bears are particularly vulnerable to oil spills due to inability to thermo-regulate and to poisoning due to ingestion of oil from grooming and/or eating contaminated prey (St. Aubin 1990). Additionally, polar bears are curious and are likely to investigate oil spills and oil contaminated wildlife. Although it is not known whether healthy polar bears in their natural environment would avoid oil spills and contaminated seals, bears that are hungry are likely to scavenge contaminated seals, as they have shown no aversion to eating and ingesting oil (St. Aubin 1990, Derocher and Stirling 1991).

Due to the seasonal distribution of polar bears, the times of greatest impact from an oil spill are summer and autumn (Amstrup et al. 2000a). This is important because distributions of polar bears are not uniform through time. In fact, near-shore densities of polar bears are two to five times greater in autumn than in summer (Durner et al. 2000), and polar bear use of coastal areas during the fall open water period has increased in recent years in the Beaufort Sea.

Though there is a low probability that a large number of bears (i.e. 25-60) might be affected by a large oil spill, the impact of a large spill, particularly during the broken ice period, could be significant to the polar bear population (Federal Register 71:43926, USFWS 2006). The number of polar bears affected by an oil spill could be substantially higher if the spill spread to areas of seasonal polar bear concentrations, such as the area near Kaktovik, in the fall, and could have a significant impact to the Southern Beaufort Sea (SB) polar bear population. It seems likely that an oil spill would affect ringed seals the same way the Exxon Valdez oil spill affected harbour seals (Frost et al. 1994a, Frost et al. 1994b, Lowry et al. 1994, Spraker et al. 1994). As with polar bears the number of animals killed would vary depending upon the season and spill size (NRC 2003).

Industrial development in polar bear habitat may also expose individuals to other hazardous substances through improper storage or spills. For example, one polar bear died in Alaska from consuming ethylene glycol in 1988 (Amstrup et al. 1989).

b. Persistent Organic Pollutants (POPS)

Contamination of the Arctic and sub-Arctic regions through long-range transport of pollutants has been recognized for over 30 years (Bowes and Jonkel 1975, deMarch et al. 1998, Proshutinsky and Johnson 2001, MacDonald et al. 2003, Lie et al. 2003). These compounds are transported via large rivers, air, and ocean currents from the major industrial and agricultural centers located at more southerly latitudes (Barrie et al. 1992, Li et al. 1998a, Proshutinsky and Johnson 2001, Lie et al. 2003). The presence and persistence of these contaminants within the Arctic is dependent on many factors, including transport routes, distance from source and the quantity and chemical composition of the contaminants released to the environment. The Arctic ecosystem is particularly sensitive to environmental contamination due to the slower rate of breakdown of persistent organic pollutants (POPs), including organochlorine compounds, relatively simple food chains, and the presence of long-lived organisms with low rates of reproduction and high lipid levels. The persistence and lipophilic nature of organochlorines increase the potential for bioaccumulation and biomagnification at higher trophic levels (Fisk et al. 2001). Polar bears are well suited for monitoring environmental contaminants because of their position at the top of the food chain, wide circumpolar distribution, and ability to accumulate a wide range of persistent contaminants. Polar bears, because of their position at the top of the Arctic marine food chain, have some of the highest concentrations of OCs of any Arctic mammals (Braune et al. 2005 p. 23). Organochlorine metabolites, particularly MeSO2-PCB and HO-PCB, which have potential endocrine disrupting properties, are an example of biotransformation of OCs in polar bears (Letcher et al. 1998). Adipose tissue and/or blood samples from most of the polar bear populations in the Arctic have been sampled at least once for the main groups of persistent organic pollutants described below.

The most studied POPS in polar bears include polychlorinated biphenyls (PCBs), chlordanes (CHL), DDT and its metabolites, toxaphene, dieldrin, hexachloroabenzene (HCB), hexachlorocyclohexanes (HCHs), and chlorobenzenes (ClBz). Overall, the relative proportion of the more recalcitrant compounds, such as PCB 153 and β-HCH, appears to be increasing in polar bears (Braune et al. 2005). Although temporal trend information is lacking, newer compounds, such as polybrominated diphenyl ethers (PBDEs), polychlorinated naphthalenes (PCNs), perflouro-octane sulfonate (PFOS), perfluoroalkyl acids (PFAs), and perflourocarboxylic acids (PFCAs) have been recently found in polar bears (Braune et al. 2005). Of this relatively new suite of compounds, there is concern that both PFOS, which are increasing rapidly, and PBDEs are a potential risk to polar bears (deWit 2002, Martin et al. 2004, Braune et al. 2005, Smithwick et al. 2006). Currently the polychlorinated dibenzo-p-dioxins (PCDDs), dibenzofurans (PCDFs) and dioxin-like PCBs are at relatively low concentrations in polar bears (Norstrom et al. 1990).

Geographic and temporal trends in Persistent Organic Pollutants in polar bears and their habitats

PCBs

The highest Σ PCB concentrations have been found in polar bears from the Russian Arctic (Franz Joseph Land and the Kara Sea), with decreasing concentrations to the east and west (Andersen et al. 2001). Throughout the Arctic the highest concentrations of ΣPCBs in descending order by region or (population) are Franz Josef Land (Kara Sea) > Kara Sea > Svalbard > East Greenland > North Baffin Island (Baffin Bay) > South Baffin Island (Baffin Bay) > Western Hudson Bay > Amundson Gulf (Northern Beaufort Sea) > Foxe Basin/Gulf of Boothia > Beaufort Sea (Southern Beaufort Sea) > Siberian Sea (Laptev Sea) > Chukchi Sea (Norstrom et al. 1998, Muir and Norstrom 2000, Andersen et al. 2001, Lie et al. 2003, Verreault et al. 2005, Braune et al. 2005). In a comparison of polar bear adipose tissues from Alaska, Canada, East Greenland, and Svalbard, Norway from 1996 to 2002, East Greenland and Svalbard populations had the highest concentrations of the more persistent PCB congeners (hepta- to nona-chlorinated) whereas Alaska had the highest proportion of the lower chlorinated PCB congeners (tri- to penta-chlorinated) (Verreault et al. 2005). Andersen et al. (2001), in a comparison of PCB congeners in blood samples from Svalbard, Franz Joseph Land, Kara Sea, Siberian Sea, and Chukchi Sea (1987-1995), found that the higher chlorinated PCBs decreased from Svalbard east to the Chukchi Sea.

Assessment of temporal trends requires long-term data sets which are available for only a few populations. Direct temporal comparisons between populations or within a population often cannot be made, as contaminant concentrations are influenced by factors such as sex ratio, age composition, nutritional and reproductive status, feeding habits, analytical techniques, congeners analyzed, tissues sampled, and statistical analyses used (AMAP 1998, Muir et al. 1999).

Braune et al. (2005) presents a detailed summary of temporal changes in PCBs and chlorinated pesticides for Canadian ringed seal and polar bear populations. The Western Hudson Bay population has been studied since the late 1960s and thus has one of the most complete temporal data sets that can be used to assess temporal changes in organochlorine (OC) concentrations. Although Verreault et al. (2005) reported a 32% decline in ΣPCBs in adipose tissue from adult females from Western Hudson Bay between the periods 1989-1993 and 1996-2002, Braune et al.

(2005) indicated that no long-term trend was evident as the concentrations of ΣPCBs in the 1990s were similar to those of the late 1960s. Norstrom et al. (2000) observed a significant decrease in the ΣPCBs in Western Hudson Bay in the 1990s. The composition of congeners that make up the ΣPCBs in Western Hudson Bay changed from 1968 to 2002, with a decrease in the number of highly chlorinated congeners and an increase in the less chlorinated congeners (Braune et al. 2005). Recent trends indicate an average decline of 42% of ΣPCBs from the time periods 1989-1996 (Norstrom et al. 1998) and 1996-2002 (Verreault et al. 2005) for the Alaska populations (Southern Beaufort Sea and the Chukchi Sea combined), Amundsen Gulf, Western Hudson Bay, Foxe Basin/Gulf of Boothia, Lancaster Sound, North Baffin Island, and South Baffin Island (Verreault et al. 2005). A comparison of ΣPCBs concentrations between the same time periods indicated a decrease of 50% and 75% in Svalbard and East Greenland (Verreault et al. 2005). Although Derocher et al. (2003) found that ΣPCBs concentrations in blood plasma from polar bears in Svalbard, Norway increased from 1967 to 1993-1994, other studies have found declining ΣPCBs concentrations in both Svalbard (Henriksen et al. 2001) and East Greenland (Dietz et al. 2004). Peak Svalbard PCB concentrations probably occurred between the mid-1970s to the mid-1980s and may have been quite high (≈ 100 ppm) based on backward extrapolation from the steep decline in the early 1990s (Henriksen et al. 2001). Overall there is evidence for recent declines in ΣPCBs for most populations.

Other Chlorinated Hydrocarbon Contaminants

The pattern of distribution of most other chlorinated hydrocarbons and metabolites generally follows that of ΣPCBs, with the highest concentrations of DDT-related compounds and ΣCHL in Franz Joseph Land and the Kara Sea, followed by East Greenland, Svalbard, the eastern Canadian Arctic populations, the western Canadian populations, the Siberian Sea, and finally the lowest concentrations in Alaska populations (Bernhoft et al. 1997, Norstrom et al. 1998, Andersen et al. 2001, Kucklick et al. 2002, Lie et al. 2003, Verrault et al. 2005, Braune et al. 2005). In a comparison of chlorinated hydrocarbon contaminants and metabolites in polar bears from Alaska, Canada, East Greenland, and Svalbard, Norway from 1996 to 2002, ΣCHL concentrations were fairly uniformly distributed throughout the Arctic, with the lowest concentrations occurring in Alaska (Verreault et al. 2005). In contrast to the pattern exhibited by most other OCs, Alaska had the highest concentrations of ΣHCH and pentachlorobenzene (PnClBz), with polar bears from Alaska showing a six fold increase in ΣHCH concentrations relative to Svalbard after adjusting for age (Verreault et al. 2005).

Decreases in ΣHCH in polar bear adipose tissue were noted between 1990 and 2000-2001 in East Greenland (Dietz et al. 2004) and in Svalbard from 1991-1996 (AMAP 2004). In the Canadian Arctic, ΣHCH declined significantly between 1984 and the 1990s (Braune et al. 2005) and has remained relatively constant for the last decade (Norstrom 2000). From 1968 to the 1990s, the proportion of β-HCH making up the ΣHCHs increased significantly for most populations, whereas the proportion of α-HCH decreased. The prevalence of the β-HCH isomer in polar bears is in contrast to ringed seal, a primary prey item, where α-HCH is the most common isomer (Kucklick et al. 2002). Suspected sources for the high concentrations of β-HCH in Alaska are China and Southeast Asia Li, et al. 1998a, Li et al. 1998b).

ΣCHL concentrations have been shown to vary with sex (Muir et al. 1999), age (Dietz et al. 2004), and season (Polischuk et al. 2002, Deitz et al 2004). Concentrations of ΣCHL increased between 1968 and 1984 (Norstrom et al.1998) and appeared to decline in most populations from 1989-2002, except for Western Hudson Bay where they remained relatively unchanged (Verreault et al. 2005). HCB concentrations also have shown a similar decline (Braune et al. 2005).

ΣDDT concentrations in adipose tissues declined in most Arctic polar bear populations since the active DDT period in the 1970s (Norstrom 2001, Fisk et al. 2003, Dietz et al. 2004, DeWit et al 2004, Verreault et al. 2005, Braune et al. 2005). A comparison of mean p,p'-DDE concentrations from female polar bears during 1989-1993 with samples from 1996-2002 indicated a continued decline in most populations except for Amundsen Gulf and East Greenland populations (Verreault et al. 2005), where p,p'-DDE concentrations remained relatively unchanged. In a similar study, Dietz et al. (2004 p. 107) found that ΣDDT and p,p'-DDE concentrations declined 66% in East Greenland from 1990 to 1999-2000. The BMF for DDE from seals is relatively low, indicating that polar bears can metabolize this compound rather quickly. Although the proportion of DDE with respect to ΣDDT may be increasing, DDE concentrations are generally low compared to other POPs and thus not currently an important POP in polar bears.

Polybrominated Diphenyl Ethers

Polybrominated diphenyl ethers *(*PBDEs) share similar physical-chemical properties with PCBs (Wania and Dugani 2003), and are thought to be transported to the Arctic by similar pathways. Muir et al. (2006) analyzed archived samples (Dietz et al 2004, Verreault et al. 2005) for PBDE concentrations, finding the highest mean ΣPBDE concentrations in female polar bear adipose tissue from East Greenland and Svalbard. Lower concentrations of PBDE were found in adipose tissue from the Canadian and Alaskan populations (Muir et al. 2006). Differences between the PBDE concentrations and composition in liver tissue between the Southen Beaufort Sea and the Chukchi/Bering seas populations in Alaska suggest differences in the sources of PBDE exposure (Kannan et al. 2005). Overall, ΣPBDEs concentrations are much lower and less of a concern compared to PCBs, oxychlordane, and some of the more recently discovered perfluorinated compounds. PBDEs are metabolized to a high degree in polar bears and thus do not bioaccumulate as much as PCBs (Wolkers et al. 2004). Of the four principal PBDE congeners (PBDE 47, 99, 100, and 153), PBDE 47 was the major congener (65-82%) found in polar bears (Ikonomou 2002, Muir et al. 2006). Ikonomou (2002) found that PBDE 47 concentrations were higher in polar bears than ringed seals from the Amundsen Gulf region in western Canada. Samples from the Canadian Arctic populations had higher proportions of PBDE 99, 100, and 153 than the other populations (Muir et al. 2006).

Ikonomou (2002) found that ΣPBDEs increased exponentially in ringed seals from the Amundsen Gulf region between 1981 and 2000, but more recent data from 2000 to 2003 suggest that ΣPBDE concentrations may be leveling off or declining in this area (Ikonomou 2005). The annual production of PBDEs increased in the 1990s from the 4.0 kt in 1990 (Arias 1992). Use of PBDEs in 1999 was estimated to be 8.5 kt, of which >90% was in North America (AMAP 2004).

By 2000, the global use of PBDEs was considerably less in Europe compared to 1990 due to restrictions put in place in different countries beginning in 2001 (BSEF 2000).

Perfluorooctane Sulphonate

Perfluorooctane sulphonate (PFOS) levels were 10 times greater in polar bear livers from eastern Hudson Bay (Martin et al. 2004) than Alaska (Giesy and Kannan 2001, Kannan et al. 2001), which suggests that eastern Hudson Bay may be closer to dominant mid-latitude manufacturing and use centers, relative to Alaska. Although PFOS concentrations have not been determined for most polar bear populations, concentrations found in eastern Hudson Bay indicate that PFOS is the most abundant organohalogen compound found to date (Martin et al. 2004). Even within Alaska, PFOS concentrations in polar bear livers from the CS subpopulation were greater than other persistent organic pollutants analyzed, including PBDEs, PCBs, and other OC compounds (Kannan et al. 2005). Although high concentrations of PFOS in the livers may have toxic significance, PFOS concentrations are probably not a major contaminant of the whole body as are PCBs and oxychlordane. The distribution of PFOS in polar bear tissues is unknown, since liver is the only tissue in which PFOS concentrations have been measured. The best study to date on the distribution of PFOS in the whole body was done in trout (Martin et al. 2003). In that study, the highest PFOS concentrations were in the liver, kidney, and blood plasma and the lowest concentrations were in muscle and adipose tissue and thus were not uniformly distributed throughout the body (Martin et al. 2003). The unique toxicological properties of PFOS, its environmental persistence and the increasing concentrations reported in polar bear livers from 1972 to 2002 by Smithwick et al. (2006) are of concern. Doubling times in the eastern (near Baffin Island, Canada) and western (Barrow, Alaska) Arctic populations were 3.6 years and 13.1 years, respectively (Smithwick et al. 2006), indicate that polar bear populations closer to source areas experience increased risk.

Biological Effects of Persistent Organic Pollutants

Although baseline information on contaminant concentrations is available, determining the biological effects of these contaminants in polar bears is difficult. The synergistic effects of different contaminants (Payne et al. 2001), variations in bioaccumulation and biomagnification rates of different compounds through the food web, variation in the persistence and changes in chemical composition of compounds due to metabolism and abiotic degradation, and polar bear physiology (delayed implantation, lactation, fat metabolism, food habits, reproductive status, condition, age) are all factors to be considered in determining overall biological effects (Fisk et al. 2001, Fisk et al. 2005). PCBs have been linked directly to impaired reproduction in ringed seals (Addison 1980), but not polar bears, since controlled experiments have not been conducted. However, field observations of reproductive impairment in females, lower survival of cubs, and increased mortality of females in Svalbard, Norway (Wiig 1998, Wiig et al. 1998, Skaare et al. 2000, Haave et al. 2003, Oskam et al. 2003, Derocher et al. 2003) suggest that high concentrations of PCBs may have contributed to population level effects in the past. Currently it is not thought that present PCB concentrations are having population level effects. Other effects linked to PCB exposure in polar bears include induction of hepatic P450 enzymes (Letcher et al. 1996), altered and impaired immune systems (Bernhoft et al. 2000, Skaare et al. 2001b, Larsen et al. 2002, Lie et al. 2004), and changes in endocrine system function (Braethen et al. 2000, Skaare et al. 2001a, Letcher et al. 2002, Haave et al. 2003, Oskam et al. 2003). Table 3.1 summarizes biological effects (AMAP 2004).

Table 3-1. Overview of toxic properties of various POPs. ▼= suppression or decrease, ▲ = induction or increase.

	Reproductive/ developmental effects	*Neurotoxic effects*	*Cytochrome P450 effects*	*Immune effects*	*Thyroid/ retinol effects*	*Cancer*	*Other*
Aldrin and dieldrin	▼ Reproduction		Induces cytochrome P450 2B	Suppresses immune system		Non-mutagenic. Increased liver tumors	
Chlordanes	▼ Reproduction		Induces cytochrome P450 2B	Suppresses immune system		Non-mutagenic tumor promoter	
DDT and metabolites	Egg-shell thinning in bird eggs. ▼ Reproduction		Induces cytochrome P450 2B	Suppresses immune system	▼ Thyroid weight		Adrenal cortex hyperplasia
HCBz	Fetotoxic. Teratogenic. ▼ Reproduction		Induces cytochrome P450 1A and 2B	Suppresses immune system	▼ T3 and T4 ▲ TSH ▲ Thyroid weight	Non-mutagenic tumor promoter	▲ Porphyria
α-HCH	No information		Induces cytochrome P450 2B			Non-mutagenic tumor promoter	
β-HCH	Estrogenic		Induces cytochrome P450 2B	Suppresses immune system	▲ Thyroid weight	Non-mutagenic tumor promoter	
γ-HCH (lindane)	Estrogenic and antiestrogenic. ▼ Reproduction		Induces cytochrome P450 1A and 2B			Non-mutagenic tumor promoter	
Mirex	▼ Reproduction		Induces cytochrome P450 2B	Suppresses immune system		Non-mutagenic. Induces tumors	
Toxaphenes	Fetotoxic. ▼ Reproduction		Induces cytochrome P450 1A, 2B and 3A	Suppresses immune system	▲ Thyroid-weight ▲ TSH	Mutagenic, potent carcinogen. Inhibits GJIC	▲ Bone brittleness in fish. Adrenal hypertrophy
Endosulfan	Fetotoxic. ▼ Reproduction		Induces cytochrome P450 1A and 2B	Suppresses immune system		Non-mutagenic	
PCDD/Fs and nPCBs and metabolites	Fetotoxic. Deformities. ▼ Reproduction	Permanent changes in learning, behavior, memory (nPCB)	Induces cytochrome P450 1A	Thymic atrophy. Suppresses immune system	▼ T3 and T4 ▼ Vitamin A	Non-mutagenic tumor promoters. Affects GJIC	▲ Porphyria
Other PCBs	Fetotoxic. Deformities. ▼ Reproduction	Permanent changes in learning, behavior, memory. Decreased dopamine	Induces cytochrome P450 2B	Suppresses immune system	▼ T3 and T4 ▼ Vitamin A	Non-mutagenic tumor promoters. Affects GJIC	▲ Porphyria Hyperadrenocortism
SCCPs	Fetotoxic Deformities. ▼ Reproduction	▼ Motor performance	Induces cytochrome P450 1A	No information	▼ T4 ▲ TSH	Non-mutagenic. ▲ Peroxisome proliferation. Inhibits GJIC	
PCNs	Embryotoxic. ▼ Reproduction		Induces cytochrome P450 1A				
Octachlorostyrene and metabolites			Induces cytochrome P450 1A and 2B		Binds to TTR *in vitro*		
PBDEs	Estrogenic and antiestrogenic	Permanent changes in learning, behavior, memory	Induces cytochrome P450 1A and 2B	Suppresses immune system	▼ T4 ▼ Vitamin A	Non-mutagenic	
PFOS/PFOA	▼ Reproduction					Non-mutagenic, tumor promoter ▲ Peroxisome proliferation. Inhibits GJIC	
TBT and metabolites	Imposex in invertebrates. Deformities. ▼ Reproduction		Inhibits liver cytochrome P450 1A, 2B, and 3A	Suppresses immune system		May be carcinogenic	

Endocrine System

Polar bears, because of their position at the top of the Arctic marine food chain, have some of the highest concentrations of OCs of any Arctic mammals (Braune et al. 2005). Polar bears are able to biotransform OC contaminants, resulting in high concentrations of OC metabolites, some of which have demonstrated endocrine disrupting activity (Letcher et al. 2000, Braune et al. 2005). Braune et al. (2005) concluded that the "effects of OC exposure in Arctic wildlife are greatest for this species" because of the high OC concentrations and the ability of polar bears to metabolize these compound to toxic metabolites. PCBs and hydroxylated (HO) PCBs have been shown to interfere with retinol (vitamin A) (Rolland 2000, Simms and Ross 2000) and thyroid hormones (Brouwer et al. 1989, Braethen et al. 2004) which are important for the growth and development of mammals (Skaare et al. 2001a). Specifically retinol is thought to be important in the growth and development of epithelial tissues and the immune system (Skaare et al. 2001a). The presence of 4-OH-HpCS, a metabolite of octochlorostyrene, is thought to be able to bind to transthyretin (TTR), a transport protein, thus affecting the transport of the thyroid hormone and circulating retinol concentrations (Sandau et al. 2000). Polar bears with higher ΣPCBs concentration had significantly lower retinol concentrations (Sandau 2000). In contrast, polar bears with higher concentrations of HO-PCBs (Letcher et al. 2005, Sandala et al. 2004, Sandau et al. 2000) had higher retinol concentrations. PCB metabolites have also been shown to disrupt the normal activity of thyroid and estrogen in endocrine system in laboratory animals (Letcher et al. 2000). High levels of PBDEs have been shown to affect thyroid function and have been associated with developmental toxicity in laboratory rats (de Wit 2002) and in polar bears from Svalbard (Braethen et al. 2004, Skaare et al. 2001a). In contrast, concentrations of ΣPCBs, ΣCHLs, ΣDDTs, ΣHCHs, HCB, Dieldrin, and ΣPBDEs found in polar bears from East Greenland were not thought to have adverse effects on lymph nodes, spleen, thyroid and thymus tissues which are involved in immunological responses (Kirkegaard et al. 2005). The presence of higher secondary follicle counts in response to higher concentrations of ΣCHLs ΣHCHs HCB, and dieldrin may indicate increased infection rates in the spleens from East Greenland polar bears. High concentrations of ΣPCBs, ΣCHLs, ΣDDTs, and dieldrin are suspected to reduce the bone mineral density in subadult male and female polar bears and adult males (Sonne et al. 2004).

Reproduction

Numerous laboratory studies have linked PCBs and OC pesticides, including PCDDs, PCDFs, PCBs, SCCPs, PCNs, OCs, PBDEs, and PFOS to reproductive and developmental toxicity (de Wit et al. 2004). However, more study is needed to fully understand the biological effects of contaminants on polar bear recruitment and survival rates. Polischuk et al. (1995, 2002) found that adult female polar bears with cubs had significantly lower concentrations of ΣPCBs, ΣDDTs, ΣCHLs, ΣHCHs, ΣClBs than females that had lost their cubs by the following fall. The loss of these contaminants from the females that retained their cubs was not due to offloading the contaminants to the cubs through nursing because the contaminants were measured in milk as the females emerged from the den when all females still had their cubs. Polischuk et al. (2002) found that concentrations of ΣPCBs and ΣCHLs in milk approximately doubled when polar bears were using their fat resources (i.e. fasting), thus increasing the exposure of nursing cubs to high concentrations of OCs during a critical developmental period. The data from Polischuk et al. 1995, suggests that the critical point for cub survival may be between 1-6 ppm in the breast milk. However this may also be due to the low fat content in the female which in turn may result in higher PCB concentrations. However, if there is a toxic link between PCB concentrations and cub survival this would explain the lower cub survival and a scarcity of older females ($\geq$ 16 yrs) in the Svalbard population (Wiig et al. 1998, Derocher et al. 2003). Adult female polar bears with higher PCB concentrations from Svalbard, Norway exhibited higher progesterone concentrations (Haave et al 2003). Haave et al. (2003) speculated that high levels of progesterone could inhibit secretion of follicle-stimulating hormone, thus preventing normal ovulation from occurring.

Immune System

An assessment of the effects of high concentrations of OCs on the immune system of free ranging polar bears in Svalbard, Norway, and Churchill, Canada, found that bears with high concentrations of ΣPCBs, sum of organochlorine pesticides (ΣOCPs), or the interaction of the

ΣPCBs and ΣOCPs had decreased ability to produce antibodies to influenza-, reo- and herpes viruses, tetanus toxoid, and *Mannheimia sp*. (Lie et al. 2004). Lie et al. (2004) also found that high ΣPCBs and ΣOCPs concentrations reduced the ability of lymphocyte populations to proliferate after stimulation with mitogens and antigens in vitro. Thus polar bears with high concentrations of ΣPCBs and ΣOCPs may be more susceptible to infections than polar bears with lower contaminant concentrations. The importance of immune competence is something that would only be tested during an epizootic event.

c. Metals

Numerous essential and non-essential elements have been reported on for polar bears, but the focus has been primarily on the most toxic and/or abundant elements in marine mammals, including mercury, cadmium, selenium, and lead. Increased development in the Arctic, release from natural deposits, and long-range transport of metals to the Arctic and sub-Arctic have raised concern about the potential effects on polar bears and other marine mammals (Norstrom et al. 1986, Braune et al. 1991, Pacyna and Keeler 1995, Pacyna 1996, Dietz et al. 1998, Lindberg et al. 2002, and Braune et al. 2005). Although other elements are of potential concern, the focus of this section will be on mercury, because of its potential toxicity at relatively low concentrations, ability to biomagnify and bioaccumulate in the food web, and due to 7-11 fold increases in the Arctic since pre-industrial times (Braune et al. 2005, Nilsson and Huntington 2002, Dietz et al. 2006). Mercury is a non-essential element that arises from both natural and anthropogenic sources (Dietz et al. 1998, Lindberg et al. 2002, Skov et al. 2004). Dietz et al. 1998 estimated that 200-300 tons of mercury are transported to the Arctic annually through long-range atmospheric, oceanic, and riverine import. The primary source of mercury in polar bears is from their diet of phocid seals. Although mercury concentrations generally decrease in the order of liver > kidney > muscle in most marine mammals, the highest observed concentrations occur in the kidney in polar bears, followed by liver and muscle tissue.

Geographic and temporal trends in mercury concentrations in polar bears and their habitat

Polar bears from the western Canadian Arctic and southwest Melville Island, Canada (Braune et al. 1991, Norstrom et al. 1986), and ringed seals from the western Canadian Arctic (Wagemann et al. 1996, Deitz et al. 1998, Dehn et al. 2005, Riget et al. 2005), have some of the highest known mercury concentrations. Wagemann et al. (1996) observed an increase in mercury from eastern to western Canadian ringed seal populations and attributed this pattern to a geologic gradient in natural mercury deposits.

Assessment of temporal trends is limited by lack of long-term data sets, poor or limited geographical coverage, and datasets that use varying analytical methods, statistical analyses, and sampling protocols. Analysis of mercury concentrations in sediments, peat bogs, and ice (Braune et al. 2005), beluga teeth from the Mackenzie Delta (Outridge et al. 2002), and polar bear hair from Greenland (Wheatley and Wheatley 1988, Dietz et al. 2005) all indicate that mercury concentrations have increased from the pre-industrial era to the present. Despite reductions in mercury emissions in North America and Western Europe, global emissions may be increasing (AMAP 2005). Asia accounted for the majority of the mercury emissions in 1995 (AMAP 2005) Recent trends from short-term data sets are variable, with mercury levels declining (East Greenland, Dietz et al. 2006), remaining stable (European Arctic, Braune et. al. 2005), or increasing (Pond Inlet, Canada: Wagemann et al. 1996; East Greenland: Deitz et al. 2006).

Biological effects of mercury

Although the contaminant concentrations of mercury found in marine mammals often exceed those found to cause effects in terrestrial mammals (Fisk et al. 2003), most marine mammals appear to have evolved effective biochemical mechanisms to tolerate high concentrations of mercury. Prior to 1997, almost no information was available to assess the effects of mercury on marine mammals, including polar bears (Fisk et al. 2005). The biological effects of mercury are determined by the amount and type of exposure, overall health of the bear, and age (AMAP 2005). Methylmercury (organic mercury) is more toxic than inorganic mercury, and more readily accumulated. Thus the amount of methylmercury and the percentage of organic mercury to total mercury are important biological measures. Mercury poisoning in mammals is characterized by neurological impairment, compromised immune response, and damage to the central nervous system, liver, and kidney (WHO 1989, 1990, 1991). Consumption of as little as 4µg of mercury per kilogram of body weight in humans can elicit clinical signs of mercury poisoning (Clarkson 1987). Fetuses and polar bear cubs may be particularly susceptible to methylmercury during development of the central nervous system (Dietz et al. 1998 p 399). However, marine mammals with high concentrations of mercury often have high concentrations of selenium which combines with the mercury forming mercuric selenide in the liver (AMAP 2005). The 1:1 molar ratio of mercury to selenium which is commonly found in marine mammal livers, including polar bear, and the lack of evidence of mercury toxicity suggest that polar bears are able to demethylate Hg, by forming Hg/Se complexes, and accumulate higher levels of mercury than their terrestrial counterparts without detrimental effects. Evidence of mercury poisoning is rare in marine mammals, but Dietz et al. (1990) noted that sick marine mammals often have higher concentrations of methylmercury, suggesting that these animals may no longer be able to detoxify methylmercury. Hepatic mercury concentrations are well below those expected to cause biological effects in most polar bear populations (AMAP 2005). Only two polar bear populations have concentrations of mercury close to the biological threshold levels of 60µg ww reported for marine mammals (Law et al. 1996), the Viscount Melville (southwest Melville Sound), Canada and the Southern Beaufort Sea (eastern Beaufort Sea) (Dietz et al. 1998).

d. Future Impacts from Contaminants

The highest concentrations of OCs have been found in species at the top of the marine food chains such as glaucous gulls which scavenge on marine mammals and polar bears which feed primarily on seals (Braune et al. 2005). Consistent patterns between OC and mercury contamination and trophic status have been documented in Arctic marine food webs (Braune et al. 2005). Changes in the food web dynamics could further change availability and access to seals which in turn could result in polar bears becoming more nutritionally stressed and perhaps more susceptible to effects of contaminants. These types of impacts are likely to vary between polar bear populations, age and sex cohorts, habitat use patterns, and the ability of polar bears to adapt to changes in sea ice dynamics.

Polar bears are not distributed evenly throughout the Arctic and concentrate in the most productive areas over the continental shelf and the inter-island archipelagos surrounding the Arctic Basin (Derocher et al. 2004). Potential changes to contaminant pathways and contaminant concentrations as a result of global warming, which are presented in the AMAP report (MacDonald et al. 2003), are discussed below.

Changes in circulation patterns of atmospheric and oceanic currents would result in changes to contaminant transport pathways. This could result in both increases and decreases of contaminant concentrations. Loss of sea ice will affect the deposition and volatilization of certain compounds, particularly POPs. Increased precipitation would increase deposition of airborne contaminants, particularly those associated with particulates. Warmer temperatures could influence microbial degradation rates and species composition, which could affect the release of some compounds such as HCH. In addition, changes in the climate and sea ice conditions due to warming could result in the release of contaminants trapped in the pack ice, increased exposure to new contaminants, increased bear densities on the remaining sea ice, changes in habitat use and an increase in energetic demands associated with locating food. All of these factors could reduce the overall health of the polar bear populations. Polar bears that become nutritionally stressed may become more susceptible to mercury poisoning and the effects of other contaminants. It has been documented that concentrations of PCBs and oxychlordane are inversely proportional to fat content of the bear (Polischuk et al. 2002). Thus starvation will induce significantly higher contaminant concentrations in all tissues (Polischuk et al. 2002). Currently PFOS concentrations are group of POPs that are of the most concern because of their widespread use, potentially toxic effects at least in the livers, and the rapidly increasing concentrations found in Arctic marine mammals (Smithwick et al. 2006).

Contaminant concentrations in most populations are presently not thought to have population level effects. However, one or several factors acting independently or together, such as loss or degradation of the sea ice habitat, decreased prey availability and accessibility, and increased exposure to contaminants have the potential to lower the recruitment and survival rates which ultimately would have negative population level effects. Svalbard, East Greenland, and the Kara Sea populations, which currently have some of the highest contaminant concentrations and thus have the potential for population level effects, should continue to be monitored closely.

Increases in Arctic oil and gas development and trans-Arctic shipping will increase the probability of an oil spill and release of contaminants. Melting of the permafrost could also affect pipelines in some parts of the Arctic. In addition, a large oil spill could have immediate population effects. The median number of bears affected by a hypothetical oil spill (5912 bbl – the largest spill thought probable from a pipeline spill) from the proposed Liberty offshore oil well, in the Beaufort Sea in Alaska, during the autumn freeze-up was less than 12 (range 0-61 bears). For the purposes of this "worst-case scenario" it was assumed that a polar bear would die if it contacted oil. However, it should be noted that oil is expected to persist and last many months to years in this cold environment, not just the 10 days following the spill which was the limit of the model's analytical power. Peterson et al. (2003), when evaluating the long-term effects of the Exxon Valdez oil spill in the sub-Arctic Prince William Sound, noted that persistence of toxic subsurface oil and chronic exposure through bioaccumulation, even at sub-lethal concentrations, can have long-term effects on wildlife.

To determine whether polar bears will experience negative biological effects from exposure to environmental contaminant concentrations, additional research needs to be conducted to determine threshold values (including sublethal effects such as reduced resistance to disease, potential for endocrine disruption, and altered behavior) for all contaminants found in polar bear tissues. A better understanding of how contaminant mixtures may affect polar bears is needed since contaminants are rarely found in isolation. Factors for consideration should include the biological effects of contaminant concentrations that exceed currently defined threshold levels, documentation of the exposure to new organohalogen compounds of concern, and the effects of climate change on contaminant exposure and biological consequences to polar bears.

e. Status of regulatory actions pertaining to contaminants

The formation of the Arctic Environmental Protection Strategy (AEPS) in 1989, supported by Canada, Denmark/Greenland, Iceland, Norway, Sweden, former Soviet Union, and the U.S., was one of the first international initiatives to address environmental protection of the Arctic (AEPS 1991a, Wilson 1998). Five programs, the Arctic Monitoring and Assessment Programme (AMAP), Conservation of Arctic Flora and Fauna (CAFF), Emergency Prevention, Preparedness and Response (EPPR), Protection of the Arctic Marine Environment (PAMI), and Sustainable Development and Utilization (SDU), were created under AEPS to implement this initiative. Since then there have been many international and national initiatives and agreements that recognize the need to prevent and reduce environmental impacts of contaminants to the Arctic (AEPS 1991b, see Wilson (1998) for a list and brief summary of some of these initiatives and agreements). Some of the pollutants now regulated by international treaties include a suite of POPs, including PCBs, dioxins, furans, hexachlorobenzene, aldrin, chlordane, dieldrin, DDT, endrin, heptachlor, mirex, and toxaphene. Two of the more important agreements, which have been signed, but not ratified by all the countries that participate in AEPS, are the Convention of the Long-Range Transboundary Air Pollution (LRTAP) and the Stockholm Convention on Persistent Organic Pollutants (AMAP 2002). The LRTAP convention seeks to reduce and control existing transboundary air pollution and new sources throughout the Arctic and mid-latitude regions. The Stockholm Convention on Persistent Organic Pollutants identified a suite of POPs to be banned or restricted (UNEP 2002). Although it is difficult to assess the success and implementation of individual agreements, the manufacture, use, and emissions of some of the pollutants found in the Arctic has been reduced.

The Montreal Protocol set standards to reduce the production of CFCs and other ozone-depleting substances (Albritton et al. 2001). The greenhouse gases which cause depletion of the stratospheric ozone layer seem to be in decline after peaking in 1994 (Albritton et al. 2001). This overall decline is occurring even though some new greenhouse gases such as hydrochlorofluorocarbons (HCFCs) and hydroflurocarbons (HFCs), which either were previously used or developed to replace the currently regulated CFCs, are increasing (Albritton et al. 2001).

PCBs, which have been produced in the U.S. since 1929, decreased from a high of 38,630 metric tons in 1970 to 18,400 metric tons in 1971 (Chemical Engineering News 1971). Breivik et al. (2002) estimated that 86% of the use of PCBs occurred in the industrialized areas in the northern hemisphere (30^o to 60^oN). Within this area the U.S., Japan, Italy, Germany, France, United Kingdom, and Spain contributed 68% of the global usage (Breivik et al. 2002). In the U.S. and Canada the use of PCBs is now restricted to closed systems that existed before the ban took effect in 1974 (Ramamoorthy and Ramamoorthy 1997). Approximately 2000 capacitors (closed systems) out of an estimated 2.8 million in the U.S. rupture every year, spilling PCBs into the environment (Ramamoorthy and Ramamoorthy 1997). Although Russia stopped production in 1992, a significant amount of PCBs are still being used and are being released annually to the environment (AMAP 2000). In Norway approximately 650 tons of PCBs out of 1500 tons of technical PCB are contained in products that are still in use (de March et al. 1998). In Sweden, approximately 8000-10,000 tons PCBs were imported to be used in condensers and transformers. Open use of PCBs was banned in Sweden 1971 and closed sources in 1994 (de March et al. 1998). In Sweden it is estimated that approximately 100-500 tons of PCBs used in sealants in pre-fabricated buildings prior to 1972, which are currently eroding (Hammar 1992 in De March et al. 1998), 50-100 tons in existing insulated window glass, and 20-30 tons in floor paints (KEMI 1996a in De March et al. 1998) occur in Sweden. Iceland banned PCBs in 1988 and sent all equipment containing PCBs abroad for destruction.

Production of Technical HCH, which consists of α-, β-, γ- (the only insecticidally active isomer), and δ-HCH isomers, began in 1943, between 1948 and 1997 it is estimated that 10,000 million tons were used globally (Li et al. 1998a). China was the largest producer of technical HCH from 1945-1983. Technical HCH was banned, which means the use was actually stopped, in Canada in 1971, the U.S. in 1976, China in 1983, and the Russian Federation in 1990 (Li et al. 1998b). In 1980, 95% of the global consumption of α-HCH occurred in India, China, and the Russian Federation. From 1980 to 1990 the estimated annual tonnage of α-HCH increased in India and the former Soviet Union and decreased dramatically in China (de March et al. 1998). India banned technical HCH in 1990 for agricultural use but kept it for public health uses (De Wit et al. 2004).

Lindane, which contains almost 100% γ-HCH, replaced technical HCH in the late 1970s and 1980s in the U.S., Canada, and western Europe and in China in 1991 (De Wit et al. 2004) and was used as a crop pesticide and seed treatment by France, Canada, and the U.S. in the 1990s. By 1990 the use of lindane increased in India, the former Soviet Union, France, Canada, Nigeria, and Mexico and decreased in China, Italy, East Germany, and the U.S. (Li et al. 1998b, de March et al. 1998). Although lindane is still used worldwide, the global usage dropped significantly by 2000, compared to 1980, due primarily to restrictions and bans implemented by many countries (De Wit et al. 2004).

Production of DDT has decreased globally since 1980 in most countries. Based on information provided to the UNEP, at the Stockholm Convention, only India (the largest producer) and China currently produce DDT for fighting malaria and other insect-borne diseases (UNEP 2002).

Since 1992, the use of polychlorobornanes and polychlorinated camphenes (toxaphene), have been either banned or severely restricted worldwide. Current information from the Stockholm Convention suggests that production of toxaphene may have ceased globally (De Wit et al. 2004). However toxaphene is still being released from agricultural soils in U.S., Mexico, Central America, and the former Soviet Union (De Wit et al. 2004).

The U.S. was the primary producer and user of technical grade chlordane, which consists of 120 compounds, and is used primarily as a soil insecticide and termiticide. Following the voluntary closure of the national and international plants of the sole U.S. manufacturer in 1997, Singapore and China have the only remaining chlordane production facilities (de Wit et al. 2004).

Although production of dieldrin ceased in 1991, emissions from old stock piles which were donated to African countries in the 1980 and 1990s still continue (UNEP 2002). Dieldrin is used as a soil insecticide and in tropical countries for locust and disease vector control (De Wit et al. 2004).

PBDEs have been used as flame retardants in North America and Europe, including polyurethane foams, since the 1970s (de Boer et al. 2000). Between 2001 and 2004 several European nations restricted the use and manufacture of PBDEs resulting in sharp decrease in global use in Europe by 1999 (BSEF 2000). Canada recently implemented a notice to list all PBDEs under Canadian Environmental Protection Act. Although it is not yet a national policy, eight states, within the U.S., have either passed or proposed legislation to ban penta-BDE and Octa-BDE. It is expected the global use of PBDEs will gradually decline in Canadian Arctic and U.S. although the large inventory of polyurethane foam may continue to be a source of PBDEs for some time to come.

Currently there is not enough information to assess the temporal trends of PAHs or PCDD/Fs, and PFOS, and PFOA in the Arctic. The PAHs that are the most abundant in the atmosphere are primarily from the burring of fossil fuels to produce electricity and heat, vehicle exhausts, forest fires, fertilizer production and production of ferrous and non-ferrous metals (de Wit et al. 2004). The primary sources of PCDD/Fs include the burning of plastics and other materials that contain chlorines, exhaust from vehicles that burn leaded gasoline, pulp and paper mills, and metallurgical industries (de Wit et al. 2004).

Overall the Arctic monitoring data suggests that the global circulation for most of the POPs is reaching equilibrium in the Arctic. The evidence for this comes from the lack of circumpolar variation in HCB, relatively uniform concentrations in chlordanes, and the narrowing of the differences between the PCB concentrations in polar bears the European and the Canadian Arctic. Many of the POPs in the Arctic, such as PCBs, DDT and DDE, and chlordanes, are declining or relatively flat.

Despite the regulatory steps taken to decrease the production or emissions of toxic chemicals, increases in hexachlorobenzene (HCB) and relatively new compounds such as PBDEs and PFOSs, are cause for concern. PBDEs, which may have impacts similar to already regulated chemicals such as PCBs, have increased in the last decade (AMAP 2002, Ikonomou et al. 2002, Muir et al. 2006). PFCs remain the class of chemicals of most concern as we do not know how long it will take for voluntary phase-outs or bans to result in declines because of the widespread use of these compounds in consumer products. More information is needed on the specific biological effects of many of these contaminants on Arctic marine mammals in order to assess the potential impact on polar bears, and their primary prey, ringed and bearded seals.

2. Oil and gas exploration, development, and production

a. Overview

Each of the Parties to the Agreement on the Conservation of Polar Bears has developed detailed regulations pertaining to the extraction of oil and gas within their countries. The greatest level of oil and gas activity within polar bear habitat is currently occurring in the U.S. (Alaska). Exploration and production activities are also actively underway in Russia, Canada, Norway, and Denmark (Greenland) to varying degrees. In the U.S. all leasing and production activities are required to be consistent with the National Environmental Policy Act and a multitude of other statutes guide exploration, development and production.

The greatest concern for future oil and gas development is for those activities that occur in the marine environment due to the chance for oil spills to impact polar bears or their habitats. Another area of concern is for activities that occur in areas suitable for polar bear denning.

NRC (2003) concluded the following regarding cumulative effects of oil and gas development on polar bears and seals in Alaska:

- “Industrial activity in the marine waters of the Beaufort Sea has been limited and sporadic and likely has not caused serious cumulative effects to ringed seals or polar bears.
- Careful mitigation can help to reduce the effects of oil and gas development and their accumulation, especially if there is no major oil spill. However, the effects

of full-scale industrial development of waters off the North Slope would accumulate through the displacement of polar bears and ringed seals from their habitats, increased mortality, and decreased reproductive success.

- A major Beaufort Sea oil spill would have major effects on polar bears and ringed seals.
- Climatic warming at predicted rates in the Beaufort Sea region is likely to have serious consequences for ringed seals and polar bears, and those effects will accumulate with the effects of oil and gas activities in the region.
- Unless studies to address the potential accumulation of effects on North Slope polar bears or ringed seals are designed, funded, and conducted over long periods of time, it will be impossible to verify whether such effects occur, to measure them, or to explain their causes."

Historically, oil and gas activities have resulted in little direct mortality to polar bears. Future oil and gas activities are increasing as development continues to expand throughout the U.S. Arctic and internationally. Oil and gas exploration and development occur within the Arctic on land as well as offshore in the marine environment, although today the development of offshore production sites has been limited to Northstar and Endicott facilities located in the Beaufort Sea. Lentfer (1990) stated that oil and gas exploration and development in the Arctic can impact polar bears in following ways: (1) damage or destruction of essential habitat; (2) contact with and ingestion of oil from acute and chronic oil spills; (3) contact with and ingestion of other contaminants; (4) attraction to or disturbance by industrial noise and harassment by aircraft, ships, and other vehicles; (5) death, injury, or harassment resulting from interactions with humans; (6) increased hunting pressures; and (7) potential mortality, injury, and stress resulting from capture, handling and interaction associated with studies to evaluate the previous concerns.

Documented impacts on polar bears by the oil and gas industry in the United States during the past 30 years are minimal. Polar bears spend a limited amount of time on land, coming ashore to feed, den, or move to other areas. At times, fall storms deposit bears along the coastline where bears remain until the ice returns. For this reason, polar bears have mainly been encountered at or near most coastal and offshore production facilities, or along the roads and causways that link these facilities to the mainland. During those periods, the likelihood of interactions between polar bears and industry activities increases. We have found that the polar bear interaction planning and training requirements set forth in these regulations and required through the letters of authorization (LOA) process have increased polar bear awareness and minimized these encounters. LOA requirements have also increased our knowledge of polar bear activity in the developed areas.

No lethal take associated with industry has occurred during the period covered by incidental take regulations. Prior to issuance of regulations, lethal takes by industry were rare. Since 1968, there have been two documented cased of lethal take of polar bears associated with oil and gas activities. In both instances, the lethal take was reported to be in defense of human life. In the winter of 1968 – 1969, an industry employee shot and killed a polar bear. In 1990, a female polar bear was killed at a drill site on the west side of Camden Bay. In contrast, 33 polar bears were killed in the Canadian Northwest Territories from 1976 to 1986 due to encounters with industry. Since the beginning of the incidental take program, which includes measures that minimize impacts to the species, no polar bears are known to have been killed due to encounters associated with the current industry activities on the North Slope of Alaska.

To date, oil and gas exploration and development activities have been more extensive in Alaska than in other areas of the Arctic, but Canada, Norway, Russia and Greenland also are experiencing oil and gas exploration and development.

b. Oil and gas development by Country

1. United States (Alaska)

The most extensive active oil and gas activities in the Arctic occur on Alaska's North Slope and in the adjacent Beaufort Sea. The footprint of oil and gas operations since initial development at

Prudhoe Bay in the late 1970s has expanded both to the east and west. Exploration is underway in the National Petroleum Reserve, and seismic operations began in 2006 in the Chukchi Sea.

There are 31 producing oil fields on Alaska's Arctic Slope (MMS 2003, 2004). A network of roads, pipelines, and power lines serve as infrastructure to connect drill sites, production facilities, support facilities, and transportation hubs. The area of activity extends from northeastern portion of the National Petroleum Reserve – Alaska ("National Reserve") to the Canning River and the eastern boundary of the Arctic National Wildlife Refuge ("Arctic Refuge") (NRC 2003).

Seven of the 31 producing oil fields are offshore. Three additional onshore fields are in the planning stages for development. Other potential future development includes 16 discoveries that may undergo some development-related activities within the next 15-20 years. Nine of sixteen potential fields are located offshore (MMS 2003, 2004).

Offshore oil development is expanding and is forecasted to continue into the future. To date, offshore oil development accounts for only a small percentage of oil production on Alaska's Arctic slope – as of December 2001 only about .429 billion barrels have been produced offshore compared to approximately 13.256 billion barrels on shore (NRC 2003).

A 2001 Presidential Executive Order 13212 directed US departments and agencies to expedite projects that increase the production, transmission, or conservation of energy (MMS 2003, 2004). A Proposed Final 5-Year Offshore Oil and Gas Leasing Program for 2002-2007 (MMS 2003, 2004) has been developed and includes three lease sales on the Beaufort Sea outer continental shelf, covering approximately 9.8 million acres for leasing (MMS 2003). Leasing incentives have included reduced royalties on oil production and lowered the minimum bid amount and rental rates for tracts leased (MMS 2004). The MMS states that at oil prices of $39 per barrel or greater the incentives would not be needed since the high price alone would spur exploration and development activities (MMS 2004).

Other developments planned or proposed for Alaska's Arctic will contribute to the cumulative effect of development. These include a gas pipeline to transport natural gas from the Arctic to market, and the State of Alaska's proposal to expand the Arctic Slope road networks connecting the Arctic Slope villages to Interior Alaska and to the North American road network (MMS 2004).

2. Canada

In the Canadian Beaufort Sea extensive exploration was conducted in the 1970s and 1980s, including 85 offshore exploration programs that resulted in significant oil and gas discoveries (Devon Canada Corporation 2004). Recently the Canadian government granted the Devon Canada Corporation an exploration license to conduct petroleum exploration within polar bear habitat in the southern Beaufort Sea (Devon Canada Corporation 2004). Nine offshore drilling locations within the landfast ice zone have been identified (Devon Canada Corporation 2004). Devon must drill at least one well in each of four areas delineated within the general lease prior to expiration of the license in 2009. Failure to comply results in drilling rights reverting back to the federal government. Devon plans to drill the first well during the winter of 2005-2006, and one well per winter season thereafter through 2009.

The largest potential future development in the region is the Mackenzie Gas Project, a pipeline through the Mackenzie River corridor to transport natural gas to market (Devon Canada Corporation 2004). The proposed gas pipeline has spurred a great deal of exploration for natural gas in the Mackenzie Delta and parts of the Tuktoyaktuk Peninsula (MMS 2003, Devon Canada Corporation 2004). In eastern Canada, the provinces of Newfoundland and Quebec oversee regulatory actions that may lead to additional exploration and production of the Hebron, Ben Nevis, and West Ben Nevis prospects. Existing producing fields in this area include the Hibernia, Terra Nova, White Rose, and Grand Banks.

3. Norway

Oil and gas development in polar bear habitat in Norwegian territory (Barents Sea) is relatively recent. In May 1997, the Norwegian government awarded production licenses for seven areas of the Barents Sea, including four as seismic exploration areas (Larstad and Gooderham 2004). In December 2003, the Norwegian government opened areas of the southern Barents Sea to continued year-round petroleum operations, with the exception of certain areas that will be re-assessed in an integrated management plan for the Barents Sea (Andersen and Gooderham 2004).

The first producing gas field in this area, the Snøhvit field, was approved in 2002 and is expected to begin producing in 2007 (Norwegian Petroleum Directorate 2006). In order to promote the discovery of additional gas resources near Snøhvit, the Norwegian government included an area close to Snøhvit in the announcement of awards in pre-defined areas for 2004 (Larstad and Gooderham 2004). A facility is also under construction at Melkøya outside of Hammerfest to process gas and natural gas liquids from Snøhvit, from which gas is transported under water from the gas field to the production facility, with production scheduled to begin in 2006, now delayed to late 2007 (Norwegian Petroleum Directorate 2006, Andresen and Gooderham 2004). The government has recognized special environmental constraints on oil production in the Barents Sea region (Andresen and Gooderham 2004, Larstad and Gooderham 2004), although oil and gas development in the Norwegian Arctic in polar bear habitat is expected to continue and to increase. The northern Barents Sea has not been opened for any oil and gas activities and will not be for many years. The management plan is open for reevaluation in 2010, and then new areas and fields could be opened. Present constraints include no petroleum activities in areas closer than 50 km of land, no activities closer than 65 km from Bjørnøya (Bear Island), and no activities in the areas of the polar front and ice edge.

4. Denmark (Greenland)

The Greenland and Danish governments have been promoting oil and gas exploration and development off the coast of Greenland, and oil and gas activities have increased during the past several years (GBMP 2004). The 3,985 km^2 Attamik license area about 200 km northwest of

Nuuk, Greenland was licensed to EnCana corporation and NUNAOIL A/S, a state-owned oil company (GBMP 2004). In 2003, EnCana carried out extensive exploration off the coast of West Greenland (GBMP 2004). Seismic testing has been conducted on an 50,000 km^2 area since 1990 (GBMP 2004).

In 2004, Greenland opened four areas off the west coast, the Lady Franklin Basin, Kangaamiut Basin, Ikermiut Ridge, and Paamiut Basin, in the Labrador Sea, Davis Strait, and Baffin Bay to oil exploration. A 2,897 km^2 area was licensed to EnCana and NUNAOIL over the Lady Franklin Basin (GBMP 2005). Large petroleum deposits are thought to exist offshore of Western Greenland (GBMP 2005). The Labrador Sea, Davis Strait, and Baffin Bay all pose serious challenges to oil exploration and development, including extreme climates and broken ice conditions for much of the year (GBMP 2004). Greenland and Danish governments' have promoted oil and gas exploration and development off the East Coast of Greenland that may also increase in the future.

5. Russia

Parallel plans for oil and gas development in the Russian Barents Sea are also moving forward (Derocher et al. 2002b). The Russian government has approved plans for a privately owned oil pipeline from Russia's oil fields to Murmansk in North-west Russia (WWF 2003). Should the pipeline be built, major shipping terminals could be in operation by 2007 (WWF 2003). Approximately 2.5 million barrels of oil a day could be transported by tanker from Murmansk to the US through the Barents Sea (WWF 2003).

There are also plans for industrial oil production on the oil fields in the southeastern part of the Barents Sea (Belikov et al. 2002).

3. Bear-Human Interactions

Polar bear distribution changes will likely contribute to an increase in bear-human interactions in the coming years. In addition to polar bear distribution changes, climate change will likely promote human populations to shift northward (AMAP 2003), increasing direct interactions between bears and humans (AMAP 2003, Derocher et al. 2004). Other consequences beyond direct interactions with humans include increased development pressure, disturbance to bears from increased shipping activity, potential prey availability reductions from expanded commercial fisheries, and increased risk of oil spills (AMAP 2003). In many instances the results of human interactions are fatal to polar bears or may result in injury or disturbance. In some instance these interactions can result in human injuries or deaths.

Polar bears come into conflict with humans partly because they will scavenge for food at sites of human habitation and also because they may occasionally prey or attempt to prey upon humans (Stirling 1988). "Problem bears" are most often sub-adults, because they are inexperienced hunters and have the most difficulty hunting, and because their feeding habits include more scavenging than adult bears (Stirling 1988). Subadults are also more vulnerable than adults to environmental effects (Taylor et al. 1987). Observations of density dependent and density independent effects on populations of other marine mammals indicate that environmental effects are typically first manifested as reductions in annual breeding success and reduced subadult survival rates (Eberhardt and Siniff 1977). Because of the greater maternal investment a weaned subadult represents, reduced survival rates of subadults have a greater impact on population growth rate than reduced litter production rates (Taylor et al. 1987). In the NWT, a preliminary study found that 36 of 44 "problem bears" killed between 1972 and 1999 were under five years of age (Lunn et al. 2002b). In the Canadian Beaufort Sea, 12 of the 16 "problem bears" killed from 1973-1983 whose ages were determined were 5 years of age or less, with an average age of 2.25 years (Stirling 1988). After sub-adults, females with cubs are the most likely type of bear to interact with humans, because females with cubs are likely to be thinner and hungrier than single adult bears and starving bears will risk death in an attempt to obtain food (Stirling 1988). In Churchill, an area of predictably high polar bear use, in years when bears came ashore in poorer condition, more females with cubs fed at the dump in the fall when their stored fat reserves ran low (Stirling 1988). Adult females are more important than subadults from a population dynamics standpoint since they detemine population growth (Taylor et al. 1987).

Research indicates that human-bear interactions, and the number of defense kills, increase when food is less available in the wild. Following a period of reduced seal abundance in the eastern Beaufort Sea during spring 1974, researchers predicted that subadults would be in poorer condition, interact more with humans, and suffer a higher death rate in the winter of 1974-75 (Stirling 1988). The predictions proved true with seven defense kills that winter. In subsequent years when seal populations had recovered defense kills declined to an average of two per winter (Stirling 1988).

Adult male polar bears, unlike adult black or grizzly bears, are less likely to frequent areas of human habitation, presumably because adult male polar bears are usually in better physical condition than other sex or age classes (Stirling 1988). In the Beaufort Sea adult males were present for protracted periods of time near settlements feeding on bowhead whale remains during the fall period of 2002-2005 (Miller et al. 2006). The reason for the unusual presence of adult males near a North Slope village is unknown but suggests that these animals were attracked by the presence of the carcasses and may have been nutritionally stressed.

In Nunavut, Canada the details from 618 polar bear defense of life and property (DLP) kills that occurred from 1970-2000 were analyzed (Dyck 2006). The study found that most bears were ≤ 6 years of age (73%), the majority of bears killed were males (71%), and most interactions occurred at Native hunting camps (74%). Sources of food were believed to be a contributing factor in many instances but other possible reasons were an increase in land use activities, or the number of camps, increased human populations in areas of high polar bear activity, increased polar bear population size, and climatic warming related to earlier departure from ice habitat to terrestrial habitats. The implementation of a DLP monitoring program in 1980 resulted in a decrease in the number of kills. More recently (Aars et al. 2005, Dowsley 2005, Dyck 2006) increased levels of DLP have been reported. The Baffin Region accounted for 74% of the DLP kills. Reasons for the sex bias toward males may be related to the following: young and subadult males account for > 50% of the population based on capture data; male subadult dispersal has been noted for other species with polygynous mating systems (Greenwood 1980, Dobson 1982, Derocher and Stirling 1990, McClellan and Hovey 2001, Dyck 2006); males tend to be more aggressive (Tate and Pelton 1983, Ramsay and Stirling 1986, Ramsay and Stirling 1988); and subadults may be more curious and less cautious, and possibly more nutritionally stressed than older bears (Stirling and Latour 1978, MacArthur Jope 1983, in Dyck 2006). Increased future interactions were predicted based on expanding human populations, resource extraction and exploration activities. Enhanced monitoring of bear-human interactions would be useful in better understanding and mitigating for these incidents.

Defense kills of “problem bears” are a concern when they are not included in an area’s hunting quota, because the number of interactions and bears killed can cause sustainable quotas to be exceeded and impact the population if quotas are not in place or not adjusted in subsequent years. Some experts predict that the number of interactions and defense kills will increase as climate change continues (Derocher et al. 2004). Amstrup (2000) observed that direct interactions between people and bears in Alaska have increased markedly in recent years, and that this trend is expected to continue. Schliebe et al. (2006) confirmed this observation with data from hunter-harvested polar bears in Alaska (Figure 3). The number of bears taken for safety reasons, based on 3 year running averages, increased steadily from about 3 per year in 1993, to about 12 in 1998, and has averaged about 10 in recent years. There are several plausible explanations for this increase. First it could be an artifact of increased reporting by the hunters, or of an increased polar bear population and corresponding increased probability of interactions with humans. Alternatively or in combination, polar bears from the Southern Beaufort Sea and CS populations typically move from the pack ice to the near shore environment in the fall to take advantage of the higher productivity of ice seals over the continental shelf. In the 1980s and early 1990s the near shore environment would have been frozen by early or mid October, allowing polar bears to effectively access seals in the area. Since the late 1990s the timing of ice formation in the fall has occurred later in November or early December, resulting in an increased amount of time that the area was not accessible to polar bears. Consequently, bears spent a greater amount of time on land and not feeding. The later formation of near-shore ice increases the probability of bear-human interactions occurring in coastal villages (Schliebe et al. 2006). The increased use of coastal habitats by polar bears during the fall in recent years is further supported by data from aerial surveys along the coast and barrier islands from Barrow to the Canadian border and from information from local residents in coastal villages in northern and western Alaska. The number of bears using coastal habitats has been relatively stable in the most recent years possibly explaining why DLP kills have stabilized.

In Nunavut, increased bear-human encounters reported by residents of numerous communities (Dowsley 2005) resulted in quota increases for Western Hudson Bay, BB, and Davis Strait populations. Whether the increased incidence of polar bear use of terrestrial habitat in the open water season is evidence of increased population size or a change in distribution is a subject to conjecture.

4. Shipping and Transportation

Observations over the past 50 years show a decline in arctic sea-ice extent in all seasons, with the most prominent retreat in the summer. Some studies estimate arctic-wide reductions in annual average sea-ice extent of about 5-10% and a reduction in the average thickness of about 10-15% over the past few decades. Submarine sonar measurement taken in the central Arctic Ocean revealed a 40% reduction in ice thickness. These trends indicate an Arctic Ocean with longer seasons of reduced sea-ice cover which will improve ship accessibility around the margins of the Arctic Basin – although increased accessibility will not be uniformly distributed (ACIA 2005).

The Oceanographer of the Navy, the Office of Naval Research, the Arctic Research Commission, and the Naval Ice Center co-sponsored a symposium on Naval Operations in an ice-free Arctic on 17 and 18 April 2001. Their findings were that submarine data reveal a 40% decrease in arctic sea ice volume. Satellite passive microwave data since the 1970s demonstrate a decrease in sea ice extent of 3% per decade. Model data suggest a sea ice thickness decrease of 30% and an ice volume decrease between 15% and 40% by 2050. Scientific models consistently suggest that seasonal sea lanes may appear as soon as 2015 due to open water periods. Summertime disappearance of the ice cap could be possible by 2050 if climatic trends continue. These trends translate into a possibility that the US Navy will be required to operate in the Arctic.

Climate models project an acceleration of this trend with periods of extensive melting that will spread progressively further away from most Arctic land masses into the spring and autumn, thus opening new shipping routes and extending the period that shipping is practical (ACIA 2005).

The navigation season is normally defined as the number of days per year when less than 50% ice cover persists. The navigation season for the Northern Sea Route is projected to increase from 20-30 days per year to 90-100 days per year. Since navigation for ships with ice-breaking capability is possible in seas with up to 75% ice coverage, this navigation season may extend to 150 days per year by 2080.

The Northern Sea Route is the name for the seasonally ice-covered marine shipping routes across the north of Eurasia from Novaya Zemlya in the west to the Bering Strait in the east (Brude et al. 1998, ACIA 2005). The Northern Sea Route is administered by the Russian Ministry of Transport and has been open to marine traffic of all nations since 1991(ACIA 2004). For trans-Arctic voyages, the Northern Sea Route represents up to a 40% savings in distance from northern Europe to northeastern Asia and the northwest coast of North America compared to southerly routes via the Suez or Panama Canals (ACIA 2005)

Regional as well as trans-Arctic shipping along the Northern Sea Route is very likely to benefit from a continuing reduction in sea ice, which currently poses major challenges and requires specially reinforced ships as well as ice-breakers (ACIA 2005). The further north the ice edge retreats, the further north ships can sail in open water on trans-Arctic voyages, thereby avoiding the shallow shelf waters (which require ships of shallow draft, thereby reducing the amount of cargo that may be carried and profitability) and narrow straits of the Russian Arctic (ACIA 2005). Ships involved in expanded use of the Northern Sea Route would likely use leads and polynyas to avoid breaking ice and reduce transit time (USFWS 1995). Russian scientists cite increasing use of a Northern Sea Route for transit and regional development as a major source of disturbance to polar bears in the Russian Arctic (Wiig et al. 1996, Belikov and Boltunov 1998). Commercial navigation on the Northern Sea Route could disturb polar bear feeding and other behaviors and would increase the risk of oil spills (Belikov et al. 2002, especially in winter and spring, and heavy shipping traffic could disturb the bears during critical times (USFWS 1995).

Increased shipping activity may disturb polar bears in the marine environment, adding additional energetic stresses. If ice breaking activities occur they may alter habitats used by polar bears, possibly creating emphemeral lead systems and concentrating ringed seals within the refreezing leads. This in turn may allow for easier access to ringed seals and may have some beneficial values. Conversely, this may cause polar bears to use areas that may have a higher incidence of human encounters as well as increased likelihood of exposure to oil, waste products or food wastes that are intentionally or accidentally placed into the marine environment. If shipping involved the tanker transport of crude oil or oil products there would be some increased likelihood of small to large volume spills and corresponding oiling of polar bears as well as potential effects on seal prey species (Richardson et al. 2005c).

The PBSG (Aars et al. 2006) recognized the potential for increased shipping and marine transportation in the Arctic with declining summer/fall ice conditions. The group recommended that the Parties to the International Agreement on the Conservation of Polar Bears take appropriate measures to monitor, regulate and mitigate ship traffic impacts on polar bear subpopulations and habitats (Aars et al. 2006).

5. Tourism

Increasing levels of tourism and photography in polar bear viewing areas and natural habitats is of concern. In some such situations, carelessness or ignorance has resulted in polar bear being killed to protect people (PBSG 2006). As tourism continues to increase in the Arctic, the number of conflicts is expected to rise.

Tourists and photographers may inadvertently displace bears from preferred habitats or alter natural behaviors. Polar bears are inquisitive animals and often investigate novel odors or sights. This trait can lead to polar bears investigating food odors at cabins and remote stations where they may be killed. Dumps near human settlements have a history of being frequented by polar bears.

Clark (2003) documented 52 perceived aggressive interactions between people and polar bears, and one interaction that resulted in human injury, in Canadian National Parks. Two interactions resulted in bears fatalities. Most (87%) interactions took place in Wapusk National Park, outside of Churchill, Manitoba, where most of the Western Hudson Bay population comes on shore between July and November (Clark 2003). Interactions took place on land during summer or fall (Clark 2003). The number of interactions and the number of bears captured in and around Churchill appeared to be greater during years when bears came ashore earlier, however, small sample sizes likely limit statistical significance (Clark 2003).

Clark (2003) found no relationship between the rates of interaction and and the mean number of park visitors and mean number of visitor nights, suggesting that sea-ice availability and the amount of time the bears spend on land appears to be the primary factor influencing the rate of interactions. Clark's analyses were consistent with Derocher et al.'s (2004) hypothesis that longer ice-free periods will contribute to an increase in the number of polar bear-human interactions.

Clark (2003) found that bears were reported killed in only 4% of the perceived aggressive interactions, which was much less than the 61% reported by Fleck and Herrero (1998). Fleck and Herrero (1988) compiled data from bear-human interactions throughout Canada. Possible explanations include the fact that Clark's (2003) study was confined to interactions in national parks, where visitors are not encouraged to carry firearms and are educated on bear safety, and that many interactions took place near established research camps that have formalized bear response procedures, including non-lethal deterrent measures (Clark 2003).

Bear sightings near camps were also much more likely to lead to perceived aggressive interactions than bear sightings away from camps (Clark 2003). This could be due to a number of factors, including the fact that attractants such as food motivate bears into encounters with people, and the fact that people may perceive bears as more aggressive near a camp rather than when they are in the field (Clark 2003).

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VII. Appendices, Figure, Tables

Appendix 1. Agreement on the Conservation of Polar Bears

Agreement on the Conservation of Polar Bears.

The Governments of Canada, Denmark, Norway, and the Union of Soviet Socialist republics, and the United States of America,

Recognizing the special responsibilities and special interests of the States of the Arctic Region in relation to the protection of the fauna and flora of the Arctic Region;

Recognizing that the polar bear is a significant resource of the Arctic Region which requires additional protection;

Having decided that such protection should be achieved through co-ordinated national measures taken by the States of the Arctic Region;

Desiring to take immediate action to bring further conservation and management measures into effect;

Have agreed as follows:

ARTICLE I

1. The taking of polar bears shall be prohibited except as provided in Article III.
2. For the purpose of this Agreement, the term "taking" includes hunting, killing and capturing.

ARTICLE II

Each Contracting Party shall take appropriate action to protect the ecosystems of which polar bears are part, with special attention to habitat components such as denning and feeding sites and migration patterns and shall manage polar bear populations in accordance with sound conservation practices based on the best available scientific data.

ARTICLE III

1. Subject to the provisions of Articles II and IV, and Contracting Party may allow the taking of polar bears when such taking is carried out:

(a) for *bona fide* scientific purposes; or

(b) by that Party for conservation purposes; or

(c)to prevent serious disturbance of the management of other living resources, subject to forfeiture to that Party of the skins and other items of value resulting form such taking; or

(d) by local people using traditional methods in the exercise of their traditional rights and in accordance with the laws of that Party; or

(e) wherever polar bears have or might have been subject to taking by traditional means by its nationals.

2. The skins and other items of value resulting from taking under sub-paragraphs (b) and (c) of paragraph 1 of this Article shall not be available for commercial purposes.

ARTICLE IV

The use of aircraft and large motorized vessels for the purpose of taking polar bears shall be prohibited, except where the application of such prohibition would be inconsistent with domestic laws.

ARTICLE V

A Contracting Party shall prohibit the exportation from, the importation and delivery into, and traffic within, its territory of polar bears or any part or product thereof taken in violation of this Agreement.

ARTICLE VI

1. Each Contracting Party shall enact and enforce such legislation and other measures as may be necessary for the purpose of giving effect to this Agreement.
2. Nothing in this Agreement shall prevent a Contracting Party from maintaining or amending existing legislation or other measures or establishing new measures on the taking of polar bears so as to provide more stringent controls than those required under the provisions of this Agreement.

ARTICLE VII

The Contracting Parties shall conduct national research programs on polar bears, particularly research relating to the conservation and management of the species. They shall as appropriate coordinate such research with research carried out by other Parties, consult with other Parties on the management of migrating polar bear populations, and exchange information on research and management programs, research results and data on bears taken.

ARTICLE VIII

Each Contracting Party shall take action as appropriate to promote compliance with the provisions of the Agreement by nationals of States not party to this Agreement.

ARTICLE IX

The Contracting Parties shall continue to consult with one another with the object of giving further protection to polar bears.

ARTICLE X

1. This Agreement shall be open for signature at Oslo by the Governments of Canada, Denmark, Norway, the Union of Soviet Socialist Republics and the United States of America until 31st March 1974.
2. This Agreement shall be subject to ratification or approval by the signatory Governments. Instruments of ratification or approval shall be deposited with the Government of Norway as soon as possible.
3. This Agreement shall be open for accession by the Governments referred to in paragraph 1 of this Article. Instruments of accession shall be deposited with the Depositary Government.
4. This Agreement shall enter into force ninety days after the deposit of the third instrument of ratification, approval, or accession. Thereafter, it shall enter into force for a signatory or acceding Government on the date of deposit of its instrument of ratification, approval or accession.
5. This Agreement shall remain in force initially for a period of five years from its date of entry into force, and unless any Contracting party during that period requests the termination of the Agreement at the end of that period, it shall continue in force thereafter.
6. On the request addressed to the Depositary Government by any of the Governments referred to in paragraph 1 of this Article, consultations shall be conducted with a view to convening a meeting of representatives of the five Governments to consider the revision or amendment of this Agreement.
7. Any Party may denounce this Agreement by written notification to the Depositary Government at any time after five years from the date of entry into force of the Agreement. The denunciation shall take effect twelve months after the Depositary Government has received the notification.
8. The Depositary Government shall notify the Governments referred to in paragraph 1 of this Article of the deposit of instruments of ratification, approval or accession, of the entry into force of this Agreement and of the receipt of notifications of denunciation and any other communications from a Contracting Party specifically provided for in this Agreement.
9. The original of this Agreement shall be deposited with the Government of Norway which shall deliver certified copies thereof to each of the Governments referred to in paragraph 1 of this Article.
10. The Depositary Government shall transmit certified copies of this Agreement to the Secretary General of the United Nations for registration and publication in accordance with Article 102 of the Charter of the United Nations.

IN WITNESS WHEREOF the undersigned, being duly authorized by their Governments, have signed this Agreement.

DONE at Oslo, in the English and Russian languages, each text being equally authentic, this fifteenth day of November, 1973.

I hereby certify that this is a true copy of the original document deposited in the archive of the Royal Norwegian Ministry of Foreign Affairs.

Per Tresselt.
Head of Division, Legal Department
Royal Norwegian Ministry of Foreign Affairs.

Resolution E appended to the 1973 Agreement on the Conservation of Polar Bears by the Plenipotentiaries who signed the Polar Bear Agreement

RESOLUTION ON SPECIAL PROTECTION MEASURES

THE CONFERENCE,

BEING CONVINCED that female polar bears with cubs and their cubs should receive special protection;

BEING CONVINCED FURTHER that the measures suggested below are generally accepted by knowledgeable scientists to be sound conservation practices within the meaning of Article II of the Agreement on the Conservation of Polar Bears;

HEREBY REQUESTS the Governments of Canada, Denmark, Norway, the Union of Socialist Republics and the United States of America to take such steps as possible to:

1. Provide a complete ban on the hunting of female polar bears with cubs and their cubs; and

2. Prohibit the hunting of polar bears in denning areas during periods when bears are moving into denning areas or are in dens.

Appendix 2. NatureServe Conservation Status

Determining which plants and animals are thriving and which are rare or declining is crucial for targeting conservation towards those species and habitats in greatest need. NatureServe and its natural heritage member programs have developed a consistent method for evaluating the relative imperilment of both species and ecological communities. These assessments lead to the designation of a conservation status rank. For plant and animal species these ranks provide an estimate of extinction risk, while for ecological communities they provide an estimate of the risk of elimination. There are currently no conservation status ranks determined for Ecological Systems.

Conservation status ranks are based on a one to five scale, ranging from critically imperiled (G1) to demonstrably secure (G5). Status is assessed and documented at three distinct geographic scales- global (G), national (N), and state/province (S). These status assessments are based on the best available information, and consider a variety of factors such as abundance, distribution, population trends, and threats.

- Interpreting NatureServe Conservation Status Ranks
- Global, National, and Subnational Assessments
- Assessment Criteria
- Relationship to Other Status Designations
- Global Conservation Status Definitions
- National and Subnational Conservation Status Definitions

Interpreting NatureServe Conservation Status Ranks

The conservation status of a species or community is designated by a number from 1 to 5, preceded by a letter reflecting the appropriate geographic scale of the assessment (G = Global), N = National, and S = Subnational). The numbers have the following meaning:

1 = critically imperiled
2 = imperiled
3 = vulnerable to extirpation or extinction
4 = apparently secure
5 = demonstrably widespread, abundant, and secure.

For example, G1 would indicate that a species is critically imperiled across its entire range (i.e. globally). In this sense the species as a whole is regarded as being at very high risk of extinction. A rank of S3 would indicate the species is vulnerable and at moderate risk within a particular state or province, even though it may be more secure elsewhere.

Extinct or missing species and ecological communities are designated with either an "X" (presumed extinct or extirpated) if there is no expectation that they still survive, or an "H" (possibly extinct or extirpated) if they are known only from historical records but there is a chance they may still exist. Other variants and qualifiers are used to add information or indicate any range of uncertainty. See the following conservation status rank definitions for complete descriptions of ranks and qualifiers.

- Global Conservation Status Definitions
- National and Subnational Conservation Status Definitions

(S-rank) document the condition of the species or community within a particular state or province. Again, there may be as many subnational conservation status ranks as the number of states or provinces in which the species or community occurs.

National and subnational status ranks must always be equal to or lower than the global rank for a particular species or community (in this sense a "lower" number indicates greater risk). On the other hand, it is possible for a species or community to be more imperiled in a given nation or state/province than it is range-wide. As an example, a species may be common and secure globally (G5), vulnerable in the United States as a whole (N3), yet critically imperiled in Florida (S1). In the United States and Canada, the combination of global and subnational ranks (e.g. G3S1) are widely used to place local priorities within a broader conservation context.

Global conservation status assessments generally are carried out by NatureServe scientists with input from relevant natural heritage member programs and experts on particular taxonomic groups. NatureServe scientists similarly take the lead on national-level status assessments in the United States and Canada, while state and provincial member programs assess the subnational conservation status for species found in their respective jurisdictions.

Status assessments ideally should reflect current conditions and understanding, and NatureServe and its member programs strive to update these assessments with new information from field surveys, monitoring activities, consultation, and scientific publications. NatureServe Explorer users with significant new or additional information are encouraged to contact NatureServe or the relevant natural heritage program.

To ensure that NatureServe's central databases represent the most current knowledge from across our network of member programs, data exchanges are carried out with each natural heritage program at least once a year. The subnational conservation status ranks (S-ranks) presented in NatureServe Explorer are therefore only as current as the last data exchange with each local natural heritage program, coupled with the latest web site update (shown in the "small print" at the bottom of each NatureServe Explorer report). Although most subnational conservation status ranks do not change frequently, the most current S-ranks can be obtained directly from the relevant local natural heritage program (contact information available at http://www.natureserve.org/visitLocal/index.jsp).

Status Assessment Criteria

Use of standard criteria and rank definitions makes NatureServe conservation status ranks comparable across organism types and political boundaries. Thus, G1 has the same basic meaning whether applied to a salamander, a moss species, or a forest community. Similarly, an S1 has the same meaning whether applied to a species or community in Manitoba, Minnesota, or Mississippi. This standardization in turn allows NatureServe scientists to use the subnational ranks assigned by local natural heritage programs to help determine and refine global conservation status ranks.

Status assessments are based on a combination of quantitative and qualitative information. Criteria for assigning ranks serve as guidelines, however, rather than arithmetic rules. The assessor's overall knowledge of the species or community allows them to weigh each factor in relation to the others, and to consider all pertinent information. The general factors considered in assessing species and ecological communities are similar, but the relative weight given to each factor differs.

For species, the following factors are considered in assessing conservation status:

- total number and condition of occurrences (e.g. populations)
- population size
- range extent and area of occupancy
- short- and long-term trends in the above factors
- scope, severity, and immediacy of threats
- number of protected and managed occurrences
- intrinsic vulnerability
- environmental specificity

For ecological communities, the association level generally is the classification unit assessed and ranked (see Classification of Ecological Communities for an explanation of the classification hierarchy). Only global conservation status ranks are currently available for ecological communities on *NatureServe Explorer*. The primary factors for assessing community status are:

Species known in an area only from historical records are ranked as either H (possibly extirpated/possibly extinct) or X (presumed extirpated/presumed extinct). Other codes, rank variants, and qualifiers are also allowed in order to add information about the element or indicate uncertainty. See the lists of conservation status rank definitions for complete descriptions of ranks and qualifiers.

- total number of occurrences (e.g. forest stands)
- total acreage occupied by the community.

Secondary factors include the geographic range over which the community occurs, threats, and integrity of the occurrences. Because detailed information on these factors may not be available, especially for poorly understood or inventoried communities, preliminary assessments are often based on the following:

- geographic range over which the community occurs
- long-term trends across this range
- short-term trend (i.e. threats)
- degree of site/environmental specificity exhibited by the community
- imperilment or rarity across the range as indicated by subnational ranks assigned by local natural heritage programs.

Relationship to Other Status Designations

NatureServe conservation status ranks are a valuable complement to legal status designations assigned by government agencies such as the U.S. Fish and Wildlife Service and the National Marine Fisheries Service in administering the U.S. Endangered Species Act (ESA), and the Canadian Wildlife Service in administering the Species at Risk Act (SARA). NatureServe status ranks, and the documentation that support them, are often used by such agencies in making official determinations, particularly in the identification of candidates for legal protection. Because NatureServe assessment procedures-and subsequent lists of imperiled and vulnerable species-have different criteria, evidence requirements, purposes, and taxonomic coverage than official lists of endangered and threatened species, they do not necessarily coincide.

The IUCN Red List of threatened species is similar in concept to NatureServe's global conservation status assessments. Due to the independent development of these two systems, however, minor differences exist in their respective criteria and implementation. Recent studies indicate that when applied by experienced assessors using comparable information, the outputs from the two systems are generally concordant. NatureServe is an active participant in the IUCN Red List Programme, and in the region covered by *NatureServe Explorer*, NatureServe status ranks and their underlying documentation often form a basis for Red List threat assessments.

Global Conservation Status Definitions

Listed below are definitions for interpreting NatureServe global conservation status ranks (G-ranks). These ranks reflect an assessment of the condition of the species or ecological community across its entire range. Where indicated, definitions differ for species and ecological communities.

NatureServe Global Conservation Status Ranks

Basic Ranks

Rank	Definition
GX	**Presumed Extinct** (species)— Not located despite intensive searches and virtually no likelihood of rediscovery. **Eliminated** (ecological communities)—Eliminated throughout its range, with no restoration potential due to extinction of dominant or characteristic species.
GH	**Possibly Extinct** (species)— Missing; known from only historical occurrences but still some hope of rediscovery. **Presumed Eliminated**— (Historic, ecological communities)-Presumed eliminated throughout its range, with no or virtually no likelihood that it will be rediscovered, but with the potential for restoration, for example, American Chestnut Forest.
G1	**Critically Imperiled**—At very high risk of extinction due to extreme rarity (often 5 or fewer populations), very steep declines, or other factors.
G2	**Imperiled**—At high risk of extinction due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors.
G3	**Vulnerable**—At moderate risk of extinction due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors.
G4	**Apparently Secure**—Uncommon but not rare; some cause for long-term concern due to declines or other factors.
G5	**Secure**—Common; widespread and abundant.

Variant Ranks

Rank	Definition
G#G#	**Range Rank**—A numeric range rank (e.g. G2G3) is used to indicate the range of uncertainty in the status of a species or community. Ranges cannot skip more than one rank (e.g. GU should be used rather than G1G4).
GU	**Unrankable**—-Currently unrankable due to lack of information or due to substantially conflicting information about status or trends. Whenever possible, the most likely rank is assigned and the question mark qualifier is added (e.g. G2?) to express uncertainty, or a range rank (e.g. G2G3) is used to delineate the limits (range) of uncertainty.
GNR	**Unranked**—Global rank not yet assessed.
GNA	**Not Applicable**—A conservation status rank is not applicable because the species is not a suitable target for conservation activities.

Rank Qualifiers

Rank	Definition
?	**Inexact Numeric Rank**—Denotes inexact numeric rank (e.g. G2?)
Q	**Questionable taxonomy**—Taxonomic distinctiveness of this entity at the current level is questionable; resolution of this uncertainty may result in change from a species to a subspecies or hybrid, or the inclusion of this taxon in another taxon, with the resulting taxon having a lower-priority conservation priority.
C	**Captive or Cultivated Only**—At present extant only in captivity or cultivation, or as a reintroduced population not yet established.

Infraspecific Taxon Conservation Status Ranks

Infraspecific taxa refer to subspecies, varieties and other designations below the level of the species. Infraspecific taxon status ranks (T-ranks) apply to plants and animal species only; these T-ranks do not apply to ecological communities.

Rank	Definition
T#	**Infraspecific Taxon** (trinomial)—The status of infraspecific taxa (subspecies or varieties) are indicated by a "T-rank" following the species' global rank. Rules for assigning T-ranks follow the same principles outlined above for global conservation status ranks. For example, the global rank of a critically imperiled subspecies of an otherwise widespread and common species would be G5T1. A T-rank cannot imply the subspecies or variety is more abundant than the species as a whole-for example, a G1T2 cannot occur. A vertebrate animal population, such as those listed as distinct population segments under under the U.S. Endangered Species Act, may be

	considered an infraspecific taxon and assigned a T-rank; in such cases a Q is used after the T-rank to denote the taxon's informal taxonomic status. At this time, the T rank is not used for ecological communities.

National and Subnational Conservation Status Definitions

Listed below are definitions for interpreting NatureServe conservation status ranks at the national (N-rank) and subnational (S-rank) levels. The term "subnational" refers to state or province-level jurisdictions (e.g. California, Ontario).

Assigning national and subnational conservation status ranks for species and ecological communities follows the same general principles as used in assigning global status ranks. A subnational rank, however, cannot imply that the species or community is more secure at the state/province level than it is nationally or globally (i.e. a rank of G1S3 cannot occur), and similarly, a national rank cannot exceed the global rank. Subnational ranks are assigned and maintained by state or provincial natural heritage programs and conservation data centers.

National (N) and Subnational (S) Conservation Status Ranks

Status	**Definition**
NX **SX**	**Presumed Extirpated**—Species or community is believed to be extirpated from the nation or state/province. Not located despite intensive searches of historical sites and other appropriate habitat, and virtually no likelihood that it will be rediscovered.
NH **SH**	**Possibly Extirpated** (Historical)—Species or community occurred historically in the nation or state/province, and there is some possibility that it may be rediscovered. Its presence may not have been verified in the past 20-40 years. A species or community could become NH or SH without such a 20-40 year delay if the only known occurrences in a nation or state/province were destroyed or if it had been extensively and unsuccessfully looked for. The NH or SH rank is reserved for species or communities for which some effort has been made to relocate occurrences, rather than simply using this status for all elements not known from verified extant occurrences.
N1 **S1**	**Critically Imperiled**—Critically imperiled in the nation or state/province because of extreme rarity (often 5 or fewer occurrences) or because of some factor(s) such as very steep declines making it especially vulnerable to extirpation from the state/province.
N2 **S2**	**Imperiled**—Imperiled in the nation or state/province because of rarity due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors making it very vulnerable to extirpation from the nation or state/province.
N3 **S3**	**Vulnerable**—Vulnerable in the nation or state/province due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors making it vulnerable to extirpation.
N4	**Apparently Secure**—Uncommon but not rare; some cause for long-term concern

S4	due to declines or other factors.
N5 **S5**	**Secure**—Common, widespread, and abundant in the nation or state/province.
NNR **SNR**	**Unranked**—Nation or state/province conservation status not yet assessed.
NU **SU**	**Unrankable**—Currently unrankable due to lack of information or due to substantially conflicting information about status or trends.
NNA **SNA**	**Not Applicable** —A conservation status rank is not applicable because the species is not a suitable target for conservation activities.
N#N# **S#S#**	**Range Rank** —A numeric range rank (e.g. S2S3) is used to indicate any range of uncertainty about the status of the species or community. Ranges cannot skip more than one rank (e.g. SU is used rather than S1S4).
Not Provided	Species is known to occur in this nation or state/province. Contact the relevant natural heritage program for assigned conservation status.

Contact information for individual natural heritage programs is available at http://www.natureserve.org/visitLocal/index.jsp.

Breeding Status Qualifiers

Qualifier	Definition
B	**Breeding**—Conservation status refers to the breeding population of the species in the nation or state/province.
N	**Nonbreeding**—Conservation status refers to the non-breeding population of the species in the nation or state/province.
M	**Migrant**—Migrant species occurring regularly on migration at particular staging areas or concentration spots where the species might warrant conservation attention. Conservation status refers to the aggregating transient population of the species in the nation or state/province.

Note: A breeding status is only used for species that have distinct breeding and/or non-breeding populations in the nation or state/province. A breeding-status S-rank can be coupled with its complementary non-breeding-status S-rank if the species also winters in the nation or state/province, and/or a migrant-status S-rank if the species occurs regularly on migration at particular staging areas or concentration spots where the species might warrant conservation attention. The two (or rarely, three) status ranks are separated by a comma (e.g. "S2B,S3N" or "SHN,S4B,S1M").

Other Qualifiers

Rank	Definition

?	**Inexact or Uncertain**—Denotes inexact or uncertain numeric rank. (The ? qualifies the character immediately preceding it in the S-rank.)

Appendix 3. Criteria for Listing Species as Threatened or Endangered under the Canadian Species at Risk Act Source: Adapted from SARA Registry 2005.

<table>
<tr><th colspan="2">ENDANGERED</th><th>THREATENED</th></tr>
<tr><td colspan="3">A. DECLINING TOTAL POPULATION – Reduction in population size based on any of the following 4 options and specifying a-e as appropriate</td></tr>
<tr><td colspan="2">$\geq$ 70 %</td><td>$\geq$ 50 %</td></tr>
<tr><td colspan="3">(1) population size reduction that is observed, estimated, inferred, or suspected in the past 10 years or 3 generations, whichever is longer, where the causes of the reduction are clearly reversible AND understood AND ceased, based on (and specifying) any combination of a-e below.</td></tr>
<tr><td colspan="2">$\geq$ 50 %</td><td>$\geq$ 30 %</td></tr>
<tr><td colspan="3">(2) population size reduction that is observed, estimated, inferred, or suspected in the past 10 years or 3 generations, whichever is longer, where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any combination of a-e below.</td></tr>
<tr><td colspan="3">(3) population size reduction that is projected or suspected to be met within in the next 10 years or 3 generations, whichever is longer (up to a maximum of 100 years), based on (and specifying) and combination of b-e below.</td></tr>
<tr><td colspan="3">(4) population size reduction that is observed, estimated, inferred, projected or suspected over any 10 year or 3 generation period, whichever is longer (up to a maximum of 100 years), where the time period includes both the past and the future, AND where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any combination of a-e below.</td></tr>
<tr><td colspan="3">a) direct observation
b) an index of abundance appropriate for the taxon
c) a decline in area of occupancy, extent of occurrence and/or quality of habitat
d) actual or potential levels of exploitation
e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors, or parasites</td></tr>
<tr><td colspan="3">B. SMALL DISTRIBUTION, AND DECLINE OR FLUCTUATION</td></tr>
<tr><td>1. Extent of occurrence</td><td>< 5,000 km^2</td><td>< 20,000 km^2</td></tr>
<tr><td colspan="3">OR</td></tr>
<tr><td>2. Area of occupancy</td><td>< 500</td><td>< 2,000 km^2</td></tr>
</table>

	km²	
For either of the above, specify at least two of a-c:		
(a) either severely fragmented or known to exist at # locations	≤ 5	≤ 10
(b) continuing decline observed, inferred or projected in any of the following:		

	ENDANGERED	THREATENED
i) extent of occurrence ii) area of occupancy iii) area, extent and/or quality of habitat iv) number of locations or populations v) number of mature animals		
(c) extreme fluctuations in any of the following:	> 1 order of magnitude	> 1 order of magnitude
i) extent of occurrence ii) area of occupancy iii) number of locations or populations iv) number of mature animals		
C. SMALL TOTAL POPULATION SIZE AND DECLINE		
Number of mature individuals	< 2,500	< 10,000
And 1 of the following 2:		
(1) an estimate of continuing decline at a rate of at least:	20% in 5 years or 2 generations (up to a maximum of 100 years in the future)	10% in 10 years or 3 generations (up to a maximum of 100 years in the future)
(2) continuing decline, observed, projected or inferred, in numbers of mature individuals and at least one of the following (a-b):		
(a) fragmentation – population structure in the form of one of the following:	(i) no population estimated to contain >250 mature individuals	(i) no population estimated to contain >1,000 mature individuals
	(ii) at least 95% of mature individuals in one population	(ii) all mature individuals are in one population
(b) extreme fluctuations in the number of mature individuals		
D. VERY SMALL POPULATION OR RESTRICTED DISTRIBUTION		
(1) Number of mature individuals	< 250	< 1,000
(2) Applies only to threatened: Population with a very restricted area of occupancy or number of locations such that is prone to the effects of human activities or stochastic events within a very short time period in an uncertain future, and thus is capable of becoming highly endangered or even extinct in a very short time period.		
	(not applicable)	Area of occupancy typically < 20 km² or number of locations ≤ 5
E. QUANTITATIVE ANALYSIS		
Indicating the probability of extinction in the wild to be at least:	20 % in 20 years or 5 generations, whichever is longer (up to a maximum of 100 years)	10 % in 100 years

Appendix 4. IUCN Red List Criteria (Vulnerable)

IUCN Red List Criteria Definitions and criteria are available in the IUCN Red List of Threatened Species, 2001, Categories and criteria (v.3.1) and can be found at http://www.iucn.org/themes/ssc/redlists/RLcats2001booklet.html.
A synopsis of the 5 main categories and the evaluation for polar bears (2006) follows.

VULNERABLE (VU)
A taxon is Vulnerable when the best available evidence indicates that it meets any of the criteria A to E for Vulnerable, and it is therefore considered to be facing a high risk of extinction in the wild.

A. Reduction in population size based on any of the following:

1. An observed, estimated, inferred or suspected population size reduction of ≥50% over the last 10 years or three generations, whichever is the longer, where the causes of the reduction are: clearly reversible AND understood AND ceased, based on (and specifying) any of the following:
    - (a) direct observation
    - (b) an index of abundance appropriate to the taxon
    - (c) a decline in area of occupancy, extent of occurrence and/or quality of habitat
    - (d) actual or potential levels of exploitation
    - (e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.

2. An observed, estimated, inferred or suspected population size reduction of ≥30% over the last 10 years or three generations, whichever is the longer, where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.

3. A population size reduction of ≥30%, projected or suspected to be met within the next 10 years or three generations, whichever is the longer (up to a maximum of 100 years), based on (and specifying) any of (b) to (e) under A1.

4. An observed, estimated, inferred, projected or suspected population size reduction of ≥30% over any 10 year or three generation period, whichever is longer (up to a maximum of 100 years in the future), where the time period must include both the past and the future, and where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.

B. Geographic range in the form of either B1 (extent of occurrence) OR B2 (area of occupancy) OR both:

1. Extent of occurrence estimated to be less than 20,000 km^2, and estimates indicating at least two of a-c:

    a. Severely fragmented or known to exist at no more than 10 locations.
    b. Continuing decline, observed, inferred or projected, in any of the following:
        (i) extent of occurrence

(ii) area of occupancy
(iii) area, extent and/or quality of habitat
(iv) number of locations or subpopulations
(v) number of mature individuals.

c. Extreme fluctuations in any of the following:

i) extent of occurrence
(ii) area of occupancy
(iii) number of locations or subpopulations
(iv) number of mature individuals.

2. Area of occupancy estimated to be less than 2000 km², and estimates indicating at least two of a-c:

a. Severely fragmented or known to exist at no more than 10 locations.

b. Continuing decline, observed, inferred or projected, in any of the following:

(i) extent of occurrence
(ii) area of occupancy
(iii) area, extent and/or quality of habitat
(iv) number of locations or subpopulations
(v) number of mature individuals.

c. Extreme fluctuations in any of the following:

(i) extent of occurrence
(ii) area of occupancy
(iii) number of locations or subpopulations
(iv) number of mature individuals.

C. Population size estimated to number fewer than 10,000 mature individuals and either:

1. An estimated continuing decline of at least 10% within 10 years or three generations, whichever is longer, (up to a maximum of 100 years in the future) OR

2. A continuing decline, observed, projected, or inferred, in numbers of mature individuals AND at least one of the following (a-b):

(a) Population structure in the form of one of the following:

(i) no subpopulation estimated to contain more than 1000 mature individuals, OR
(ii) all mature individuals are in one subpopulation.

(b) Extreme fluctuations in number of mature individuals.

D. Population very small or restricted in the form of either of the following:

1. Population size estimated to number fewer than 1000 mature individuals.
2. Population with a very restricted area of occupancy (typically less than 20 km²) or number of locations (typically five or fewer) such that it is prone to the effects of human activities or stochastic events within a very short time period in an uncertain future, and is thus capable of becoming Critically Endangered or even Extinct in a very short time period.

E. Quantitative analysis showing the probability of extinction in the wild is at least 10% within 100 years.

Relationship between loss of habitat and population reduction

Under criterion A, a reduction in population size may be based on a decline in area of occupancy, extent of occurrence and/or quality of habitat. The assumptions made about the relationship between habitat loss and population reduction have an important effect on the outcome of an assessment. The sensible use of inference and projection is encouraged when estimating population reductions from changes in habitat. For example, if a forest species' extent of occurrence has been 70% clear cut in the last five years it might be justified to infer a 50% decline in the population over the past ten years. The species would therefore qualify as Endangered A2c**.**

In all cases, an understanding of the taxon and its relationship to its habitat, and the threats facing the habitat is central to making the most appropriate assumptions about habitat loss and subsequent population reduction. All assumptions about this relationship, and the information used should be included with the assessment documentation.

Data on effects of change in habitat quality on polar bears

- CA: Evidence of substantial variation in body size and reproductive output over short periods (3-4 yrs) mediated by varying ice conditions and for longer term changes (+10 yrs) in reproduction and body mass
- WHB: Declining reproductive rates, subadult survival, and body size was postulated to be affected by earlier break up of sea ice
- WHB: decline in abundance due to decline in habitat quality
- SVAL: Number of maternity dens dependent on sea ice conditions in autumn

- There is no doubt that polar bears will have a much less AOO, EOO and habitat quality in the future. It has been speculated that polar bears might get extinct in 100 years from now which would indicate a population decrease of > 50% in 45 years based on a precautious attitude to the uncertainty in data. A more realistic attitude to the risk involved in the assessment make it fair to suspect population reduction of > 30%. Therefore the classification is Vulnerable (A3.c).

Other population stress factors that may operate to impact recruitment or survival include toxic contaminants, shipping, recreational viewing, oil and gas industry.

In addition to this comes a potential risk of overharvest due to increased quotas or free quotas in Canada and Greenland and poaching in Russia

Figure 1. Distribution of polar bear populations throughout the Arctic circumpolar basin. CS=Chukchi Sea, BS=Southern Beaufort Sea, NB=Northern Beaufort Sea,VM=Viscount Melville Sound, NB=Norwegian Bay, LS=Lancaster Sound, MC=M'Clintock Channel, GB=Gulf of Boothia, FB=Foxe Basin, WH=Western Hudson Bay, SH=Southern Hudson Bay, KB=Kane Basin, BB=Baffin Bay, DS=Davis Strait, EG=East Greenland, BS=Barents Sea, KS=Kara Sea, LV=Laptev Sea, AB=Arctic Basin

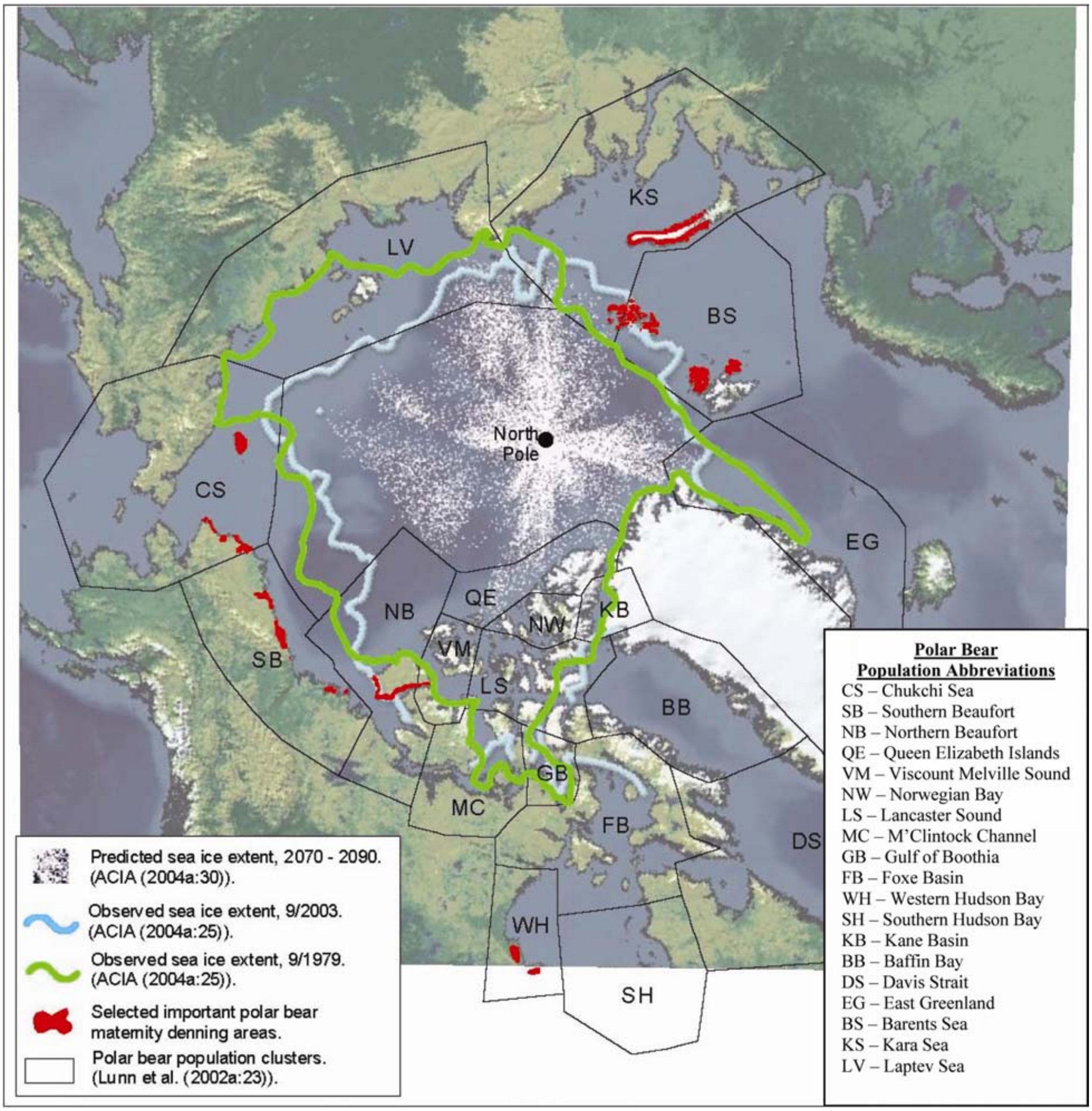
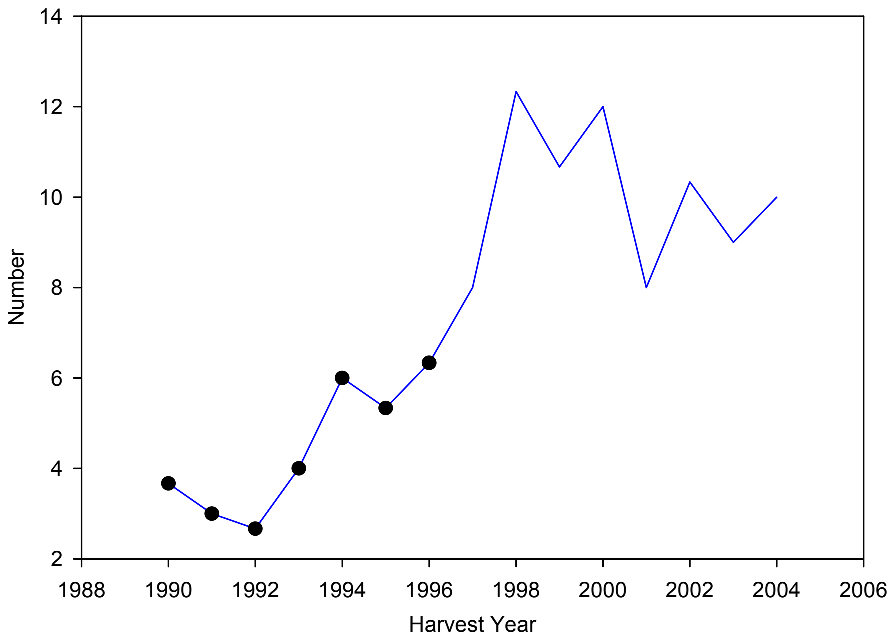


Figure 2. Circumpolar Map of Higher Density Polar Bear Denning Areas. Selected Polar Bear Terrestrial Denning Areas Compared to Past, Present, and Future Summer Sea-Ice Extent Source: Adapted from Lunn et al. (2002a:23) and ACIA (2004:25, 30).


14
12
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2002
2004
2006
Harvest Year