BEFORE THE SECRETARY OF INTERIOR

PETITION TO LIST THE PACIFIC WALRUS (*ODOBENUS ROSMAURS DIVERGENS*) AS A THREATENED OR ENDANGERED SPECIES UNDER THE ENDANGERED SPECIES ACT

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CENTER FOR BIOLOGICAL DIVERSITY

FEBRUARY 7, 2008

Notice of Petition

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PETITIONER

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Date: this 7th day of February, 2008

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Pursuant to Section 4(b) of the Endangered Species Act ("ESA"), 16 U.S.C. §1533(b), Section 553(3) of the Administrative Procedures Act, 5 U.S.C. § 553(e), and 50 C.F.R. § 424.14(a), the Center for Biological Diversity hereby petitions the Secretary of the Interior, through the United States Fish and Wildlife Service ("USFWS"), to list the Pacific walrus (*Odobenus rosmarus divergens*) as a threatened or endangered species and to designate critical habitat to ensure its survival and recovery.

The Center for Biological Diversity works through science, law, and policy to secure a future for all species, great or small, hovering on the brink of extinction. The Center has over 40,000 members throughout Alaska and the United States. The Center and its members are concerned with the conservation of endangered species, including the Pacific walrus, and the effective implementation of the ESA.

USFWS has jurisdiction over this petition. This petition sets in motion a specific process, placing definite response requirements on USFWS. Specifically, USFWS must issue an initial finding as to whether the petition "presents substantial scientific or commercial information indicating that the petitioned action may be warranted." 16 U.S.C. §1533(b)(3)(A). USFWS must make this initial finding "[t]o the maximum extent practicable, within 90 days after receiving the petition." *Id.* Petitioners need not demonstrate that listing *is* warranted, rather, Petitioners must only present information demonstrating that such listing *may* be warranted. While Petitioner believes that the best available science demonstrates that listing the Pacific walrus as endangered *is* in fact warranted, there can be no reasonable dispute that the available information indicates that listing the species as either threatened or endangered *may* be warranted. As such, USFWS must promptly make a positive initial finding on the petition an commence a status review as required by 16 U.S.C. § 1533(b)(3)(B).

The term "species" is defined broadly under the ESA to include "any subspecies of fish or wildlife or plants and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature." 16 U.S.C. § 1532 (16). A Distinct Population Segment ("DPS") of a vertebrate species can be protected as a "species" under the ESA even though it has not formally been described as a separate "species" or "subspecies" in the scientific literature. A species may be composed of several DPSs, some or all of which warrant listing under the ESA. As described in this petition, the Pacific walrus (*Odobenus rosmarus divergens*) is a currently recognized subspecies of the walrus (*Odobenus rosmarus*) and therefore meets the definition of a "species" eligible for listing under the ESA. In the event USFWS does not recognize the taxonomic validity of the Pacific walrus as described in this petition, we request that USFWS evaluate whether the walrus of the Bering and Chukchi Sea that are the subject of this petition constitute a DPS of the full walrus species and/or represent a significant portion of the range of the full walrus species and are therefore eligible for listing on such basis.

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Introduction

The Pacific walrus (*Odobenus rosmarus divergens*) is the largest and most gregarious of eight ice-breeding pinnipeds of the Arctic shelf region (Kelly 2001, Burns 2002). The Pacific walrus primarily occurs in the shallow shelf waters of the Bering and Chukchi Seas and is separated geographically and differs morphologically from its sister subspecies, the Atlantic walrus (*O. r. rosmarus*). It is readily distinguished by an ever-growing pair of tusks which are used for defense, social purposes, and to help them haul out on sea ice, inspiring their scientific name meaning "tooth-walking sea horse" (Fay 1985, Ray and McCormick-Ray 2004). Also unique among pinnipeds, the walrus's broad snout is covered by 600 to 700 stiff bristles (mystacial vibrissae) that help them detect their benthic prey (Heptner et al. 1976, Lowry 1984).

During the winter reproductive season, the entire Pacific walrus population congregates on the broken pack ice of the Bering Sea, which it relies on for courtship, giving birth, nursing, and as a resting platform while foraging. During spring, females and young walruses follow the retreating sea ice northward and spend the summer on the sea-ice edge of the Chukchi Sea, using offshore ice floes as platforms for resting, nursing, and molting. In contrast, most adult males remain in the Bering Sea during summer, principally in Bristol Bay and the Gulf of Anadyr, and use island and coastal haulouts for resting and molting. Pacific walruses are restricted to the shallow waters of the continental shelf where their benthic bivalve prey are abundant and where they can reach the bottom while diving for food. They are dependent on haulouts for resting between foraging bouts, typically foraging for several days followed by a period of resting lasting one to two days.

The population size of the Pacific walrus has fluctuated markedly since the late 1700s due to overexploitation by commercial hunting which resulted in dramatic declines in the late 1800s and the 1930s-1950s. Population censuses from 1960 to 1990 suggest that the Pacific walrus population increased from the 1960s through the early 1980s and subsequently declined beginning in the mid-1980s, concurrent with an increased rate of harvest. The current status of the Pacific walrus population is unknown. The most recent available population estimate conducted jointly by the U.S. and former Soviet Union reported ~200,000 individuals (Gilbert et al. 1992). The results of a 2006 census are not yet available.

The Pacific walrus faces population declines and possible extinction in the wild due to global warming which is resulting in the rapid melt of the Pacific walrus's sea-ice habitat throughout its range. Walruses require sea ice as a platform for resting between foraging bouts, courtship, giving birth, nursing calves, completing molt, and as passive transport to new foraging areas (Fay 1982, Ray and McCormick Ray 2004). As females and young walruses follow the sea-ice edge throughout the year, the sea ice acts as a floating conveyer belt between the Bering and Chukchi Seas that keeps them over the shallow, productive continental shelf waters and continually transports them to new foraging grounds. In addition to providing the substrate for critical life-cycle activities (reproduction, molting, resting), sea ice provides isolation from terrestrial predators and disturbance, proximity to food resources over the shelf, and increased space and reduced competition for haul-out sites (Burns et al. 1981).

The Pacific walrus's sea-ice habitat is threatened by rapid Arctic climate change that is occurring at a pace that is exceeding the predictions of the most advanced climate models (Stroeve et al. 2007). Arctic surface temperatures increased twice as much as the global average during the 20th century (Trenberth et al. 2007). The Bering Strait and Chukchi Sea inhabited by the Pacific walrus experienced sea surface temperatures in 2007 that were 3.5°C warmer than historical averages during the past century and 1.5°C warmer than the historical maximum (Hines 2007). In recent decades (1979-2006), summer sea-ice extent in the Chukchi Sea experienced significant declines in June through November (Meier et al. 2007), when females and young depend on the sea-ice edge. Chukchi sea-ice loss in September occurred at a rate of -26.3% per decade (Meier et al. 2007), which is almost three times higher than the rate of Arctic-wide September sea-ice loss during the same time period (1979-2006), -9.1% per decade (Stroeve et al. 2007). As a result of increasing sea-ice loss, the Chukchi shelf was effectively ice-free during the summer in 5 of the last 6 years (2002-2007), but only once (1999) in the previous 23 years (1979-2001) (Jay et al. 2008). In the Bering Sea, winter sea-ice cover declined significantly by ~-5% per decade during the March breeding season and even more in fall (-43% per decade in October and -20% per decade in November) (Meier et al. 2007), which suggests that sea-ice resting platforms are less available for walruses on their southward migration and that the winter sea ice is forming later.

The loss of summer sea ice in the Chukchi Sea is already having significant impacts on the Pacific walrus. These impacts include the shift of females and young from the sea-ice edge in the Chukchi Sea to land-based haulouts as the summer sea ice disappears, high mortality at land-based haulouts, abandonment of calves at sea, and evidence of increasing physiological stress: (1) Pacific walruses came earlier and stayed longer at coastal haulouts along the northwest Alaskan coast and northern Chukotka coast in the summer of 2007, congregating in extremely dense herds of up to 40,000 individuals (Joling 2007b). Not only were walruses stranded at land-based haulouts at unprecedented numbers for up to three months in the summer, but females and calves were forced to come ashore which is a highly anomalous behavior since they normally remain along the Chukchi Sea ice edge in summer (Fay 1982). (2) Walruses that were concentrated at dense land-based haulouts in 2007 suffered high mortality and injury from trampling during stampedes. When alarmed by human disturbance or predators, walruses will stampede en masse to enter the safety of the water, and calves are especially vulnerable to being crushed to death (Fay 1982). In the summer of 2007, 3,000 to 4,000 mostly young walrus died in stampedes at the extremely-dense, land haulouts on the Chukotka coast, which represents significant mortality (Joling 2007b). (3) The retreat of the Chukchi summer sea ice northward of the shelf may have resulted in higher calf mortality in 2004 due to abandonment. In July-August 2004, researchers observed nine Pacific walrus calves separated from adult females in a region of deep water typically covered with sea ice during summer (Cooper et al. 2006). Cooper et al. (2006) attributed the unprecedented number of separations of mother-calf pairs to the rapid loss of sea ice over the shelf, since the disappearance of sea-ice resting platforms would have prevented females from simultaneously foraging and caring for their young. Female-calf pairs may become more easily separated without sea-ice resting platforms over shallow waters where females can leave their calves while they feed and where calves can rest. (4) In years with low summer sea ice, walruses in the Bering Strait have been observed in poor physical condition, which has been linked to their decreased ability to forage in these years (Pungowiyi 2000).

Of foremost concern for the Pacific walrus, the effects of global warming are likely to worsen in this century. Arctic air temperatures are projected to increase by an average of 8°C during winter by the end of the century (Christensen et al. 2007). Summer sea ice may disappear throughout the Arctic as early as 2012 (Amos 2007, Borenstein 2007) or 2030 (Stroeve et al. 2008). By 2050, the Bering Sea is predicted to lose 40% of its winter sea ice under a mid-level emissions scenario (Overland and Wang 2007) which the world is currently on the path to exceeding (Canadell et al. 2007, Raupach et al. 2007). Because sea ice will be thinner and the period of sea-ice melt will be longer, the remaining winter sea-ice habitat will likely be of lower quality. Habitat loss of this magnitude will undoubtedly commit Pacific walrus to population declines and to an increased risk of extinction.

Global warming will impact the Pacific walrus by degrading and eliminating critical sea-ice habitat, decreasing prey availability, altering interactions with predators and disease, and increasing human disturbance throughout the range. Specifically, the impacts of global warming on the Pacific walrus include the following:

(1) Lost access to foraging grounds. The loss of summer sea ice and significant reductions in winter sea ice will deprive the Pacific walrus of access to large portions of its foraging habitat on the Chukchi and Bering Sea shelves. Without sea-ice resting platforms over the Chukchi Sea shelf in summer, females and young will be forced to use land-based haulouts during the summer months. Instead of the population being distributed across the shallow shelf, the entire Pacific walrus population will be concentrated at land-based haulouts for extended periods of time in summer and will only be able to access benthic prey resources within a proscribed distance from shore before needing to return to land to rest. During the winter, the remaining sea ice in the Bering Sea will be smaller in extent and the sea-ice edge will continue to retreat farther northward. Therefore, the entire Pacific walrus population will have access to progressively smaller areas of the Bering Sea shelf for foraging in winter.

(2) Increased physiological stress due to loss of sea-ice haulouts. Pacific walrus adults and young are likely to experience increased physiological stress due to the loss of sea-ice haulouts since this will preclude them from resting at sea during foraging trips, and from nursing their young and molting on safe, offshore sea-ice floes. In fall, winter, and spring, the reduction and thinning of sea ice will likely require females and young to swim farther before finding adequate sea-ice floes for these essential behaviors, increasing their energetic costs. During the summer, the loss of the summer sea ice will force females and young onto land-based haulouts, as observed in 2007. Concentrated groups of walruses can quickly deplete local benthic prey resources surrounding haulout sites, and walruses would be forced to swim progressively longer distances from shore to reach unexploited areas of benthic prey, which will increase their metabolic costs (Lowry 2000). In addition, females and young at land-based haulouts will likely face increased exposure to disturbances that cause them to enter the water during their resting and molting periods, also increasing metabolic stress. Increased physiological stress from these sources could have negative consequences for walrus fecundity and survival.

(3) Increased calf mortality due to loss of sea-ice haulouts. Calf mortality is also likely to increase as sea ice disappears as a result of increased metabolic stress during foraging trips and higher risk of abandonment. Calves that accompany their mothers on foraging trips from land-

based haulouts will not have sea-ice platforms for needed resting and nursing during these trips, heightening physiological stress. In addition, the risk of calf abandonment may increase, as observed in 2004 (Cooper et al. 2006), because females will not be able to leave their calves on or near sea-ice floes while they forage at the benthos.

(4) Increased mortality at land-based haulouts due to stampedes and predation. Walruses concentrated at land-based haulouts will likely suffer high mortality and injury from trampling during stampedes, as was observed in 2007. When alarmed by human disturbances or predators, walruses will stampede en masse to enter the safety of the water (Fay 1982). When walruses are aggregated in dense concentrations, calves are especially vulnerable to being crushed to death due to their small size. In addition, females and young may be at greater risk of predation by polar bears and terrestrial predators at land-based haulouts during summer (Lowry 2000, Kelly 2001).

(5) Interruption of breeding activities and seasonal cycle. The reduction of winter sea ice and shrinking length of the sea-ice season is likely to interrupt the timing and success of Pacific walrus breeding activities, including courtship, birthing, and nursing, with consequent negative impacts on fecundity (Tynan and DeMaster 1997). Pacific walrus migrations are closely linked to the seasonal cycle of sea ice (Fay 1982). The timing and pattern of onset of seasonal ice provide environmental cues for the entire Pacific walrus population to congregate at their breeding sites in the Bering Sea in winter. The delayed onset of the winter sea-ice season and northward retreat of the winter sea-ice edge may interrupt this seasonal migration and aggregation at the breeding grounds. Furthermore, walruses require winter sea ice for courtship displays, giving birth, and nursing. Reductions in quantity and quality of winter sea ice may negatively impact these activities, lowering reproductive success.

(6) Decreased prey availability. Coincident with rising temperatures and sea-ice loss, the northern Bering Sea ecosystem is undergoing a shift from a benthic-dominated ecosystem rich in prey for Pacific walruses to one dominated by pelagic fish (Grebmeier et al. 2006a, Grebmeier et al. 2006b). This ecosystem shift will lower prey availability for the Pacific walrus.

(7) Changing interactions with predators and disease. Global warming is likely to increase depredation and disease occurrence in Pacific walrus populations. Walruses that are forced to concentrate at terrestrial haulouts due to loss of sea ice may increase their risk of predation by polar bears and terrestrial predators including grizzly bears, wolves, and Arctic foxes (Lowry 2000, Kelly 2001). The break-up of the sea ice may also increase predation opportunities for killer whales that will be able to further penetrate the ice (Lowry 2000). Global warming also poses a risk to Pacific walrus by improving conditions for disease spread (Harvell et al. 1999, ACIA 2005).

(8) Increased human disturbance in the Pacific walrus range. The disappearance of seasonal and perennial sea ice in the Arctic will encourage increased shipping activity and oil and gas exploration throughout the Pacific walrus's range (ACIA 2005). Tourism and commercial fisheries are also likely to expand (AMAP 2003).

The Pacific walrus also faces ongoing threats of on and offshore oil and gas development throughout its range, rising contaminant levels in the Arctic, and bycatch mortality from commercial fisheries. In the U.S., the Oil and Gas Leasing Program for 2002-2007 approved four lease sales in Pacific walrus habitat, and in 2007-2012, lease sales in Pacific walrus habitat are planned in the Chukchi Sea in 2008, 2010, and 2012, in the Beaufort Sea in 2009 and 2011, and in Bristol Bay in the southeastern Bering Sea in 2011 (Table 4, Figure 13) (MMS 2007). Chukchi Lease Sale 193, held on February 6, 2008, offered important Pacific walrus foraging habitat on the Chukchi continental shelf for leasing, thereby opening the door for oil and gas development in a significant portion of the Pacific walrus's summer range. In Russia, oil and gas companies have already begun or are planning ambitious development projects in the Chukotka region of the Bering and Chukchi Seas in important areas of Pacific walrus breeding and foraging habitat. Adverse impacts of oil industry activities on the Pacific walrus include contact with and ingestion of oil from acute and chronic spills; industrial noise pollution from ice-breakers, aircraft, and seismic surveys; and harassment from aircraft, ships, and other vehicles that can disrupt breeding, foraging, resting, and breathing activities (Fair and Becker 2000). Additionally, increased oil and gas production translates into higher greenhouse gas production, which furthers global warming's impact on the Pacific walrus and its habitat.

Existing regulatory mechanisms have been ineffective in mitigating the principal threats to the Pacific walrus, the most important of which is global warming. There are currently no legal mechanisms regulating greenhouse gases on a national level in the United States. The immediate reduction of greenhouse gas pollution is essential to slow global warming and ultimately stabilize the climate system while there is still suitable Pacific walrus sea-ice habitat remaining. Unless greenhouse gas emissions are cut dramatically in the immediate future, the disappearance of the sea ice and the decline of the Pacific walrus are essentially assured.

This Petition summarizes the natural history of the Pacific walrus, its population status, and the threats to the Pacific walrus and its habitat. The Petition then clearly demonstrates that, in the context of the ESA's five statutory listing factors, the U.S. Fish and Wildlife Service should promptly list the Pacific walrus as endangered.

Natural History and Biology of the Pacific Walrus

I. Species Description

The walrus (*Odobenus rosmarus*) is the largest and most gregarious of the eight ice-breeding pinnipeds of the Arctic shelf region (Kelly 2001, Burns 2002). Walruses have a rotund body with a girth nearly equal to their length, a massive neck, and a small, blocky head with a blunt snout, small eyes, and no external ears (Lowry 1984, Fay 1985). Walrus calves are covered in a dense, dark brown coat while adults have a coarser, less dense, tawny or cinnamon coat that often becomes lighter with age (Heptner et al. 1976, Fay 1982). Walrus skin is thick and tough and appears pale when animals are immersed in cold water but becomes perfused with blood when hauled out, turning a distinctive rosy color (Fay 1982). The walrus's most distinguishing feature is an ever-growing pair of tusks, which are modified canine teeth possessed by adults of both sexes and which become visible at age two (Buckley 1958, Fay

1982). Walruses use their tusk for defense, social purposes, and occasionally to help them haul out on sea ice by jabbing them into the substrate and pulling the body forward, inspiring their scientific name meaning “tooth-walking sea horse” (Fay 1985, Ray and McCormick-Ray 2004). Also unique among pinnipeds, 600 to 700 stiff bristles (the mystacial vibrissae) cover the walrus’s broad snout below the nasal region and help in food detection (Heptner et al. 1976, Lowry 1984).

The Pacific walrus (*Odobenus rosmarus divergens*) is separated geographically and differs morphologically from its sister subspecies, the Atlantic walrus (*O. r. rosmarus*) in several ways. The Pacific walrus in confined principally to the Bering and Chukchi Seas while the Atlantic walrus occurs in or adjacent to the North Atlantic in four regions: the Hudson Bay-Davis Strait, eastern Greenland, Svalbard and Franz Josef Land, and Kara Sea and Novaya Zemlya (Fay 1982). Morphologically, the Pacific walrus is larger in size; bears longer and thicker tusks; has a broader, more square snout and a greater anterior breath and depth of the skull; and has lumpier neck and shoulder skin in adult males (Heptner et al. 1976, Fay 1982).

Male and female Pacific walruses are similar in appearance, although sexual dimorphism is manifest in body dimensions, the shape and size of tusks, and skin characteristics (Heptner et al. 1976, Fay 1982, Lowry 1984). Adult males average 3.2 meters long and 1,200 kg in weight but can reach 3.6 m in length and 1660 kg in weight, while adult females average 2.7 m in length and 830 kg in weight but can reach 3.1 m in length and 1250 kg in weight (Fay 1982). The tusks of males are stouter, straighter and more elliptical in cross-section than those of females and may be up to 80 cm long in males and weigh 4 kg or more (Heptner et al. 1976, Fay 1985). The skin, which is 2-4 cm thick over most of the body, is thicker in males, and only sexually mature males develop nodular formations on the neck and shoulders which are sparsely haired and paler than the rest of the body (Heptner et al. 1976, Fay 1985). Newborn calves average 1-1.2 m in length and weigh 45-75 kg (Fay 1982).

The Pacific walrus is adapted for feeding and traveling in water but must associate with sea ice or land as a substrate on which to rest, socialize, give birth, and care for young (Lowry 1984). Walruses propel themselves through the water by alternating strokes of the hindflippers, similar to phocid seals (Fay 1985). They use their foreflippers as paddles at low speed but hold them against the body or use them as rudders at medium to high speeds (Fay 1985). On land or ice walruses achieve a unique form of quadrapedal locomotion by bringing their hind limbs underneath the body and raising their chest using their foreflippers, (Lowry 1984).

II. Taxonomy

The Pacific walrus belongs to the order Carnivora, suborder Pinnipedia Illiger 1811, family Odobenidae Allen 1880, genus Odobenus, species *O. rosmarus* Linnaeus 1758, and subspecies *O. r. divergens* Illiger 1811 (Fay 1982). The family Odobenidae is represented by a single modern species *Odobenus rosmarus* of which two subspecies are generally recognized: the Pacific walrus (*O. r. divergens*) and the Atlantic walrus (*O. r. rosmarus*). The taxonomic status of walruses of Laptev Sea is uncertain (Fay 1982). Laptev walruses have been grouped with both the Atlantic and Pacific subspecies and also have been considered as a third subspecies *O. r. laptevi* (Fay 1982). Walruses of the Laptev Sea differ from Pacific walruses in size and are separated by at least 1200 km of unoccupied or sparsely occupied seas, with little possibility of interchange between populations (Fay 1982). Following other Pacific walrus accounts, we do not include the Laptev walrus as part of *O. r. divergens* due to their geographic isolation, morphological differences, and the absence of genetic data to clarify their taxonomic status (Fay 1982, USFWS 1994).

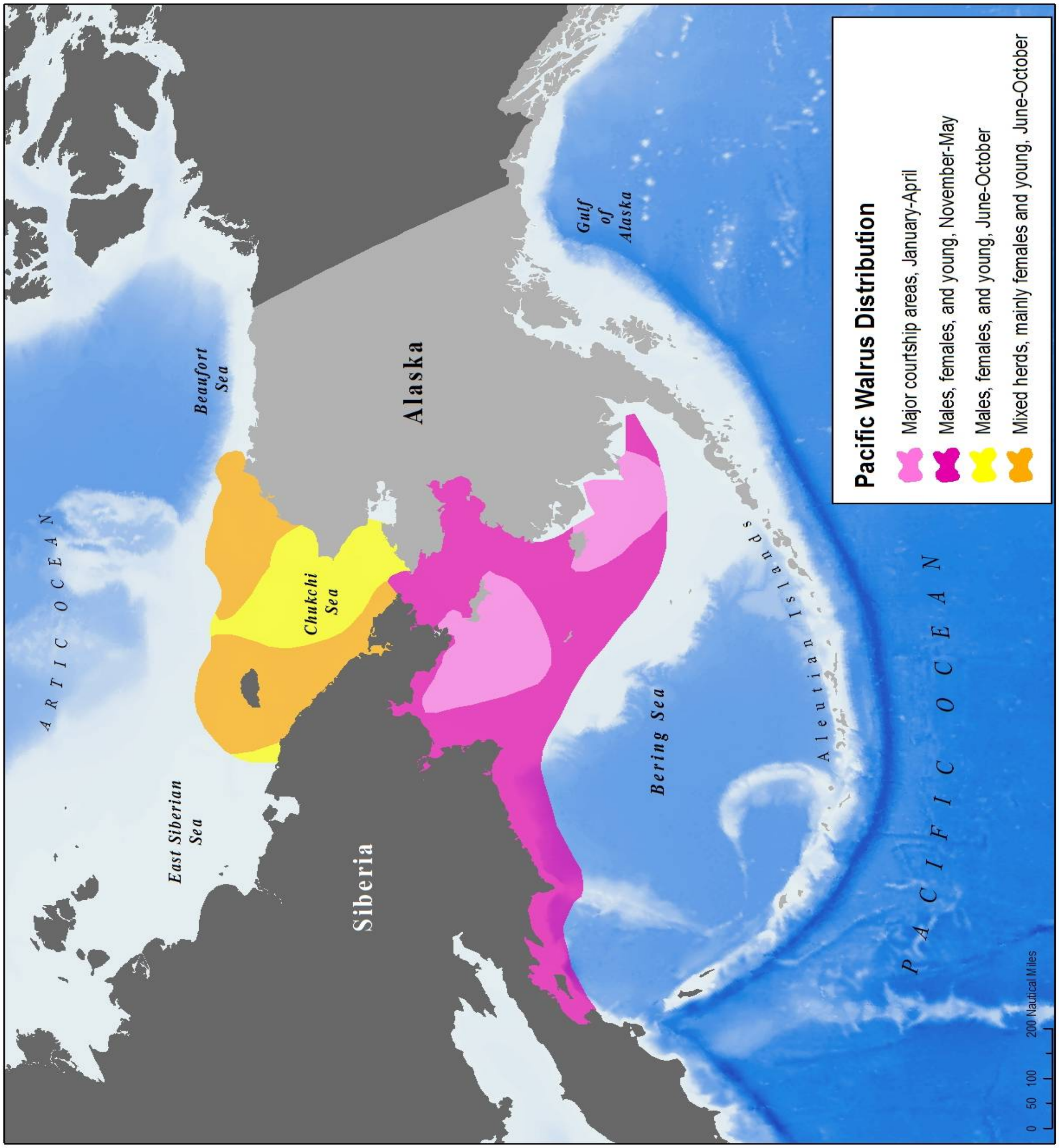
Phylogenetic studies of the relationship between walruses and other members of suborder Pinnipedia indicate that walruses are more closely related to otariids than to phocids (Arnason et al. 2006). A molecular mt-DNA analysis to resolve the phylogeny of suborder Pinnipedia determined that Pinnipeds are a monophyletic group in which Otarioidea (Otariidae and Odobenidae) and Phocidae split approximately 33 million years ago, followed by a split in Otarioidea into Odobenidae (proto-walruses) and Otariidae about 26-27 million years ago (Arnason et al. 2006). The basal split between Odobenidae and Otariidae is consistent with traditional paleontological and morphological interpretations of early otarioid evolutionary history (Arnason et al. 2006). Palentological evidence indicates that the Odobenidae evolved and diversified in the North Pacific Ocean during the Miocene around 20 million ago (Fay 1982, Arnason et al. 2006). The ancestor of the modern walrus appears to have spread into the Atlantic Ocean well before the closure of the Isthmus of Panama, North Pacific proto-walruses died out, and North Atlantic walruses re-colonized the North Pacific via the Arctic during the Pleistocene (Fay 1982, Arnason et al. 2006).

III. Distribution and Migration

The walrus *Odobenus rosmarus* occurs in a discontinuous but nearly circumpolar distribution around the perimeter of the Arctic Ocean and the contiguous subarctic seas (Fay 1982, Burns 2002). As described above, the Atlantic walrus and Laptev walrus are found in five regions adjacent to the North Atlantic: the Hudson Bay-Davis Strait; eastern Greenland; Svalbard and Franz Josef Land; the Kara Sea and Novaya Zemlya; and the Laptev Sea (Fay 1982).

The Pacific walrus is restricted primarily to the continental shelf waters of the Bering and Chukchi Seas and occasionally moves into the East Siberian and western Beaufort Seas (Figure 1) (Fay 1982, Lowry 1984). In the Bering Sea, the Pacific walrus is found from the Bering Strait southward to Bristol Bay and westward to the eastern Kamchatka peninsula (Fay 1985). In the Chukchi Sea, Pacific walruses have been observed as least as far west as Long Strait off Wrangel Island and as far east as Cape Barrow (Fay 1982). The extreme distributional limits of the Pacific walrus have been recorded in the summer (August-September) in the East Siberian Sea near the Bear Islands and Cape Shelagskii, in the Arctic Ocean as far north as 75°N, and in the Beaufort Sea at Holman Island and the Baillie Islands in the Northwest Territory (Fay 1982).

Figure 1. Distribution of the Pacific walrus.
Source: Based on Ray and McCormick-Ray (2004): Figure 6.17.



Migration between Seasonal Breeding and Foraging Grounds

The Pacific walrus undergoes a complex seasonal migration between the Bering and Chukchi Seas that is strongly coupled with the distribution of the sea ice (Fay 1982, Lowry 1984). The entire population spends the winter in the Bering Sea and a large portion of the population spends the summer in the Chukchi Sea (Fay 1982), undertaking a mass movement southward during fall and early winter and northward in spring and early summer to maintain access to the sea ice (Buckley 1958). Migratory movements differ somewhat between adult males and females which results in different summer distributions between the sexes (Ray and McCormick-Ray 2004). The seasonal distribution and movements of the Pacific walrus are described below according to Fay (1982) unless otherwise noted.

During the winter and early spring breeding season, Pacific walruses of both sexes are found exclusively in the broken pack ice of the Bering Sea (Lowry 1984, Ray et al. 2006). Reproductive subpopulations are found in two major regions: (1) the north-central Bering Sea from the Gulf of Anadyr to southwest St. Lawrence Island and (2) the southeastern Bering Sea from south of Nunivak Island into Kuskokwim Bay and northwestern Bristol Bay (Fay 1982, Lowry 1984, Ray et al. 2006).

As the Bering Sea ice disintegrates and moves northward from April-June, adult females, calves, immatures of both sexes, and some mature males begin to disperse northward with the receding sea ice into the Chukchi Sea, while most mature males move to land-based haulouts in the Bering Sea (Lowry 1984). For walruses that migrate to the Chukchi Sea, April is the month when walruses that wintered in Bristol and Kuskokwim Bays begin to move northward along the Alaskan coast, and walruses that wintered southwest of St. Lawrence move northeastward toward the Bering Strait or into the Gulf of Anadyr. In May a large part of the walrus population moves through the Bering Strait as the Bering Sea ice is reduced to a few large, wind-rafted masses of heavy floes and as large leads and polynyas open in the Bering Strait. In June most of the remainder of the population moves through the Bering Strait, passing along both sides of St. Lawrence Island, and by late June, large herds are observed in the Chukchi Sea where the pack ice is still intact, reaching Long Strait and Wrangell Island and occasionally near shore in the vicinity of Pt. Hope, Alaska.

During July and August, the spring migration into the Chukchi Sea comes to a close. Most of the population, including almost all adult females with young of the year, immatures of both sexes, and a lower percentage of mature males, concentrates along the southern edge of the pack ice in the western Chukchi Sea from the Bering Strait to Long Strait and in the eastern Chukchi Sea between Icy Cape and Barrow (Fay 1982, Lowry 1984). In August as the Chukchi and Beaufort Sea ice retreats northward, most of the population disperses northwestward to the vicinity of Wrangell Island while other animals remain along the northern Chukotka coast and off the northwestern coast of Alaska. In September when the pack ice typically retreats to its minimum extent, most animals are situated north of 70°N. Specifically, walruses concentrate along the fringe of the pack ice between Barrow and Wrangell Island but mainly east of 170°W and west of Herald Island (located 60 km east of Wrangell Island) and also along the northern Chukotka coast and in the vicinity of Barrow. In years with extreme sea-ice retreat, walruses haul out on Wrangell Island, especially at Cape Blossom (Fay 1982), and on Herald Island in enormous numbers (Heptner et al. 1976). It is important to note that mature males that have migrated to the Chukchi Sea often occupy terrestrial haulouts along the northern Chukotka coast in summer. However, females and calves spend the summer exclusively on the sea-ice edge over the Chukchi Sea shelf and only move to land-based haulouts when sea ice has disappeared from the shelf.

As noted above, many mature males move to coastal haulouts in the Bering Sea during the summer (July-September) instead of migrating into the Chukchi Sea. This leads to more marked segregation of the sexes in the summer in the Bering Sea, where adult males and females are almost totally segregated, than in the Chukchi Sea where adult males and females may form mixed groups. Two summer concentrations of bull walruses are found in the Bering Sea, south of the rest of the herd--in Bristol Bay and in the Gulf of Anadyr (Fay 1982, Lowry 1984). Male walruses in Bristol Bay appear to use four main haulout sites: Round Island, Cape Seniavin, Cape Peirce, and Cape Newenham (Jay and Hills 2005). A population survey in 1985 highlighted the importance of Bristol Bay as a haulout site since approximately 7% of the total population (roughly 230,000) summered in the Bristol Bay area in that year (Gilbert 1989). Walruses in the Gulf of Anadyr remain on ice floes, which remain nearshore from Kresta Bay to St. Lawrence Bay, until the ice has completely melted and then move to hauling grounds on shore until the end of September or October when the sea ice begins to reform (Heptner et al. 1976). Formerly, bulls also occupied summer haulout areas on the Pribilof and St. Matthew Islands and Punuk Island near St. Lawrence Island.

During fall (October-December), walruses that summered in the Chukchi Sea move southward ahead of the newly forming pack ice that advances rapidly southward as new ice forms and old ice is pushed south by strong northerly winds (Buckley 1958, Fay 1982). In October, walruses that have summered along the northern Chukotka coast arrive first in the Bering Strait, and large herds of southbound migrants may come ashore at hauling grounds in the Bering Strait and on the Punuk Islands for short periods of time (Fay 1982, Lowry 1984). In November when the pack ice edge is in or south of the Bering Strait, most walruses are between the pack ice edge and St. Lawrence Island. By late December, most walruses have passed St. Lawrence Island and concentrate along the pack ice edge. Herds of males that have summered in the Bering Sea join the rest of the population on the Bering Sea winter ice (Lowry 1984).

IV. Habitat Requirements

Water Depth and Sea Ice

Two principal factors that influence Pacific walrus distribution are water depth and characteristics of the sea ice (Lowry 1984). Pacific walruses are restricted to continental shelf waters and are rarely found in waters more than 100 m deep (Fay 1982, Burns 2002). The walrus's dependency on shallow shelf habitat is determined more by the bathymetric distribution of its prey species than by its inability to dive to depths greater than 100m (Fay and Burns 1988). The walrus's benthic invertebrate prey are particularly abundant from 10-100 m because benthic production is higher at these shallower depths (Fay and Burns 1988). For example, in the Bering Sea, the production of the middle shelf (10-100m) is an order of magnitude higher than on the outer shelf (100-200 m) due to the partitioning of primary production to the benthos in shallower waters and to the pelagic food web seaward of the 100 m isobath (Fay and Burns 1988).

The distribution, movements, and life history behaviors of the Pacific walrus are strongly influenced by the extent, quality, and position of the sea ice. All Pacific walruses depend on sea ice during the winter, and females, calves, and immatures depend on sea ice throughout the year as they follow the ice edge seasonally between the Bering and Chukchi Seas (Lowry 1984). Walruses require sea ice as a platform for resting between foraging bouts, courtship, giving birth, nursing calves, completing molt, and as passive transport to new foraging areas (Fay 1982, Ray and McCormick Ray 2004). In addition to providing the substrate for critical life-cycle activities (reproduction, molting, resting), sea ice provides numerous other important functions for the Pacific walrus: (1) isolation from terrestrial predators and disturbance; (2) proximity to food resources over the shelf; (3) sanitation provided by increased space, reduced competition for haul-out sites, and the addition of new ice; and (4) shelter from the wind provided by the ridges and cavities of accumulated snow and by the dampening of wave action (Burns et al. 1981). The critical roles that sea ice serves for the Pacific walrus are described further below.

A. Importance of Sea Ice to Foraging

Sea ice serves a critical function to Pacific walrus foraging by providing essential resting platforms between foraging bouts and passive transport to new foraging areas (Ray and McCormick-Ray 2004, Ray et al. 2006). As walruses follow the edge of the sea ice throughout the year, the sea ice acts as a floating conveyer belt between the Bering and Chukchi Seas that keeps walruses over the shallow, productive continental shelf waters and continually transports them to new foraging grounds.

Resting Platform between Foraging Bouts

Pacific walruses are dependent on sea ice for resting in between intensive foraging bouts. As described further in Section VI, Pacific walruses typically forage for several days followed by a period of one to two days when they haul out to rest (Ray et al. 2006). The characteristics of sea ice where they haul out in the winter and summer are summarized below.

In winter and early spring, the entire Pacific walrus population overwinters in large aggregations in the seasonal pack ice of the Bering Sea (Burns 2002, Ray et al. 1006). Most walruses occupy the broken pack ice where ice floes are thick and large enough to support the weight of large groups of animals, low enough to haul out on, and separated by leads and polynyas that allow access into and out of the water (Tynan and DeMaster 1997, Ray et al. 2006). Therefore, walruses are highly clumped in regions of divergent ice flow at the edge of the main pack and adjacent to polynyas, where wind, currents, and land formations create regular openings in the ice cover, rather than in areas of heavy, consolidated ice (Fay 1982, Fay 1985). As such, walruses are generally not found in areas where thick ice covers more than 80% of sea surface (Lowry 1984). Although walruses avoid areas with thick ice, they can break through thin ice up to 22 cm, using their head, and sometimes maintain ice holes with their tusks (Burns 2002). The broken pack ice preferred by the Pacific walrus typically occurs in a large area from St. Lawrence Island and the Gulf of Anadyr south to St. Matthew Island in the mid-shelf region of the Bering Sea over depths of up to ~100m (Ray et al. 2006). As noted above, this depth also delimits the shallow region where the benthic food of the walrus is most abundant and where primary productivity is largely partitioned to the benthos (Ray et al. 2006).

During spring and early summer, females, dependent young, immatures, and some mature males retreat northward with the melting sea ice to the Chukchi Sea (Fay 1982). In their summering areas in the Chukchi Sea, females, young, and immatures occur on the sea-ice edge over the continental shelf where ice occurs as smaller floes (Fay 1985). Females and young appear to lie selectively on floes with a surface area of 100 to 200 m^2 (Fay 1985). In contrast to adult females, most adult males remain in the Bering Sea during the summer, and observations in the Gulf of Anadyr suggest that males associate with sea-ice floes until they have completely melted before moving to shore-based hauling grounds (Heptner et al. 1976), typically on beaches of isolated islets and coastal headlands (Fay 1985). Thus, when sea ice is available, walruses haul out on pack ice to rest in preference to land (Fay 1982, Burns 2002).

Passive Transport to New Foraging Areas

Seasonal sea-ice advance and retreat in the Bering and southern Chukchi Seas is more extensive than in any other Arctic region (Ray and McCormick-Ray 2004). The ice edge moves freely in response to dynamic and thermodynamic forces, resulting in high variability in sea-ice cover and distribution (Francis et al. 2005). As walruses rest on sea ice or actively follow sea-ice floes while foraging, they are transported over great distances (Ray et al. 2006). A primary advantage of passive transportation by sea ice is that new feeding areas (leads) are constantly being opened up as sea ice moves (Ray and McCormick-Ray 2004). Associating with sea ice allows Pacific walruses to continually move to new unexploited foraging areas after depleting local resources (Ray et al. 2006), vastly broadening the walrus's foraging range and opportunities.

B. Importance of Sea Ice to Reproduction

Sea ice provides an essential platform for Pacific walrus reproductive activities including courtship, birthing, and nursing. During the breeding season (January-March), sea ice serves to aggregate females and males on ice floes, which allow males to compete for mates and monopolize access to groups of females (Fay 1982). Pacific walruses give birth to a single calf on the sea ice in the Bering Sea, and the ice provides several advantages that influence subsequent calf survival. First, the sea ice allows Pacific walruses to avoid excessive predation on their dependent young (Burns 2002). Since the broken pack ice used by walruses occurs south of consolidated pack ice, polar bears typically cannot reach Pacific walrus birthing areas. Second, the sea ice provides a safe, dry platform necessary for nursing during the long lactation period. Calves depend heavily on nursing for at least six months after birth to acquire a sufficient blubber layer, doubling in weight in the first five months, and may nurse for up to two years (Fay 1982). Finally, sea ice provides a critical platform for calves to rest on while their mothers forage and along the long migratory route between the Bering and Chukchi Seas.

C. Importance of Sea Ice to Molting

Similar to other pinnipeds, Pacific walruses likely need to spend time hauled out of the water to complete their molt, and sea ice provides as a safe molting platform isolated from predators and human disturbance. The growth of new hair in pinnipeds depends on high skin temperatures that allow blood to perfuse the epidermis, and these temperatures are only reached when animals are out of the water and warmed by solar radiation and ambient temperatures (Fay 1982). In addition, walruses may need to spend more time than usual resting at haulouts during molt since resting metabolic rates in phocid seals decrease as much as 20% during molt, feeding reflexes are inhibited, and overall activity decreases (USFWS 1994, Fedoseev 2000).

Pacific walrus adults molt annually during the summer over a prolonged period, beginning in some individuals as early as March and ending in others as late as October (Fay 1982). The peak period of adult hair shedding and replacement appears to occur in July and August, which overlaps with the postnatal molt of calves (Fay 1982). Calves molt their coarse, dark, natal coat in June and July, one to two months after birth, and thereafter molt annually during the summer (Fay 1982). In summer, females, calves, and immatures follow the pack ice into the Chukchi Sea and presumably use the sea ice as a molting platform. Therefore, the persistence of the Chukchi summer sea ice is important to allowing females and calves to complete their molt on safe, isolated, offshore floes rather than at land-based haulouts, where more frequent disturbances that cause animals to enter cold water may result in prolonging the molting period and increasing metabolic costs.

Coastal Haulout Characteristics

Adult male walruses use coastal locations as haulout areas in the summer. Summer land-based haulouts are typically located on rocky islands with steep cliffs and boulder beaches, low-lying sand and gravel spits extending from islands or mainland, tundra-covered islands with gently sloping sand or gravel beaches, and mainland coasts with sand or gravel beaches backed by steep bluffs (Lowry 1984). The common characteristics of these terrestrial haulouts are the absence of frequent disturbance of the animals, proximity to foraging grounds, and their location in relation to migration patterns (Lowry 1984).

V. Reproduction and Reproductive Behavior

The breeding system of the Pacific walrus is polygynous (Lowry 1984, Fay 1985). Courtship and mating occur in winter from January through March in the sea-ice environment of the Bering Sea (Ray and McCormick-Ray 2004). Spermiogenesis in males occurs from November to May, peaking in December-January for mature males and two months later for adolescents (Fay 1985). Females appear to ovulate principally in January-February (Fay 1985). Males compete for females through male-male fighting, defense of groups of females, and performing ritualized aquatic displays adjacent to ice floes with herds of females (Fay 1985, USFWS 1994, Ray and McCormick-Ray 2004). During these displays, males are spaced about 7-10 m apart and perform a distinctive sequence of tapping, pulses, and bell-like songs followed by a series of pulses and a short whistle at the surface, presumably to establish acoustic territories and to attract females (Fay 1985, Ray and McCormick-Ray 2004). Subadult and immature males are typically not present in the vicinity of displaying bulls (Fay 1982). Ray and McCormick-Ray (2004) suggest that while the sex ratio in the population is 1 male to 2-3 females, the sex ratio of those that breed is 1 male to 10 females. Whether males or females initiate mate choice is unknown (Ray and McCormick-Ray 2004). Mating likely occurs in the water but has never been observed (Fay 1982).

Implantation of the blastocyst in the uterus is delayed until June or July, approximately four to five months after fertilization, and gestation takes an additional 11-12 months (Fay 1982). Since parturition occurs 15-16 months after mating, the maximum rate of reproduction is one calf every two years per adult female, the slowest rate of reproduction among pinnipeds (Fay 1982). Fecundity appears to be greatest for females 9 to 11 years old and lower in youth and old age because of poor success in conception and gestation (Fay 1985).

Females give birth on the ice to a single calf (rarely twins) during late April to early June (Fay 1982, Burns 2002). While females often isolate themselves from other females to give birth, they may join a herd of other females and new calves soon after giving birth (Fay 1985). The sex ratio of calves appears to be 1:1 at birth (Lowry 1984). At birth, calves weigh 45-75 kg, measure an average of 1-1.2 m in standard length, and are covered with a dense, brown natal pelage of smooth hair 7-12 mm long, having lost their lanugo in utero (Fay 1982, Lowry 1984, Fay 1985, Burns 2002).

Calves are precocial and can enter the water from birth, but they depend on maternal assistance for thermoregulation and transportation (Fay 1985). Since calves are born during the northward spring migration, females with young calves often form nursery herds and migrate by passively drifting on the ice as well as by swimming (Burns 2002). Females and their calves are almost inseparable and females will lead, defend, and nurse calves for about two years (Fay 1985). Illustrating the close bond between mother and calf, mothers will help support the calf at the surface if it tires while swimming, and if one is killed the other will remain close by as long as possible (Buckley 1958). Walrus calves feed almost exclusively on their mother’s milk for the first year, during which time their weight triples (Fay 1985). During their second year, they begin to eat invertebrates, although many continue to suckle, and their weight doubles again (Fay 1985). Walrus calves are usually fully weaned at two years of age, but some may nurse for another year (Fay 1982).

VI. Diet and Foraging Behavior

Pacific walruses are specialized benthic foragers that primarily feed on bivalve mollusks (Fay 1982). Due to this specialization, they are dependent on shallow Arctic continental shelves where the bottom substrates support a high abundance of bivalve prey (ACIA 2005). While walruses can feed in water depths up to 100 m, most feeding occurs in waters less than 80 m deep (Fay and Burns 1988) in areas of muddy sand to gravel (Bornhold et al. 2005) where benthic productivity is high.

Pacific walruses feed primarily on bivalve mollusks (clams and mussels), and secondarily on other benthic invertebrates including snails, shrimp, crabs, worms, and sea cucumbers (Fay 1982). Although prey species found in the stomach contents of the Pacific walrus are comprised of more than 60 genera and 10 phyla, clams account for ~85-95% of stomach contents (Fay 1982, Lowry 1984). The primary bivalve mollusks eaten by walruses belong to at least 15 genera, most of which are long-lived and large-bodied species, and which are dominated by the clams *Mya truncata, Astarte borealis, Serripes groenlandicus,* and *Hiatella arctica* (Fay 1982, Lowry 1984). A stable isotope analysis of Pacific walrus muscle tissue collected from the Bering and Chukchi Seas (Little Diomede Island and Barrow) during summer supports the Pacific walrus's reliance on lower trophic level prey, due to the low nitrogen isotope ratios detected (Dehn et al. 2007).

Walruses occasionally supplement their diet with fish, seals, seabirds, and scavenged cetaceans (Fay 1985, Mallory et al. 2005). Lowry and Fay (1984) found that Pacific walruses may have increased their consumption of seals, including ringed (*Pusa hispida*), spotted (*Phoca largha*), and bearded (*Erignathus barbatus*) seals, in the late 1970s compared with the 1950s and 1960s. They suggested that seal consumption may increase in years when Bering Sea sea-ice extent is lower than average, leading to a greater overlap in the distributions of walruses and seals (Lowry and Fay 1984). As evidence of seabird predation, Fay et al. (1990) found a black guillemot (*Cepphus grylle*) in the stomach of a Pacific walrus, and Mallory et al. (2004) observed walruses foraging on adult thick-billed murres (*Uria lomvia*) in Canada. Walruses are also known to feed on dead cetaceans, principally skin and blubber (Fay 1985).

Walruses forage by moving along the shelf bottom by propelling themselves forward with their hind flippers (Fay 1985). They maintain vertical stability by keeping their snout and tusks in contact with the bottom, and lateral stability by touching their foreflippers to the bottom (Fay 1985). Walruses locate most prey tactilely with their mystacial vibrissae which can be erected to form a rigid, sensitive rake (Ray et al. 2006). The longer, lateral vibrissae function as large-scale detectors and their shorter, central vibrissae are used for finer resolution (Ray and McCormick-Ray 2004), enabling blindfolded walruses to distinguish objects as small as 3mm thick and 0.4cm^2 in surface area (Bornhold et al. 2005, Ray et al. 2006). Walruses unearth prey in the sediment by digging with their snout (Ray and McCormick-Ray 2004) and can jet water through their mouth to excavate deeper burrowing bivalves such as *Mya* (Bornhold et al. 2005, Ray et al. 2006). Manipulating prey with their strong, sensitive lips, walruses ingest only the fleshy parts from bivalve and gastropod mollusks, rejecting the shells, while they swallow other invertebrate prey whole (Ray and McCormick-Ray 2004). Extraction of flesh from shelled prey is accomplished by powerful sucking actions by means of a "vacuum pump" powered by a piston (the tongue) within a cylinder (oral cavity) (Fay 1982). A single walrus may discover, uncover, and consume ~6000 clams in a single feeding of ~16-17 hours duration (Ray et al. 2006). Individual walruses require about 5-7% of their total body weight in food per day, depending on size, age, and reproductive status (Fay 1982).

Foraging observations suggest that Pacific walruses typically forage for one to three days, during which benthic feeding is relatively continuous during both day and night, followed by a period of one to two days when they haul out to rest (Ray et al. 2006). During a foraging bout, walruses appear to spend 2-10 minutes underwater followed by 1-3 minutes at the surface (Fay 1982). A detailed time-depth recorder study of male walrus diving behavior in Bristol Bay in summer found that walruses spent 76.6% of their time in the water, of which 60.3% was spent diving (Jay et al. 2001). Males spent an average of 6.0 days (range 0.3 – 9.4 days) per trip and exhibited several diving behaviors: shallow, short dives (2.7 minutes) associated with traveling; deep, long dives (7.2 minutes) associated with benthic foraging; and V-shaped, moderate length

(4.7 minutes) likely related to exploration or navigation (Jay et al. 2001). Walruses appear to dive within their aerobic dive limit since there is no correlation between dive duration and the post-dive surface interval (Jay et al. 2001).

Of particular ecological importance, Pacific walruses appear to remain near specific floes of moving sea ice while foraging and return to the same ice areas to rest, thereby "homing" on particular ice floes (Ray et al. 2006). They forage and haul-out synchronously in groups, so that movements of the whole herd in and out of the water occur rather concurrently (Ray and McCormick-Ray 2004). For example, a group of walruses was observed to remain with the same ice floe area for three days even though the ice moved ~11 km/day (Ray et al. 2006). Because groups of walruses follow continually moving ice and shift between periods of intensive foraging and periods of rest, the areal extent of their feeding is patchy, unevenly distributed, and highly influenced by sea-ice dynamics, varying in intensity based on walrus group size and the rate of sea-ice movement (Ray et al. 2006). Their association with sea ice not only allows walruses to continually access new feeding areas, but allows them to impact broad swaths of the benthos as they follow the sea-ice edge.

Through their foraging activities, walruses disturb significant area of the seafloor, leaving characteristic marks of two types: long, sinuous furrows and small, shallow pits. Sidescan sonar studies have found that furrows in the Chirikov basin of the Chukchi Sea were on average 47 m long (10–200 m), 0.40 m wide and about 0.10 m deep, while studies in Bristol Bay detected furrows typically 5 to 10 m long with some reaching 20 m or more (Bornhold et al. 2005). Pits in Bristol Bay were small (>1 m diameter) and shallow, often in clusters ranging in density from 5 pits per hectare to 35 pits per hectare (Bornhold et al. 2005). In the Chukchi Sea, Nelson et al. (1994) estimated, based on sidescan sonographs, that between 24% and 36% of the seafloor was reworked by walrus foraging, concluding that the entire seafloor is reworked every three years (Bornhold et al. 2005). The ecological significance of walrus foraging is described in further detail in the next section.

Finally, studies of walrus diet suggest that partitioning of food resources occurs between males and females, between young and adults, and between the walrus and its competitor, the bearded seal. Although males and female walruses eat similar prey species, females tend to eat smaller species of clams and smaller individuals of large species while males feed primarily on large individuals of large species (Lowry 1984). In addition, young animals appear to feed on smaller items than do adults (Lowry 1984). Some seasonal resource partitioning also occurs. In winter when male and female distributions overlap in the Bering Sea, adult males apparently eat very little during the reproductive period (January-March), leaving most food in wintering areas available to females and young (Lowry 1984, Fay 1985). In summer, resource partitioning is accomplished through geographic segregation since many adult males stay in the Bering Sea while females and young migrate northward into the Chukchi Sea. This seasonal resource partitioning may be important to females since they increase their average energy intake 40-50% above their maintenance level during pregnancy and lactation (Fay 1985) and for adult males since their large size necessitates a high energy intake. Pacific walruses are thought to compete with bearded seals for food which forage benthically in the same regions (Dehn et al. 2007). However, stable isotope analysis of Pacific walrus and bearded seal tissues collected from the Bering and Chukchi Seas indicated that these species forage on somewhat different prey resources based on their different carbon isotope ratios, which were smaller in range in walruses than in bearded seals (-17.3 to -16.8 and -18.7 to -15.8, respectively) (Dehn et al. 2007).

VII. Ecological Role of the Pacific Walrus

The Pacific walrus functions as a keystone species in the Bering and Chukchi Sea continental shelf ecosystem due to its role as a major consumer of benthic resources and a bioturbator of benthic habitat (Ray and McCormick-Ray 2004, Ray et al. 2006). Specifically, Pacific walruses are thought to have a significant effect on benthic community structure and productivity by consuming a large portion of the benthic biomass, restructuring benthic sediment while feeding, and mobilizing nutrient flux from the sediments to the water column (Lowry 1984, Oliver et al. 1985, Ray and McCormick-Ray 2004, Ray et al. 2006).

Pacific walruses are estimated to consume three million metric tons of benthic biomass annually (Ray et al. 2006). As walruses search for and remove deep-dwelling clams and benthic invertebrates, they resuspend large quantities of benthic particles and fundamentally alter the sediment structure (Ray et al. 2006). In addition, walrus bioturbation produces a flux of nutrients from the sediment pore water to the water column that may be as much as two orders of magnitude per day greater than normal flux rates at the sediment-water interface (Ray et al. 2006). In the central Bering Sea, Ray et al. (2006) estimated that ~140,000 walruses could perturb thousands of square kilometers per year (~3000-5000 km^2 area) and resuspend ~650-1000 x 10^6 m^2 of sediment during their five month seasonal residence in winter and spring. Overall, Pacific walruses are capable of bioturbating 2-3% of the Bering Sea shelf annually, which is ecologically significant considering that walruses alter the sediment in widespread, patchy pulses (Ray et al. 2006).

Walrus consumption and bioturbation influence benthic community structure in several ways. First, walruses may alter community composition by selectively removing older individuals of a few species of bivalve mollusks (Bowen 1997). Second, walruses create new surfaces for the colonization of invertebrate larvae and opportunist species by producing pits and furrows while feeding and providing habitat under discarded bivalve shells (Oliver et al. 1985, Ray et al. 2006). In addition, Oliver et al. (1985) found that walrus feeding provides food for scavengers such as sea stars *Asterias amurensis* and brittle stars *Amphiodia craterodmeta*.

Walrus foraging is also thought to increase productivity locally and perhaps even on subregional scales. Walrus bioturbation increases oxygenation and associated nitrogen release from the sediments, thereby making more nitrogen available in the water column for phytoplankton production that may then be utilized by benthic fauna (Ray et al. 2006). By activating nutrient pulses from the sediment to the bottom water, walrus foraging may trigger localized phytoplankton blooms that would not otherwise occur (Ray et al. 20006). In addition, the excretion of metabolic wastes and food remains by walruses releases nutrients from the benthos into the water column which may also support production (Lowry 1984). Because walrus foraging may increase production and benthic biomass, walruses may exert a positive influence on the abundance of its prey species, thus “cultivating its own garden” (Ray et al. 2006). This possibility is supported by the co-occurrence of benthic biomass hotspots with areas heavily used by walrus--southwest of St. Lawrence and south of the Bering Strait in the Chirikov

Basin (Ray et al. 2006). Overall, walrus bioturbation appears to make an important contribution to the high productivity of the Bering Sea ecosystem due to its effect on benthic structure and regeneration of nutrients (Ray et al. 2006).

VIII. Social behavior

Pacific walruses are gregarious at all times of the year (Ray and McCormick-Ray 2004). When hauled out of the water, walruses typically rest in contact with one another, with young frequently lying in the shelter of larger animals possibly to conserve body heat (Ray and McCormick-Ray 2004). In the winter, walrus groups can number up to 200 animals but occasionally number in the thousands (Ray et al. 2006). In summer, males at terrestrial haulouts congregate in even larger concentrations, and herds of 14,000 animals have been observed (Ray et al. 2006). Cooperative behaviors have been observed among walruses. Injured individuals may be helped by others to float on the surface, and pups that tire of swimming will climb atop their mothers or other walruses (Heptner et al. 1976).

Walruses communicate through both aerial and underwater vocalizations. Aerial vocalizations include barks, grunts, bellows, and snorts and serve as threats, greetings, and female-calf communications (Kastelein et al. 2002). Underwater vocalizations include bell-like, clicks, knocks, and rasps that are thought to be mainly used by males for courtship and underwater territory establishment, and are also related to diving (Kastelein et al. 2002). Walruses may identify each other by sound as well as by smell (Ray and McCormick-Ray 2006). Social rank appears to be a function of tusk and body size evident in the fencing, posturing and jabbing among both sexes (Ray and McCormick-Ray 2004).

IX. Sources of Natural Mortality

A. Predation

The only known predators of the Pacific walrus are polar bears (*Ursus maritimus*), killer whales (*Orcinus orca*), and humans (Heptner et al. 1976, Fay 1982, Lowry 1984). Contact between polar bears and walruses occurs principally during summer when their ranges overlap in the Chukchi, Bering, and Beaufort Seas. Polar bears are thought to primarily kill walrus calves since adult walruses are more impervious to attack due to their large size (Fay 1982). Even brief separations between mothers and calves can be lethal since polar bears take advantage of the absence of the attentive, highly defensive mother to attack the calf. Killer whales have been observed to kill walruses of all ages, although the mortality rate caused by predation is unknown (Fay 1982). The Pacific walrus overlaps in range with the killer whale in spring, summer, and autumn when walruses inhabit the ice edge, the open pack, and ice-free waters in the Bering and Chukchi Seas.

B. Disease and Parasites

Numerous disease conditions and parasites have been found in walruses but the mortality caused by these factors is unknown (Heptner et al. 1976, Lowry 1984). Disease conditions observed in the Pacific walrus include bacterial and viral infections (e.g. calicivirus, pneumonia), tumors, kidney stones, and hernias (Fay 1982). Pacific walruses are widely infested with a host-specific ectoparasite--an anopluran louse--which resides in the skin folds over the entire body and which appears to cause mild skin irritation (Fay 1982). Endoparasites of 14 species have been identified in the Pacific walrus, including nematodes, trematodes, and cestodes, but the impacts of these species are either unknown or are thought to not have significant adverse effect (Fay 1982).

C. Trampling

Trampling by other walruses during stampedes can result in abortion, injury, and death on haulout grounds (Fay 1982, Lowry 1984, USFWS 1994). Mass mortality can occur when walruses rush on or offshore to evade predators such as killer whales and polar bears, although human disturbance is often the cause of stampedes (Heptner et al. 1976, Fay 1982).

X. Demographic Rates

Demographically, Pacific walruses exhibit delayed maturity, low reproductive rates, high adult survival, and high longevity which are associated with a ‘slow’ life history strategy (Saether and Bakke 2000). Due to their unique biennial cycle of reproduction, Pacific walruses have the lowest rates of reproduction among pinnipeds. Accordingly, their population growth rates are sensitive to changes in adult survival (Saether and Bakke 2000) and they are slow to recover from population declines or catastrophes.

A. Age of First Breeding

Walruses are the slowest to reach sexual maturity among pinnipeds (Ray and McCormick-Ray 2004). Female walruses become sexually mature between four and ten years of age (Fay 1982). Most male walruses become capable of breeding at ten years of age, but they do not attain physical maturity and are probably seldom successful in competing for females until about 15 years of age (Fay 1982).

B. Fecundity

Walruses have the lowest rate of reproduction among pinnipeds since their maximum calf production is one calf every two years per adult female (Ray and McCormick-Ray 2004). Fay (1982) reported the highest rates of success in conception and gestation (>80%) occur among females from ages 8-15 with lower rates of success for fertile females in the youngest and oldest age classes. In each year, 41% of females of breeding age will have conceived, 38% will have produced a calf, and 21% will be neither pregnant nor have produced a calf (Fay 1982).

C. Survival

Survival rates for the Pacific walrus are not well-known. Calf survival rates are thought to be the lowest, estimated at 65-73% for the first year of life by Fedoseev and Gol’ tsev (1969) and 80% in the first two years of life by Fay (1982). Lowry (1984) reported that 50% of animals born survive to sexual maturity. In the absence of human mortality, adult survival rates are though to be very high, perhaps up to 99% after the first year of life (Ray and McCormick-Ray 2004).

D. Lifespan

Lowry (1984) estimated the maximum lifespan at 40 years.

E. Sex ratio

Adult female walruses are thought to outnumber adult males. Lowry (1984) reported a sex ratio of 2 to 3 females: 1 male, while Fay (1985) reported a sex ratio of 4.6 females: 1 male in 1972. The skewed sex ratio is likely a consequence of intense competitive fighting among males during the breeding season that increases male mortality rates, but also depends on the relative numbers of males and females in human harvests (Lowry 1984).

Abundance and Population Trends of the Pacific Walrus

Accurate estimates of Pacific walrus population size are difficult to obtain since walruses inhabit a remote and difficult-to-access environment, have a patchy distribution, and spend part of their time underwater. However, researchers have estimated walrus population size and trends over the past two centuries based on harvest levels, observed changes in distribution and abundance (i.e. losses or reductions of haulout and breeding sites), and direct censuses beginning in 1960. These data indicate that Pacific walrus population size has fluctuated markedly since the late 1700s, with declines occurring in the late 1800s, the 1930s-1950s, and most recently in the mid-1980s (Fay et al. 1989). The current status of the Pacific walrus population is unknown. The most recent available population estimate conducted jointly by the U.S. and former Soviet Union reported ~200,000 individuals (Gilbert et al. 1992). The results of a 2006 survey are not yet available.

Historic Population Size and Trends

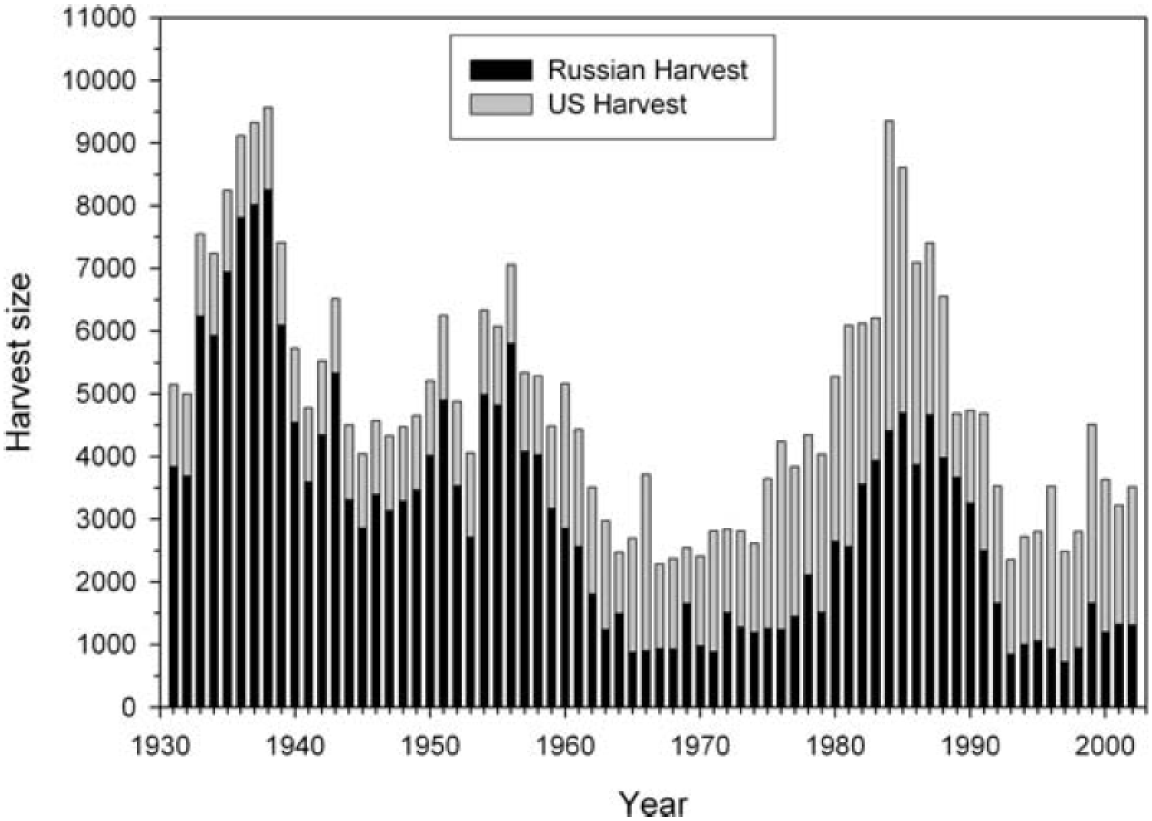
Pacific walruses have been hunted by native communities in Alaska and Russia for subsistence for centuries. The size of the Pacific walrus population before the arrival of Europeans in the Bering Sea is unknown, but Fay (1982) estimated at least 200,000 individuals. Commercial hunting of walruses began in the late 1700s, and hunters killed more than 10,000 walruses in some years between the late 1700s to late 1800s for extraction of ivory, oil and hides (Table 1) (Fay 1982). Initially, walruses were harvested primarily from the all-male herds summering in Bristol Bay and the Pribilof Islands (Fay 1982). Fay (1982) reported that 4,000-5,000 walruses were harvested from the Pribilofs in just two years, and overexploitation resulted in the near extirpation of the Pribilof population by the early 1800s. Following the decimation of the summer male herds, hunters began harvesting walruses on the pack ice, now taking females as a part of the harvest (Fay 1982). In the mid-1800s, the commercial harvest of the Pacific walrus intensified. U.S. whalers had decimated the bowhead whale (*Balaena mysticetus*) population in the Bering Sea by mid-century and switched to heavier hunting of walruses (Ray and McCormick-Ray 2004). Also, in the 1860s, killing walruses with a harpoon and lance, which retrieved virtually all animals, was replaced by shooting them with rifles, and this new hunting method resulted in very low retrieval of killed and wounded walruses (Fay 1982). According to an estimate from the late 1800s, as many as three-fourths to two-thirds of killed walruses were not retrieved and many orphaned calves were left to die from starvation (Fay 1982). Furthermore, hunters preferred to kill females which were more accessible than males and yielded more oil, but which resulted in the further decimation of the population since fewer young were being produced (Ray and McCormick-Ray 2004). As a result of this intensive hunting, the Pacific walrus population suffered a drastic decline in the late 1800s (Fay 1982). In 1874, Scammon published the first account that recognized the excessive slaughter of the Pacific walrus and its population decline: "Already the animals have suffered so great a slaughter at their [the whalers'] hands that their numbers have been materially diminished, and they have become wild and shy, making it difficult for the Esquimaux to successfully hunt them, in order to obtain a necessary supply of food" (Buckley 1958).

Table 1. Approximate number of Pacific walruses harvested annually within historic times and the minimum size of populations from which they could have been drawn.
Source: Buckley (1958): Table 1, taken from Fay (1957).

Year	Harvest	Minimum Population
1650-1790	5,000-6,000	200,000
1790-1860	10,000-15,000	200,000
1860-1880	15,000-20,000	150,000
1880-1910	8,000-12,000	80,000
1910-1930	5,000-7,000	60,000
1930-1950	6,000-7,000	60,000
1950-1956	5,000-6,000	45,000

By the early 1900s, commercial hunting of the Pacific walrus declined because walrus and whale populations were depleted, making animals harder to find, and prices for hides and ivory were low (Fay 1982). Despite the decline in commercial hunting, native people continued to harvest the walrus for subsistence and Arctic fur traders continued to hunt walruses, so the walrus population likely did not recover much in the early 1900s (Fay 1982). A second major decline in Pacific walrus population occurred between the 1930s and 1950s when the former Soviet Union sponsored an intensive vessel-based commercial hunting program from 1931-1957 (Fay 1982) that harvested up to 8,000 walruses annually, not including those walruses killed but not retrieved (Figure 2). During this same period, the U.S. began to regulate walrus hunting by prohibiting the killing of walruses in Alaska except by Alaska Natives and banning the exportation of raw ivory and hides through U.S. Department of Commerce regulations in 1937 and passage of the Walrus Act in 1941 (Buckley 1958). However, the Walrus Act did not include provisions for regulating native harvest and the prohibition against export of raw ivory was largely unenforceable (Buckley 1958). In addition, these prohibitions were weakened by an amendment to the Walrus Act in 1956 which permitted the killing of bull walruses by non-native hunters and the export of walrus hides (Buckley 1958). In the 1950s, the walrus population reached an estimated low of 45,000 individuals (Table 1), of which 2,000-2,500 were bulls that remained much of the year near the Walrus Islands in Bristol Bay (Buckley 1958). This large-scale population decline was evident in the decrease in the occupied range and loss of hauling grounds. In Russia, only 3 of 33 walrus herds remained on the coast of the Chukotka Peninsula in the 1950s (Buckley 1958), and walruses were absent from former breeding areas on Karaginsk Island and the northern Sea of Okhotsk in addition to hauling or breeding areas on Cape Kronotskii, Cape Shipunki, and the Commander Islands (Heptner et al. 1976). In the U.S., the only remaining hauling grounds regularly used by walruses were the Walrus Islands in Bristol Bay, while former hauling grounds on the Pribilof Islands, Amak Island, Port Moller on the Alaskan Peninsula, St. Lawrence Island, and near Cape Lisburne had been abandoned (Buckley 1958). Mortality rates at this time were estimated at 12% for males and 15% for females, which exceeded the estimated recruitment rate of 11% (Buckely 1958).

Figure 2. Annual harvest levels of the Pacific walrus by the United States and Russia from 1931-2002. Note: These harvest numbers do not appear to include walruses that were struck and lost.
Source: Garlich-Miller et al. (2006): Figure 1.



The dramatic, widespread decline of the Pacific walrus was recognized in the 1950s, which spurred the former Soviet Union to implement walrus hunting regulation and the U.S. to increase its regulations in the early 1960s (Fay et al. 1989). The Soviet Ministry of Fisheries implemented a harvest quota, ranging from 1000-4000 walruses, where 66% of the quota was allocated to shore-based hunting and remainder to ship-based hunting, and limited the harvest primarily to males (USFWS 1994). In the U.S., the Alaska Department of Fish and Game began regulating the walrus harvest when Alaska attained statehood in 1959 and in 1960 gained authority for walrus management from USFWS. Alaska established a sanctuary for summering male walruses in Bristol Bay in 1960 and from 1960-1972 limited native subsistence kill to five females per hunter per year (in addition to the taking of calves) but did not limit kills of males. In addition, 50 animals per year were allocated for sport hunting. With the passage of the Marine Mammal Protection Act (MMPA) in 1972, authority to manage walruses was transferred from Alaska to the USFWS. The MMPA prohibited harvest of walrus by non-natives but did not limit native harvest, although native peoples were prohibited from selling raw walrus materials unless they were made into handicrafts. From 1976-1979, Alaska briefly resumed management authority over the walrus harvest and imposed a harvest quota of 3,000 walruses per year. However, since 1979 the USFWS has managed the walrus and does not regulate subsistence harvest of walruses under the MMPA.

In response to restrictions on hunting beginning in the 1960s, the Pacific walrus population is believed to have increased rapidly in size during the 1960s and 1970s, peaking in the early 1980s (Fay et al. 1989). However, the Pacific walrus population once again showed signs of a population decline beginning in the mid-1980s (Fay et al. 1997). The high combined subsistence and commercial harvest of the U.S. and former Soviet Union during the 1980s, estimated at 6,000 to 9,000 walruses per year (Figure 2), is thought to have contributed to this decline (Fay et al. 1997). These harvest numbers represent only the walruses that were retrieved by hunters and not the walruses that escaped and later died. Using data from Alaskan harvests, Fay estimated that the retrieval of walruses that were struck by hunters was 58%, meaning that 42% of wounded animals escaped, and virtually all of these wounded walruses (99.7%) later died (Fay et al. 1997). In Russia, a similar rate of 60% of walruses that were struck were estimated to have been retrieved (Fay et al. 1997). Fay et al. (1997) also hypothesized that the Pacific walrus population may have declined in the 1980s due to density-dependent population limitation, based on evidence of decreases in the proportion of females bearing calves by the early 1980s (Fay et al. 1997).

Population estimates based on censuses between 1960 and 1990 are consistent with an increasing Pacific walruses population in the 1960s and 1970s followed by a population decline in the mid-1980s to at least early 1990s (Table 2). Population surveys conducted from 1960-1972 by the U.S. in winter and spring in the eastern Bering Sea and by the former Soviet Union in autumn in the western Chukchi and Bering Sea showed similar increasing trends, although these surveys used different methods, different times of year, and different segments of the population (Fay et al. 1997). Between 1975 and 1990, aerial surveys were carried out by the United States and the former Soviet Union at five year intervals. These estimates suggest that the Pacific walrus population was increasing in 1975 and 1980 and decreasing in 1985 and 1990. However, the estimates generated from these surveys are considered conservative population estimates because they did not include animals under water (Fay et al 1997) and unreliable because of their large confidence intervals.

Commercial hunting of the Pacific walrus was prohibited in Russia in 1991. Therefore, since 1992 harvest of Pacific walruses has been limited to subsistence hunting by native communities in Alaska and Chukotka (Garlich-Miller et al. 2006). Subsistence harvest levels in the U.S. and Russia from 1992 through 2002 ranged from 2,400 to 4,700 individuals annually, but do not include walruses wounded but not retrieved (Garlich-Miller et al. 2006). As discussed in the next section, the status of the Pacific walrus population from 1990 to the present is unknown.

Table 2. Census-based estimates of population size of the Pacific walrus, given as original estimates from censuses and as adjusted estimates reported in Fay et al. (1997). Adjusted estimates incorporate corrections for walruses not seen because they were underwater. Source: Data for 1960-1980 taken from Fay et al. (1997): Table 3. Data for 1985-1990 taken from Ray and McCormick-Ray (2004): Table 6.1.

Year	Adjusted estimate	Original estimate
1960	65,500 – 94,400	58,600 – 84,500
1961	75, 400 – 107,700	70,000 – 100,000
1968	105,900 – 159,600	73,000 – 110,000
1972	97,700 – 186,200	85,000 – 162,000
1975	220,300 – 247,800	140,000 – 200,000
1980	290,700 – 310,700	250,000 – 300,000
1985	234,020	
1990	201,039	

Current population size

The last population survey of Pacific walrus was jointly conducted by the United States and former Soviet Union in 1990 (Gilbert et al. 1992). The visual aerial survey method used for this census involves counting walruses from aircraft flown in transects over the walrus range and is complicated by many factors that are thought to make it inadequate for measuring population size with acceptable levels of accuracy and precision (USFWS et al. 2006). The problems of visual aerial surveys include narrow survey swath width, observer bias and fatigue, lack of a permanent data record, safety concerns associated with low-level flight in remote areas, and an unknown number of animals below the surface (Lowry 1984, USFWS et al. 2006). In March-April 2006, the USFWS Office of Marine Mammal Management, USGS, and Russian scientists from GiproRybFlot and ChukotTINRO conducted an aerial survey to estimate the size of the Pacific walrus population, using methods thought to solve many of the problems of previous censuses and offering the potential of providing a reliable estimate. The census methodology used high altitude infrared imaging to detect walrus groups hauled out on sea ice, high resolution digital photography to subsample the detected groups to estimate the number of walruses per detected group, and satellite radio telemetry of individual walruses to estimate the proportion of the population available to be detected by the scanner (USFWS et al. 2006). The new survey method allowed coverage of a much larger portion of the range, the potential for more accurate enumeration of groups, and a means to account for the proportion of the population not available to be detected (USFWS et al. 2006). Burn et al. (2008) reported that walruses are more difficult to detect thermally at lower ambient temperatures, which has necessitated the development of new methodologies for analyzing the census data since temperatures were colder than average during most of the survey period. Burn et al. (2008) stated that the walrus population estimate would be available to the public in late 2008.

The Pacific Walrus Warrants Listing Under the ESA

I. Criteria for Listing Species as Endangered or Threatened

Under the ESA, 16 U.S.C. § 1533(a)(1), USFWS is required to list a species for protection if it is in danger of extinction or threatened by possible extinction in all or a significant portion of its range. In making such a determination, USFWS must analyze the species' status in light of five statutory listing factors:

> (A) the present or threatened destruction, modification, or curtailment of its habitat or range;
> (B) overutilization for commercial, recreational, scientific, or educational purposes;
> (C) disease or predation;
> (D) the inadequacy of existing regulatory mechanisms;
> (E) other natural or manmade factors affecting its continued existence.

16 U.S.C. § 1533(a)(1)(A)-(E); 50 C.F.R. § 424.11(c)(1) - (5).

A species is "endangered" if it is "in danger of extinction throughout all or a significant portion of its range" due to one or more of the five listing factors. 16 U.S.C. § 1531(6). A species is "threatened" if it is "likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." 16 U.S.C. § 1531(20). While the ESA does not define the "foreseeable future," USFWS must use a definition that is reasonable, that ensures protection of the petitioned species, and that gives the benefit of the doubt regarding any scientific uncertainty to the species.

Because global warming is one of the foremost threats to the Pacific walrus, USFWS should consider the timeframes used in climate modeling. The minimum time period that meets these criteria is 100 years. Predictions of impacts in the next 100 years or more are routine in the climate literature, demonstrating that impacts within this timeframe are inherently "foreseeable." The IUCN threatened species classification system also uses a timeframe of 100 years. Moreover, in planning for species recovery, the USFWS and National Marine Fisheries Service (NMFS) routinely consider a 75-200 year foreseeable future threshold (Suckling 2006). For example, the Alaska Region of the USFWS stated in the Steller's Eider Recovery Plan:

> The Alaska-breeding population will be considered for delisting from threatened status when: The Alaska-breeding populations has <1% probability of extinction in the next 100 years; AND Subpopulations in each of the northern and western subpopulations have <10% probability of extinction in 100 years and are stable or increasing. The Alaska-breeding population will be considered for reclassification from Threatened to Endangered when: The populations has > 20% probability of extinction in the next 100 years for 3 consecutive years; OR The population has > 20% probability of extinction in the next 100 years and is decreasing in abundance (USFWS 2002 (emphasis added)).

With regard to the Mount Graham red squirrel, the USFWS stated "At least 10 years will be needed to stabilize the Mt. Graham red squirrel population and at least 100 to 300 years will be needed to restore Mt. Graham red squirrel habitat" (Suckling 2006 (emphasis added)). With regard to the Utah prairie dog, the Service defined the delisting criteria as "[t]o establish and maintain the species as a self-sustaining, viable unit with retention of 90 percent of its genetic diversity for 200 years" (Sucking 2006 (emphasis added)). NMFS stated of the Northern right whale: "[g]iven the small size of the North Atlantic population, downlisting to threatened may take 150 years even in good conditions" (Suckling 2006 (emphasis added)).

Perhaps most importantly, the time period that USFWS uses in its listing decision must be long enough so that actions can be taken to ameliorate the threats to the petitioned species and prevent extinction. Slowing and reversing impacts from anthropogenic greenhouse gas emissions, a primary threat to the Pacific walrus, will be a long-term process for a number of reasons, including the long lived nature of carbon dioxide and other greenhouse gases and the lag time between emissions and climate changes. For all these reasons, Petitioner suggests a minimum of 100 years as the "foreseeable future" for analyzing the threats to the continued survival of the Pacific walrus. The use of less than 100 years as the "foreseeable future" in this rulemaking would be clearly be unreasonable, frustrate the intent of Congress to have imperiled species protected promptly and proactively, and fail to give the benefit of the doubt to the species as required by law. USFWS must include these considerations in its listing decision.

II. The Pacific Walrus Qualifies for Listing Under the Endangered Species Act

Petitioner believes that all five listing factors threaten the future existence of the Pacific walrus. Global warming poses the most immediate and grave threat to the Pacific walrus since this species is likely to suffer dramatic population declines, if not extinction, with the rapid degradation and loss of its sea-ice habitat in this century. The loss of summer sea ice is already having significant impacts on the Pacific walrus, including shifting the distribution of females and young from the sea-ice edge in the Chukchi Sea to land-based haulouts as the summer sea ice disappears, high mortality at land-based haulouts, abandonment of calves at sea, and evidence of increasing physiological stress. Growing threats resulting from climate change include depletion of prey resources due to changing ocean conditions and ocean acidification, increasing shipping activity and oil and gas development (with associated oil and noise pollution) throughout its range as sea-ice loss increases the accessibility of previously ice-covered regions, and increasing exposure to predators and human disturbance. The Pacific walrus also faces threats from current oil and gas development throughout its range, rising contaminant levels in the Arctic, and bycatch mortality from commercial fisheries. Existing regulatory mechanisms have proven ineffective in mitigating these threats to the Pacific walrus. Clearly, the Pacific walrus is in dire need of the additional protections that only listing under the ESA can provide.

A. The Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range

1. Global Climate Change

Global warming represents the gravest threat to the long-term survival of the Pacific walrus. The Pacific walrus depends on sea ice as a platform for resting between foraging bouts, transportation to new foraging areas over the continental shelf, courtship, birthing, nursing, and molting, making the disappearance and degradation of the Pacific walrus's sea-ice habitat due to global warming the primary threat to its continued existence. The Pacific walrus's Arctic habitat has already warmed more than twice as fast as the global average, and a number of climate feedbacks will continue to accelerate future levels of warming in the Arctic. Observed changes to date in sea ice include significant declines in sea-ice cover in the Bering, Chukchi, Beaufort, and East Siberian Seas, progressively earlier break-up dates of sea ice, and decreasing sea-ice thickness. Unprecedented declines in summer sea ice have resulted in the retreat of the sea-ice edge off the shelf of the Chukchi Sea, depriving the Pacific walrus of access to these critical summer foraging grounds.

The effect of global warming will worsen in this century. Of importance for the Pacific walrus, the best available science indicates the near-complete disappearance of Arctic summer sea ice, including the ice of the Chukchi Sea, by 2030 (Stroeve et al. 2008) or even as early as 2012 (Amos 2007, Borenstein 2007). Winter sea ice in the Bering Sea is predicted to decline by 40% by mid-century (Meier et al. 2007). Without sea ice, the Pacific walrus will be forced into a shore-based existence for which it is not adapted, and without question would qualify as an endangered species. Unless greenhouse gas emissions are cut dramatically in the immediate future, the disappearance of sea ice is essentially assured. As discussed under "The Inadequacy of Existing Regulatory Mechanisms," below, such emission cuts are not likely to happen absent significant changes in domestic and global energy policies.

This section reviews the best available scientific information regarding (a) the greenhouse effect and current levels of greenhouse gases; (b) climate feedbacks that result in accelerated global warming in the Arctic; (c) environmental changes due to global warming observed to date in the Arctic and specifically in the ice-covered seas inhabited by the Pacific walrus; (d) impacts to Pacific walrus from global warming observed to date; (e) projected climate change in the Arctic and specifically in the range of the Pacific walrus; and (f) future impacts to the Pacific walrus from global warming.

a. The Climate System, Greenhouse Gas Concentrations, the Greenhouse Effect, and Global Warming

In its most recent 2007 report, the Intergovernmental Panel on Climate Change (IPCC)[1] expressed in the strongest language possible its finding that global warming is occurring: "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level" (IPCC 2007: 5). The international scientific consensus of the IPCC is that most of the recent warming observed has been caused by human activities and that it is

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[1] The IPCC was established by the World Meteorological Organization and the United Nations Environment Programme in 1988 (IPCC 2001a). The IPCC's mission is to assess available scientific and socio-economic information on climate change and its impacts and the options for mitigating climate change and to provide, on request, scientific and technical advice to the Conference of the Parties to the United Nations Framework Convention on Climate Change (IPCC 2001b). Since 1990, the IPCC has produced a series of reports, papers, methodologies, and other products that have become the standard works of reference on climate change (IPCC 2001). The 2007 *Fourth Assessment Report* is the most current comprehensive IPCC reference and has built and expanded upon the IPCC's past products.

"very likely" due to increased concentrations in anthropogenic greenhouse gases (IPCC 2007). One of the most troubling recent findings is that the concentration of atmospheric carbon dioxide, the biggest contributor to global warming, has been rapidly increasing throughout the 2000s and is generating stronger-than-expected and sooner-than-predicted climate forcing (Canadell et al. 2007, Raupach et al. 2007). Studies that have used climate projections to examine the ecological consequences of global warming have forecast catastrophic species extinctions. Using a mid-range climate scenario, Thomas et al. predicted that 15-37% of species will be committed to extinction by 2050. Malcolm et al. (2006) estimated that 11-43% of endemic species in biodiversity hotspots will go extinct by the end of the century under a scenario of doubled carbon dioxide concentrations, which includes an average of 56,000 endemic plants and 3,700 endemic vertebrate species.

The IPCC's *Fourth Assessment Report – Climate Change 2007* and the Arctic Climate Impact Assessment's[2] ("ACIA's") *Impacts of a Warming Arctic* (ACIA 2005) have synthesized the best available science on global warming in the Arctic, including a detailed analysis of observed climate trends and future climate projections for the Arctic in the range of the Pacific walrus. An ever-growing body of newer climate studies provides continuous updates to the IPCC findings. Based on these synthesis reports and the latest research, this section briefly reviews global warming, the greenhouse effect, and the contributions of greenhouse gases to global warming.

The basic physics underlying global warming are as well established as any phenomena in the planetary sciences. The earth absorbs heat in the form of radiation from the sun, which is then redistributed by atmospheric and oceanic circulations and also radiated back to space (Le Treut et al. 2007). The earth's climate is the result of a state in which the amount of incoming and outgoing radiation is approximately in balance. Changes in the earth's climate can be caused by any factor that alters the amount of radiation that reaches the earth or the amount that is lost back into space, or that alters the redistribution of energy within the atmosphere and between the atmosphere, land, and ocean (Le Treut et al. 2007). A change in the net radiative energy available to the global earth-atmosphere system is called "radiative forcing" (Le Treut et al. 2007). Positive radiative forcings tend to warm the earth's surface while negative radiative forcings tend to cool it (Albritton et al. 2001).

Radiative forcings are caused by both natural and anthropogenic factors (Albritton et al. 2001, ACIA 2005, Le Treut et al. 2007). The level of scientific understanding of these different

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[2] The Arctic Council is a high-level intergovernmental forum that addresses the common concerns and challenges faced by the Arctic people and governments of the eight Arctic nations – Canada, Denmark/Greenland/Faroe Islands, Finland, Iceland, Norway, Russia, Sweden, and the United States, as well as six Indigenous Peoples organizations – Aleut International Association, Arctic Athabaskan Council, Gwich'in Council International, Inuit Circumpolar Conference, Russian Association of Indigenous Peoples of the North, and Saami Council, as well as official observers (ACIA 2005). The Arctic Council commissioned the ACIA project and charged its working groups – Arctic Monitoring and Assessment Programme ("AMAP"), Conservation of Arctic Flora and Fauna ("CAFF"), and the International Arctic Science Committee ("IASC") - with its implementation. The efforts of hundreds of scientists over four years, as well as the special knowledge of indigenous peoples, contributed to the ACIA report. In sum, the ACIA (2005) is a comprehensively researched, fully referenced, and independently reviewed evaluation of Arctic climate change and its impacts (ACIA 2005).

forcings varies, and the forcings themselves and interactions between them are complex (Le Treut et al. 2007). The primary cause of global warming, however, is society's production of massive amounts of "greenhouse gases" such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and halocarbons that cause positive radiative forcings (Forster et al. 2007, Le Treut et al. 2007).

The Enhanced Greenhouse Effect is caused by increasing concentrations of these greenhouse gases in the earth's atmosphere. As greenhouse gas concentrations increase, more heat reflected from the earth's surface is absorbed by these greenhouse gases and radiated back into the atmosphere and to the earth's surface. Increases in the concentrations of greenhouse gases slow the rate of heat loss back into space and warm the climate, much like the effect of a common garden greenhouse (Forster et al. 2007, Le Treut et al. 2007). The higher the level of greenhouse gas concentrations, the larger the degree of warming experienced.

By the time of the Fourth Assessment Report of the IPCC in 2007, the atmospheric concentration of carbon dioxide had increased by 36% since 1750 to a level that has not been exceeded during the past 650,000 years and likely not during the past 20 million years (Denman et al. 2007). About three fourths of anthropogenic carbon dioxide emissions come from fossil fuel burning, and most of the remaining emissions are due to land-use changes, primarily deforestation (Denman et al. 2007). Carbon dioxide is considered the most important greenhouse gas overall because the volume emitted is greater that of all the other greenhouse gases combined.

Of great concern, the rate of increase of total atmospheric carbon dioxide concentrations is accelerating, with especially rapid increases observed in the 2000s (Canadell et al. 2007). Carbon dioxide emissions increased from 3.2 ± 0.1 GtC yr^{-1} during the 1990s to 4.1 ± 0.1 GtC yr^{-1} during 2000-2005 (Denman et al. 2007). These increased emissions have been attributed to rises in fossil fuel burning and cement production (average proportional growth increased from 1.3% yr^{-1} to 3.3% yr^{-1}) rather than emissions from land-use change which remained approximately constant (Canadell et al. 2007). During the past 50 years, carbon dioxide sinks on land and oceans have become less efficient in absorbing atmospheric carbon dioxide, which is also contributing to the observed rapid rise (Canadell et al. 2007). As of March 2006, the atmospheric carbon dioxide concentration was 381 ppm, and rising at over 2 ppm per year (Shukman 2006).

The atmospheric concentration of methane, another important greenhouse gas, has increased by about 150% since 1750, continues to increase, and has not been exceeded during the past 650,000 years (Forster et al. 2007). About 60% of current methane emissions come from human activities, and there is also evidence that current carbon monoxide (CO) emissions are a cause of increasing methane concentrations (Denman et al. 2007). Over a 100-year period, methane will trap about 23 times more heat than an equal amount of carbon dioxide (Albritton et al. 2001).

The atmospheric concentration of nitrous oxide (N_2O) has increased by about 18% since 1750, continues to increase, and has not been exceeded during at least the last 2000 years (Forster et al. 2007). About half of the nitrous oxide emissions to the atmosphere come from human activities (Denman et al. 2007). Over a 100-year period, nitrous oxide will trap about 296 times more heat than an equal amount of carbon dioxide (Albritton et al. 2001).

Halocarbons are carbon compounds that contain fluorine, chlorine, bromine, or iodine (Forster et al. 2007). Most types of halocarbons are produced exclusively by human activities (Forster et al. 2007). Halocarbons that contain chlorine, like chlorofluorocarbons, ("CFCs") also cause depletion of the stratospheric ozone layer and are regulated under the Montreal Protocol (Forster et al. 2007). The combined tropospheric abundance of ozone-depleting gases peaked in 1994 and is now declining slowly (Forster et al. 2007). However, some compounds which have been promoted as substitutes for now-regulated CFCs are themselves greenhouse gases, and concentrations of these gases, such as hydrochloroflurocarbons ("HCFCs") and hydroflurocarbons ("HFCs") are now increasing (Forster et al. 2007). There are many different types of halocarbons, which have global warming potentials that vary between 12 and 12,000 times that of carbon dioxide (Forster et al. 2007).

Ozone is another important greenhouse gas found in both the troposphere, the portion of the atmosphere that begins at the earth's surface and extends from 8 to 14.5 kilometers (5 to 9 miles) high, and the stratosphere, the portion of the atmosphere that starts just above the troposphere and extends to 50 kilometers (31 miles) high (Albritton et al. 2001). Ozone is not directly emitted, but rather is formed from photochemical processes involving both natural gases and manmade emissions (Albritton et al. 2001). Because ozone persists in the atmosphere for only a short period of time varying from weeks to months, its role in radiative forcing is more complex and less certain than for more persistent greenhouse gases (Albritton et al. 2001).

The loss of ozone from the stratosphere (a phenomenon popularly termed a "hole in the ozone layer") has resulted in negative radiative forcing that has offset some portion of the warming caused by other greenhouse gases (Albritton et al. 2001). However, the ozone layer is expected to rebound as a result of the Montreal Protocol, and the negative forcing caused by the current depressed levels of ozone in the stratosphere is expected to reverse (Albritton et al. 2001). The most recent findings of the Fourth Assessment Report indicate that global stratospheric ozone decreased between the late 1970s to early 1990s but has increased slightly since the early 1990s (Forster et al. 2007).

Increasing concentrations of ozone in the troposphere also cause positive radiative forcing (Albritton et al. 2001). Ozone in the troposphere is in fact the third most important greenhouse gas after carbon dioxide and methane (Albritton et al. 2001). Tropospheric ozone is estimated to have increased by approximately 35% since the Industrial Revolution, though increases have varied by region (Albritton et al. 2001). Ozone concentrations respond relatively quickly to changes in the emissions of ozone precursors such as NO and NO_2 (the sum of which is denoted NO_x) and volatile organic compounds ("VOCs") (Albritton et al. 2001).

Black carbon, or soot, consists of particles or aerosols released through the inefficient burning of fossil fuels, biofuels, and biomass (Quinn et al. 2007). Black carbon warms the atmosphere as a solid, not a gas. Unlike greenhouse gases, which warm the atmosphere by absorbing longwave infrared radiation, soot has a warming impact because it absorbs shortwave radiation, or visible light (Chameides and Bergin 2002). Black carbon is an extremely powerful greenhouse pollutant. Scientists have described the average global warming potential of black carbon as about 500 times that of carbon dioxide over a 100 year period (Hansen et al. 2007, *see also* Reddy and Boucher 2007). This powerful warming impact is remarkable given that black carbon remains in the atmosphere for only a few days to a few weeks, with a mean residence time of 5.3 days (Reddy and Boucher 2007).

Black carbon contributes to Arctic warming through the formation of "Arctic haze" and through deposition on snow and ice which increases heat absorption (Quinn et al. 2007, Reddy and Boucher 2007). Arctic haze results from a number of aerosols in addition to black carbon, including sulfate and nitrate (Quinn et al. 2007). The effects of Arctic haze may be to either increase or decrease warming, but when the haze contains high amounts of soot, it absorbs incoming solar radiation and leads to heating (Quinn et al. 2007). Soot also contributes to heating when it is deposited on snow because it reduces reflectivity of the white snow and instead tends to absorb radiation. A recent study indicates that the direct warming effect of black carbon on snow can be three times as strong as that due to carbon dioxide during springtime in the Arctic (Flanner et al. 2007). Black carbon emissions that occur in or near the Arctic contribute the most to the melting of the far north (Quinn et al. 2007, Reddy and Boucher 2007).

Other gases, such as NO_x, volatile organic compounds, and carbon monoxide are called indirect greenhouse gases because of their impact on the abundance of tropospheric ozone and other greenhouse gases such as methane (Forster et al. 2007). These compounds interact and contribute to global warming in complex ways. For example, increases in NO_x concentrations decrease methane concentrations but increase tropospheric ozone (Forster et al. 2007).

Many other natural and human caused factors contribute to positive or negative radiative forcing, including aerosol emissions, land-use changes, and changes in solar and volcanic activity, water vapor, and cloud cover (Le Treut et al. 2007). Nevertheless, scientists now know that greenhouse gases are the most important force driving global warming, and that carbon dioxide is in turn the most important of the greenhouse gases (Forster et al. 2007, Solomon et al. 2007). Carbon dioxide emissions from fossil fuel burning are virtually certain to remain the dominant control over trends in atmospheric carbon dioxide concentrations during this century (Forster et al. 2007).

b. The Arctic is Warming Much Faster than Other Regions

Due to its unique characteristics, the Arctic has warmed and is projected to warm more rapidly than any other region on earth (ACIA 2005, Anisimov et al. 2007). 'Arctic amplification' is the phenomenon of greater and more rapid warming over the Arctic compared with other regions as a result of several interactions and feedbacks. The following section reviews the most important feedbacks that contribute to rapid Arctic warming.

The first major feedback relating to Arctic climate change involves surface reflectivity, referred to as the ice-albedo feedback (ACIA 2005). As the Arctic warms, rising temperatures melt snow and ice, which begin to form later in the autumn and melt earlier in the spring (ACIA 2005). Less snow and ice cover results in lower reflectivity of solar radiation (i.e. lower "albedo") because the land and water surfaces beneath the snow and ice are much darker and absorb more of the sun's energy than the snow or ice (ACIA 2005). While sea ice reflects 85-90% of solar radiation, ocean water reflects only 10% (ACIA 2005). Greater heat absorption leads to more warming. This increased warming creates a self-reinforcing cycle by which global warming is amplified and the warming trend is accelerated (ACIA 2005). The ice-albedo feedback process is already underway in the Arctic (ACIA 2005).

An important aspect of the ice-albedo feedback that influences the melting of sea ice is that the extra heat absorbed by the ocean in the summer is carried through winter to the following year (Serreze and Francis 2006). As described above, as more sea ice melts during the summer due to rising temperatures, the ocean absorbs more heat. The growth of the autumn and winter sea ice is delayed and the resulting ice is thinner. Due to this decrease in thickness, the autumn-to-spring sea ice, which is typically 1 to 4 meters thick, is not as effective in insulating the Arctic ocean from the colder autumn-to-spring air temperatures, and more of the heat absorbed by the ocean in the summer escapes to the atmosphere, explaining why surface temperatures are expected to rise most in autumn and winter over the ocean. However, some of the extra ocean heat will be retained through the ice season and will promote the earlier melting of sea ice in spring, exposing more of the ocean surface which will absorb more solar energy. As a result of this positive feedback loop, the heat content of the ocean continues to rise, and the cycle continues until none of the sea ice survives the melt season, resulting in an ice-free Arctic summer (Serreze and Francis 2006).

The ice-albedo positive feedback loop is enhanced by three physical processes. First, as sea ice melts, meltwater pools forming on the surface of the sea ice have lower reflectivity and thus lead to increased melting of the surface (Serreze and Francis 2006). Secondly, as more gaps (i.e. leads and polynyas) open in the sea ice, more radiation is absorbed by the exposed ocean surface which triggers further melting of the edges and undersides of the ice floes (Serreze and Francis 2006). Finally, as snow melts, the snow grains increase in size which reduces the reflectivity and increases the melt rate (Serreze and Francis 2006).

Another factor that enhances the ice-albedo feedback is the deposition of black carbon in the Arctic. Black carbon, or soot, consists of particles or aerosols released from the burning of fossil fuels, in particular from fossil fuels and biomass, which are carried by winds and deposited in the Arctic (ACIA 2005). The soot deposition slightly darkens the surface of the otherwise white snow and ice, further reducing surface reflectivity, increasing heat absorption, and therefore increasing warming (ACIA 2005). Arctic warming will also be further accelerated by reflectivity changes that occur as boreal forests expand further northward and replace existing tundra (ACIA 2005). Forests are taller, darker, and more textured than the relatively smooth tundra, and therefore absorb more radiation (ACIA 2005). While the greater carbon intake of forests versus tundra may moderate this impact, scientists believe that the impacts from decreases in surface reflectivity are likely to outweigh the impacts from greater carbon uptake (Chapin et al. 2005).

The second positive feedback that enhances Arctic warming is the interaction between rising temperatures and release of greenhouse gases from permafrost (ACIA 2005). Large amounts of carbon are currently trapped as organic matter in the permafrost that underlies much of the Arctic (ACIA 2005). During the summer when the surface layer of permafrost thaws, organic matter in this layer decomposes, releasing carbon dioxide and methane into the atmosphere (ACIA 2005). Global warming accelerates the decomposition rate of organic matter in the permafrost, increasing the release of greenhouse gases and further increasing their atmospheric concentrations (ACIA 2005). A positive feedback loop is created which amplifies the rate of warming (ACIA 2005). A long-term concern is the release from the permafrost of large amounts of methane, a potent greenhouse gas that traps about 23 times more than the same amount of carbon dioxide over a 100-year period. Large amounts of methane are currently stored in permafrost and at shallow depths in cold ocean sediments (ACIA 2005). Even a relatively small rise in temperature of the permafrost or water at the seabed could initiate the release of this methane and greatly increase global warming.

c. Climate and Environmental Changes Observed to Date

Climate change in the Arctic is occurring at a rapid pace that is exceeding the predictions of the most advanced climate models. The mean model forecast from the IPCC's Fourth Assessment Report significantly under-estimates the declining trend in both summer and winter Arctic sea-ice extent (Stroeve et al. 2007). Winter sea-ice extent in 2006 and 2007 declined to a minimum which most climate models forecast would not be reached until 2070 (Stroeve et al. 2007), and summer sea-ice extent in 2007 plummeted to a record minimum (NSIDC 2007b) which most climate models forecast would not be reached until 2050 (Stroeve et al. 2007). 2007 shattered records for Arctic climate in other ways. Greenland ice sheet melt has been accelerating, and in 2007, an unprecedented 552 billion tons of ice melted from the ice sheet, which is ~12% more than in the previous worst year of 2005 (Borenstein 2007). The Bering Strait and Chukchi Sea inhabited by the Pacific walrus experienced sea surface temperatures in 2007 that were 3.5°C warmer than historical averages during the past century and 1.5°C warmer than the historical maximum (Hines 2007). Climate scientists are warning that the Arctic may have already passed a tipping point beyond which an ice-free Arctic summer is inevitable, and that a seasonally ice-free Arctic Ocean might be realized as early as 2012 (Amos 2007, Borenstein 2007). Clearly, rapid degradation of the Pacific walrus's habitat throughout its range poses a grave threat to the persistence of this species.

This section reviews the best available science on observed changes in Arctic climate conditions that are most relevant to the Pacific walrus. The most recent scientific information on Arctic-wide climate change is presented, followed by information on regional climate change in the range of the Pacific walrus.

Increases in surface temperature

Arctic surface temperatures increased twice as much as the global average during the 20th century (Trenberth et al. 2007), and warming trends have accelerated in recent decades. The Arctic Climate Impact Assessment (ACIA) evaluated the spatial and temporal variations in temperature over all land areas in the Arctic for the 20th century (1900-2003) using the Climatic Research Unit and GHCN databases (ACIA 2005). Temperature trends in the Arctic were similar to the global trends: the Arctic was cooler than average from 1890-1920, warmer from 1920s-1940s, cooler from the 1940s to the mid-1960s, and warmer from the mid-1960s onward, with warming especially strong from 1990 to present (ACIA 2005). One of the most important findings was that the rate of temperature increase in the Arctic was much larger than the global average increase during the 20th century and has been particularly rapid since the mid-1960s. The average rate of temperature increase during 1966-2003 over the Arctic was 0.4 ºC/decade, approximately four times greater than the average for 20th century (ACIA 2005). The land-surface annual air temperature trends in northwestern Alaska and northeastern Russia in coastal areas surrounding the Bering and Chukchi Seas inhabited by the Pacific walrus have increased by 1 to 2ºC per decade during 1966-2003 (ACIA 2005: Figure 2.7(d)). In some areas of western Alaska and eastern Russia, winter and spring (December-May) temperatures over land have increased by as much as 4-8°C over the last 40 years (1966-2003) (ACIA 2005: Figure 2.8(d)).

Satellite-derived temperature data for <u>both</u> land and sea surfaces, providing full coverage of the Arctic for the past 25 years, indicate that warming trends are accelerating. From 1981-2005, the Arctic region has been warming at a rate of 0.72 ± 0.10 °C per decade (Comiso 2006b). Regionally, the trends are 0.54 ± 0.11 °C per decade over sea-ice, 1.19 ± 0.20 °C per decade over Greenland, 0.84 ± 0.18 °C per decade over North America and 0.13 ± 0.16 °C per decade over Northern Eurasia (Comiso 2006b). Notably, high temperature anomalies were much more prevalent in the 2000s compared to the 1980s (Comiso 2006b).

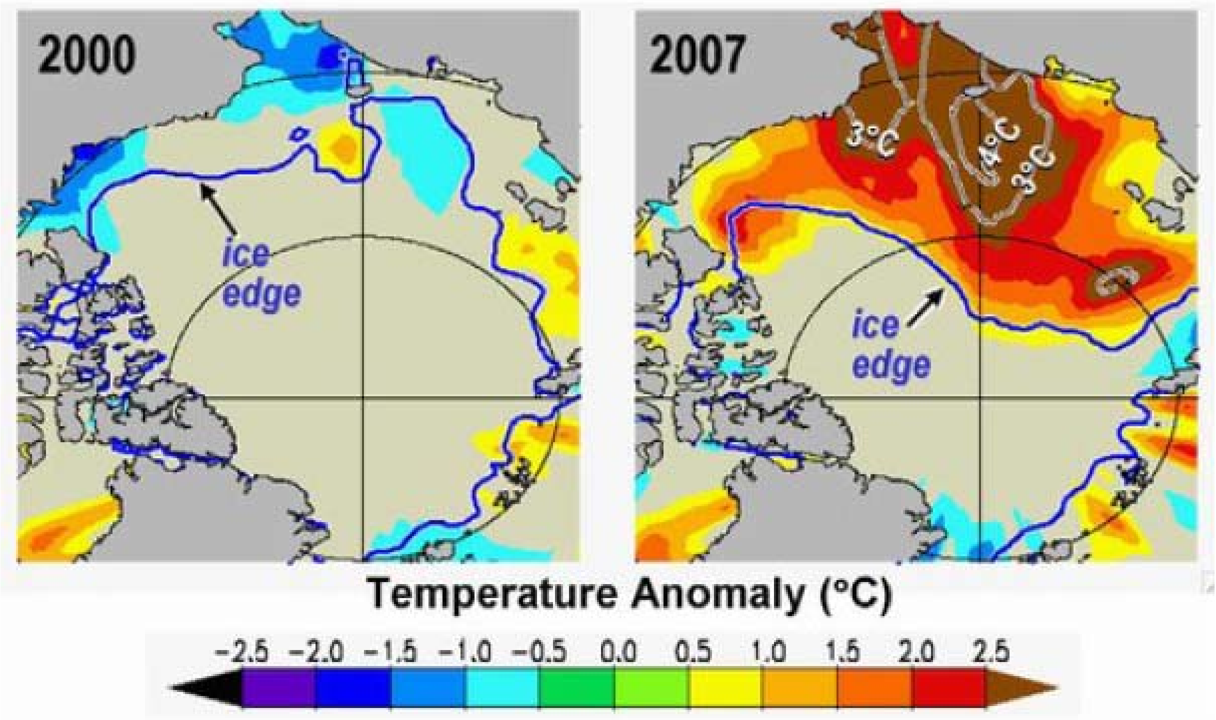
Regional analyses of surface air and ocean temperatures in the range of the Pacific walrus indicate that temperatures are rising across the Bering and Chukchi Seas. Temperature data from 1950-2002 at St. Paul Island on the southeastern Bering Sea shelf show a transition from cold to warm anomalies in 1976, consistently earlier springs beginning in 1996, and longer warm periods extending from February through November beginning in 2000 (Overland and Stabeno 2004). At St. Lawrence Island in the northern Bering Sea, air temperatures have increased from 1997-2004 (Grebmeier et al. 2006b). Depth-averaged summer ocean temperatures measured at a mooring at 70 m depth on the southeastern Bering Sea shelf were 2°C warmer in 2001-2003 compared to the mid-1990s (Overland and Stabeno 2004). In the Northern Bering Sea, bottom water temperatures have been increasing from 1988-2005 (Grebmeier et al. 2006b).

In a study of Arctic Ocean surface warming trends over the past 100 years, Steele et al. (2007) detected pronounced warming in the Chukchi, Bering, and East Siberian Seas, especially since 2000 (Stroeve et al. 2008). Of concern for the Pacific walrus, the Bering Strait and Chukchi Seas experienced the greatest summer warming, where surface temperatures during summer of 2007 were 3 to 3.5°C warmer than historical averages and 1.5°C warmer than the historical maximum (Figure 3) (Hines 2007, Stroeve et al. 2008). The region just north of the Chukchi Sea experienced sea surface temperatures 5°C above average in 2007, a record high never before observed (Hines 2007).

Changes in precipitation

Precipitation has increased in the Arctic (Anisimov et al. 2007) perhaps by as much as 8% in the past 100 years (ACIA 2005). Rain on snow events have also increased significantly across much of the Arctic, with increases of 50% recorded over the past 50 years in western Russia (ACIA 2005). At the same time, snow cover has decreased by about 10% over the Northern Hemisphere as a whole since 1972 (ACIA 2005). On a regional basis, snow cover in North America has decreased in spring extent since the 1950s (ACIA 2005). There is also evidence of a general decrease in snow depth in Canada since 1946, especially in the spring, and of decreases in winter snow depths over European Russia since the beginning of the last century (Serreze et al. 2000). Overall, decreasing snow cover over land and sea ice will lower its surface albedo and accelerate ice melt.

Figure 3. A comparison of sea surface temperature and the perennial ice edge in 2000 and 2007, illustrating the retreat of the ice edge and the warming of surface waters compared to the 100-year average.
Source: Hines (2007).



Graphic credit required: Applied Physics Laboratory/UW

Changes in permafrost

Changes in the temperature and extent of permafrost in the Arctic have been recorded as temperatures warm, providing another indicator of global warming (Lemke et al. 2007). Permafrost warming is occurring in the North American and Russian Arctic. Permafrost temperature has increased by up to 2-3°C in northern Alaska since the 1980s, by 0.3-0.8°C in the Canadian High Arctic since the 1990s, and by 0.3-0.7°C in the 1980s in western Siberia in parallel with increasing air temperature and decreasing insulating snow cover (Lemke et al. 2007). Permafrost degradation, where the thickness and areal cover of permafrost are reduced by thawing, is especially severe along Arctic coasts with ice-bearing permafrost. Over the Alaskan Beaufort Sea coast, mean annual erosion rates range from 0.7 to 3.2 m/year with maximum observed rates of 16.7 m/year (Lemke et al. 2007). Along the Russian Arctic coast, erosion rates range from 2.5-3.0 m/year for ice-rich coasts to 1.0 m/year for ice-poor permafrost coasts

(Lemke et al. 2007). Overall, warming permafrost is releasing greenhouse gases that will further increase warming.

Changes in the Greenland ice sheet

Melting of the Greenland ice sheet has accelerated far beyond what scientists predicted even just a few years ago. Using satellite observations, Rignot and Kangaratnam (2006) found that mass loss from the Greenland ice sheet more than doubled between 1996 and 2005, increasing from 91 to 224 km^3 per year, due to the acceleration of ice discharge in western and eastern Greenland. Using a longer study period, Steffen et al. (2007) reported a 30% increase in the ice sheet melt area in western Greenland between 1979 and 2006, with record melt years in 1987, 1991, 1998, 2002, 2005, and the most extreme melt year in 2007. In 2007, 552 billion tons of ice melted from the Greenland ice sheet, which is ~12% more than the previous worst year of 2005 (Borenstein 2007). These losses have been linked to extended, warm air temperatures over the Greenland ice sheet, which have increased by 4°C since 1991 (Steffen et al. 2007).

The rate of ice loss from the Greenland ice sheet has been consistently under-estimated by climate models because they do not include important physical processes that influence the magnitude of glacier response to changes in air and ocean temperature (Rignot and Kangaratnam 2006). Such physical processes include reduced surface albedo, loss of buttressing ice shelves, lowered ice surface altitude, and the formation of rivers of melt water, called "moulins," that flow down several miles to the base of the ice sheet, where they lubricate the area between the ice sheet and the rock, speeding the movement of the ice towards the ocean (Hansen et al. 2006, Rignot and Kangaratnam 2006). The accelerating melt of the Greenland ice sheet is relevant to Pacific walrus population persistence because it further reduces surface albedo in the Arctic, thus enhancing warming, and provides another warning that Arctic ice is melting much faster than climate models predict.

Changes in sea ice: Declining extent, declining length of the ice season, declining thickness

Key climate indicators of critical importance to the Pacific walrus are sea-ice extent, timing of formation and break-up, and thickness. The Pacific walrus is dependent on sea ice as a resting platform while foraging and for courtship, birthing, nursing, and molting. Reductions in sea-ice extent, duration, and quality will increase stress and mortality of Pacific walruses by disrupting these essential life history behaviors. Of primary concern for the future survival of the Pacific walrus are the significant losses of summer sea ice in the Chukchi Sea and winter sea ice in the Bering Sea (Meier et al. 2007). Unprecedented losses of summer sea ice have occurred throughout the 2000s (Stroeve et al. 2008), resulting in an effectively ice-free Chukchi continental shelf in summer in most years (Jay et al. 2008). Many climate scientists have warned that the Arctic may have already passed a tipping point beyond which an ice-free Arctic summer is inevitable. The loss of summer sea ice will increase ocean surface warming, increasing the ice-albedo feedback and accelerating the melt of winter and spring sea ice that the Pacific walrus depends on.

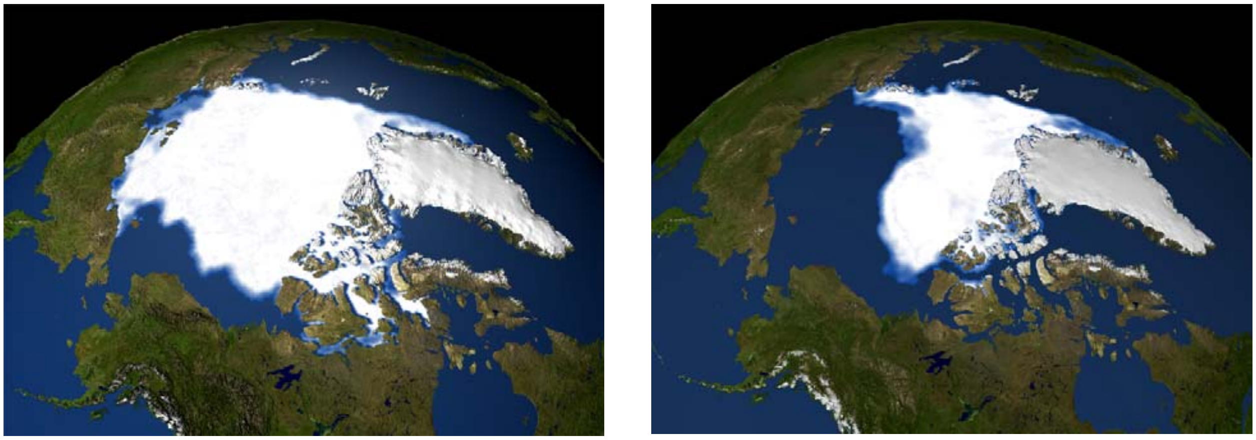
Sea-ice extent

The extent of sea ice is a key indicator of climate change (ACIA 2005). It significantly influences climate by affecting surface reflectivity, cloudiness, humidity, exchanges of heat and moisture at the ocean surface, and ocean currents, and thus likely exerts a substantial influence on climate change related to global warming (ACIA 2005). Within each year, the Arctic sea-ice cover reaches its maximum extent in March and its minimum extent in September at the end of the melt season (ACIA 2005). The perennial ice is the sea ice that survives the summer melt season which consists mainly of the thick multi-year ice floes that are the mainstay of the Arctic sea-ice cover (Comiso 2005). The Pacific walrus depends on the perennial ice in the Chukchi Sea (and to a lesser extent in the Beaufort and East Siberian Seas) in summer and the first-year ice in the seasonally ice-covered Bering Sea in winter, and both of these are rapidly shrinking. Studies of changes in sea-ice extent throughout the Arctic and in the range of the Pacific walrus are summarized below.

A. Arctic-wide declines in sea-ice extent

The extent of September Arctic sea ice declined by 10.7% per decade from 1979-2007, equivalent to a loss of 72,000 km^2 per year (NSIDC 2007b, Stroeve et al. 2008). This rate of loss has accelerated in recent decades as evident from the lower rate of decline when a longer time period is considered: -7.8% per decade from 1953–2006 (Stroeve et al. 2007). Record losses of summer sea ice occurred in 2002 and 2005, and summer sea-ice extent reached an utterly stunning new record minimum in 2007 (NSIDC 2007b). At 4.13 million km^2 (1.59 million square miles), the five-day minimum sea-ice extent in September 2007 (Figure 4) was about 39% (one million square miles[3]) below the average minimum sea-ice extent between 1979 and 2000 (NSIDC 2007b) and 23% less than the previous low in 2005 (NSIDC 2007b). Using an extended time series from the Met Office Hadley Center, Stroeve et al. (2008) calculated that September sea-ice extent in 2007 was 50% lower than conditions in the 1950s to 1970s.

Figure 4. Sea-ice extent on September 21, 1979 and September 14, 2007.
Source: Images courtesy NASA/Goddard Space Flight Center Scientific Visualization Studio.



Sea-Ice Extent in September 1979

Sea-Ice Extent in September 2007

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[3] One million square miles is equal to about the area of Alaska and Texas combined.

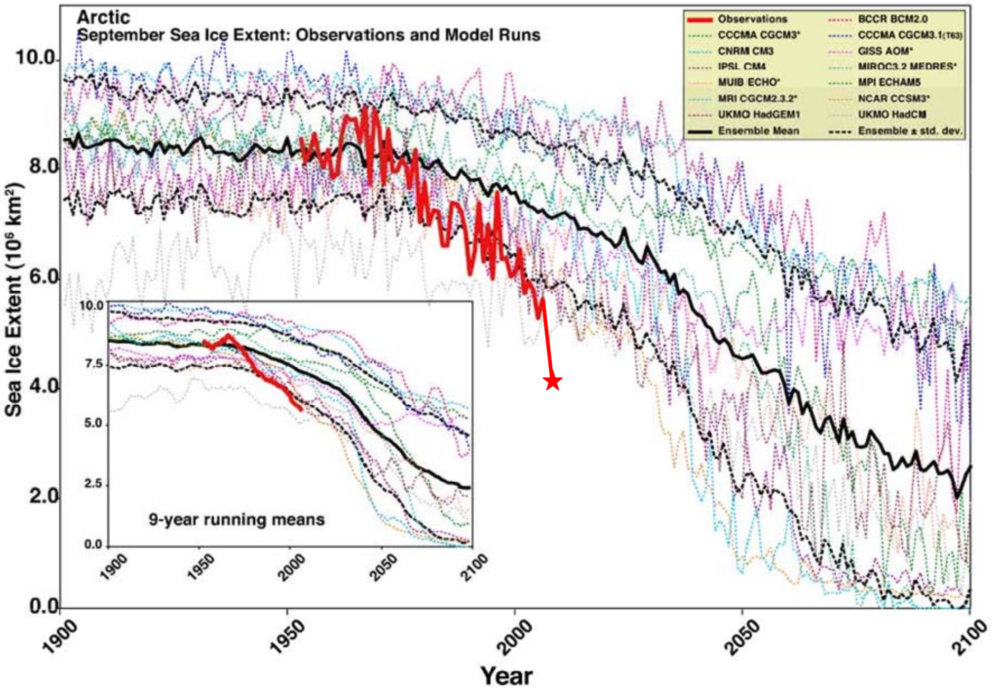
In response to this unprecedented loss of summer sea ice, NSIDC senior scientist Mark Serreze warmed that the positive feedback loop of Arctic amplification may have reached a tipping point:

> The sea-ice cover is in a downward spiral and may have passed the point of no return. As the years go by, we are losing more and more ice in summer, and growing back less and less ice in winter. We may well see an ice-free Arctic Ocean in summer within our lifetimes....The implications for global climate, as well as Arctic animals and people, are disturbing (NSIDC 2007b).

As noted above, Arctic summer sea ice is melting more rapidly than recent climate models predict. Stroeve et al. (2007) evaluated how well the IPCC Fourth Assessment Report multi-model ensemble simulated observed Arctic sea-ice loss over the 1953-2006 study period, and found that the mean model forecast significantly underestimated the declining trend in September sea-ice extent. The most striking finding was that recent summer sea-ice minima are approximately 30 years ahead of the IPCC ensemble mean model predictions (Stroeve et al. 2007; Figure 5). Most striking, the 2007 minimum was lower than the sea-ice extent most climate models predict would not be reached until 2050 (Figure 5).

Figure 5. Arctic September sea-ice extent (x 10^6 km^2) from observations (thick red line) and 13 IPCC-AR4 climate models, shown with the multi-model ensemble mean (solid black line) and standard deviation (dotted black line). Inset shows 9-year running means. Red asterisk shows 2007 observed sea-ice extent (asterisk and connecting line added by Petitioner).

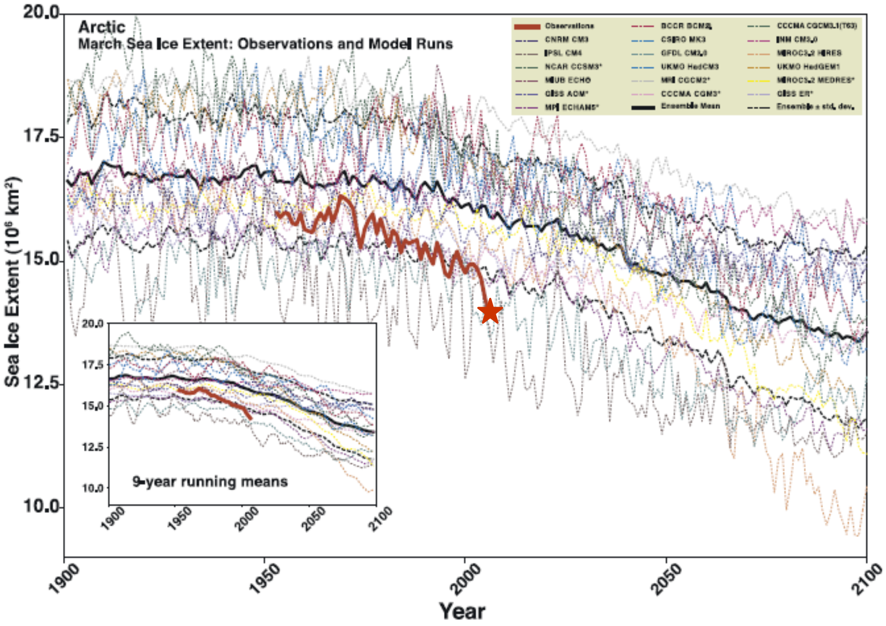
Source: Based on Stroeve et al. (2007): Figure 1.



Another troubling trend is the increasing loss of winter sea-ice, which the Pacific walrus depends on as a platform for feeding, courtship, birthing, and nursing. Despite decreasing summer sea-ice extent, sea ice has been largely able to rebound during the winter season (Meier et al. 2007). Downward trends in March sea-ice extent, which represents the climatological sea-ice maximum, were -1.8% per decade from 1953-2006 but higher over recent decades: -2.9% per decade from 1979-2006 (Stroeve et al. 2007). Meier et al. (2005) reported that sea-ice extent was anomalously low during the winter and spring 2005 (December 2004-May 2005), when every month except May 2005 had a record-low sea-ice extent. Declines in winter sea-ice extent during these months occurred in all regions of the Arctic, including the north Atlantic and north Pacific, indicating that the onset of freeze-up was delayed throughout the Arctic (Meier et al. 2005). In a second study, Comiso (2006a) found that winter sea-ice cover in 2005 was the lowest recorded during the satellite era and was followed by even lower winter sea-ice cover in 2006, corresponding to values ~6% lower than average in each year. Winter sea-ice declines were correlated with rising surface temperatures. Comiso (2006a) warned that greenhouse gas warming in the Arctic is becoming evident even in the dark winter months and that winter ice cover is likely to continue to retreat in the near future.

Consistent with these studies, Stroeve et al. (2007) found that winter sea ice is also melting more rapidly than the IPCC Fourth Assessment Report multi-model ensemble predicts (Figure 6). March sea-ice extent in 2006 fell to a record-low minimum (NSIDC 2007a) which most climate models forecast would not be reached until 2070 (Stroeve et al. 2007). March sea-ice extent in 2007 was the second-lowest in the satellite record (14.7 km^2), narrowly missing the 2006 low (14.5 km^2) (NSIDC 2007a).

Figure 6. Arctic March sea-ice extent (x 10^6 km^2) from observations (thick red line) and 18 IPCC-AR4 climate models, shown with the multi-model ensemble mean (solid black line) and standard deviation (dotted black line). Inset shows 9-year running means. Red asterisk shows 2007 observed sea-ice extent (added by Petitioner).
Source: Based on Stroeve et al. (2007): Figure 2.



B. Sea-ice declines in the Pacific walrus range

The regions inhabited by the Pacific walrus are experiencing some of the most pronounced losses in summer and winter sea-ice cover. Below we summarize research on the loss of summer sea ice in the Chukchi, Beaufort, and East Siberian Seas and the loss of winter sea ice in the Bering Sea.

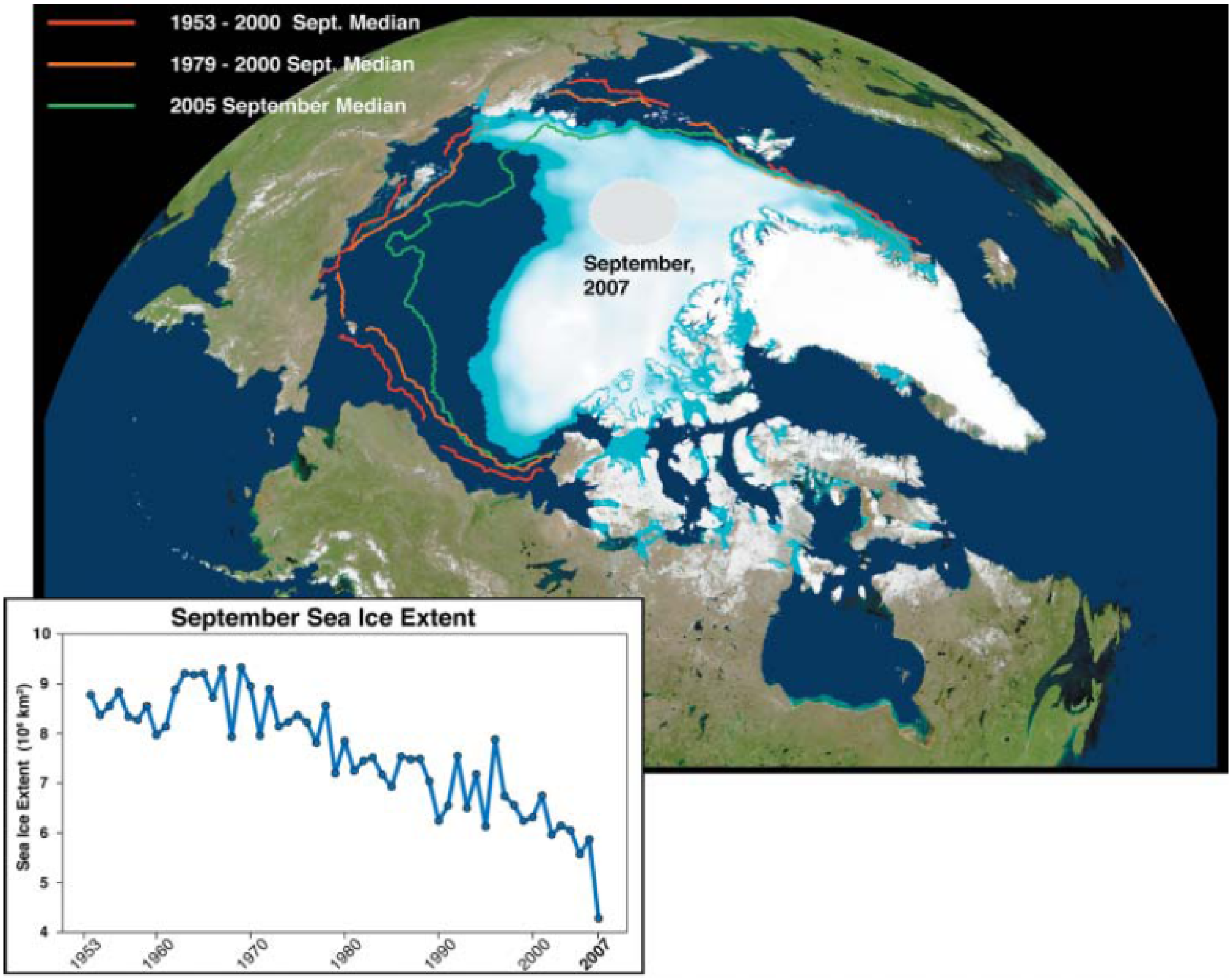
Multiple studies have identified the Chukchi and Beaufort Sea region as highly vulnerable to the loss of summer sea-ice cover. A study of regional trends in sea-ice extent from 1979-2006 using pan-Arctic satellite data indicates that sea-ice extent in the Chukchi Sea decreased significantly during June through November (Table 3) (Meier et al. 2007). The highest rates of sea-ice loss occurred during August, September, and October, at -15.4% per decade, -26.3% per decade, and -18.6% per decade, respectively (Meier et al. 2007), which are two to three times higher than the average rate of Arctic-wide sea-ice loss during the same time period, -9.1% per decade (1979-2006) (Stroeve et al. 2007). The Beaufort Sea has also experienced significant summer sea-ice losses during August through October and the East Siberian Sea in September (Table 3) (Meier et al. 2007).

Table 3. Regional trends in sea-ice extent in Arctic seas given as % per decade for each month for 1979-2006. Standard deviation values are provided in parentheses for the annual trends. Trends in bold are statistically significant at the 99% level and in italics at the 95% level. Blank fields indicate months where little or no ice is found in the region. A trend of zero generally reflects 100% ice cover in a region throughout the time series.
Source: Based on Meier et al. (2007): Table 2.

Month	Bering	Chukchi	East Siberian	Beaufort
Jan	5.4	0.0	0.0	0.0
Feb	2.0	0.0	0.0	0.0
Mar	*-4.8*	0.0	0.0	0.0
Apr	-1.8	0.0	0.0	0.0
May	-10.9	-0.19	0.0	0.0
Jun	-7.8	**-4.3**	0.1	-1.5
Jul	-39.4	**-6.7**	-0.4	-0.8
Aug		**-15.4**	**-11.5**	-2.6
Sep		**-26.3**	**-17.2**	**-9.6**
Oct	**-42.9**	**-18.6**	**-2.4**	-2.3
Nov	*-20.3*	**-8.0**	0.0	0.0
Dec	3.0	0.0	0.0	0.0
Annual	-1.9 (3.5)	**-4.9 (1.1)**	**-2.1 (0.8)**	*-1.2 (0.9)*

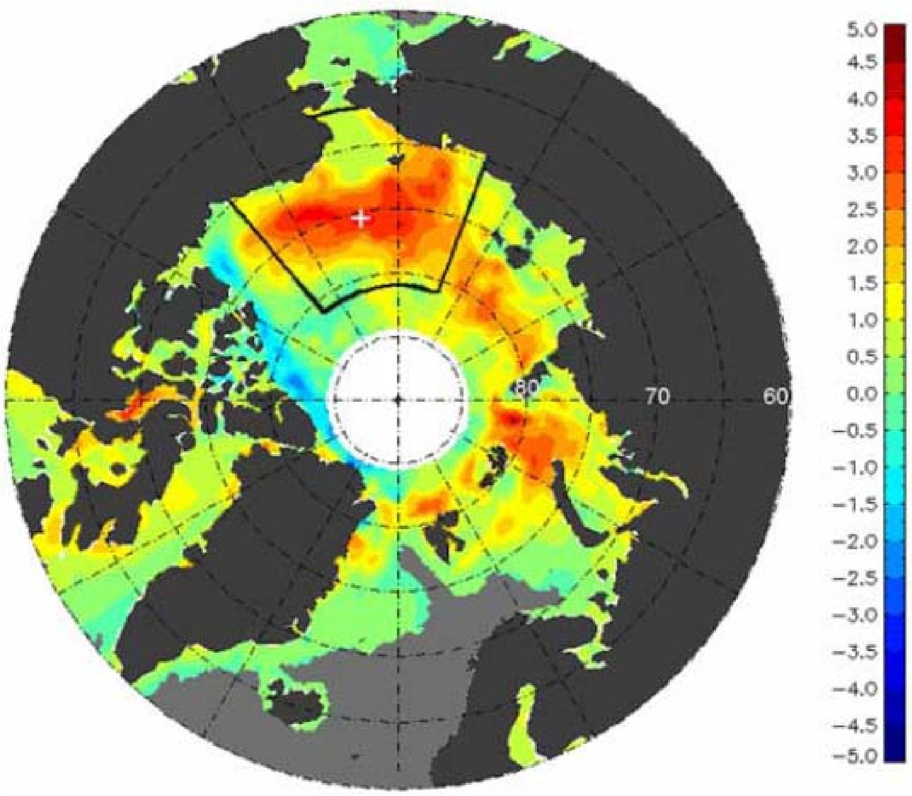
Francis and Hunter (2006) examined changes in the position of the summer southern sea-ice edge (defined as the maximum ice retreat anomaly) in six peripheral seas of the Arctic Ocean during 1979-2004 using passive microwave satellite imagery. They detected significant downward trends (>99% confidence) in the Chukchi and Beaufort Seas, where the summer sea-ice edge retreated northward at an average of 168 km per decade and 113 km per decade, respectively, during the study period (Francis and Hunter 2006). In a study of the distribution of the Pacific walrus in the Chukchi Sea during the summer, Jay et al. (2008) analyzed the number of ice-free days on the Chukchi continental shelf during 1979-2007, where the shelf was defined as the 200 m isobath or shallower. The shelf was effectively ice-free during the summer in 5 of the last 6 years (2002-2007), but only once (1999) in the previous 23 years (1979-2001) (Jay et al. 2008). Based on sea-ice extent data from 1953-2007, the estimated position of the September summer sea-ice edge in the Chukchi, Beaufort, and East Siberian Seas has retreated northward dramatically over this period (Figure 7) (Stroeve et al. 2008).

Figure 7. Fig. 1. Sea-ice concentration for September 2007, along with Arctic Ocean median extent from 1953 to 2000 (red curve), from 1979 to 2000 (orange curve), and for September 2005 (green curve). September ice extent time series from 1953 to 2007 is shown in the insert.
Source: Stroeve et al. (2008): Figure 1.



Due to declines in sea-ice cover, abnormally large open water areas have formed in summer in the Chukchi, Beaufort, and East Siberian Seas (Figure 7) (Comiso 2005, Comiso 2006b). The rise in summer open-water area has resulted in large decreases in the albedo of the Chukchi and Beaufort Seas in recent decades (Comiso 2006b). This decrease in albedo would be expected to increase the absorption of solar radiation in the surface ocean. Indeed, a study examining changes in the amount of solar energy absorbed in open water areas Arctic-wide during 1979-2005 found that the largest increases in heat content occurred in the Chukchi Sea (Perovich et al. 2007). Overall, Perovich et al. (2007) detected increases in the amount of solar energy entering the upper ocean in 89% of the study region, and found that the increase in absorbed solar energy was significantly related to the increase in open water area rather than to a change in the total incident solar radiation in the Arctic, which remained constant. The increases in annual solar heat absorption in the Chukchi Sea and adjacent regions occurred at rates up to 4% per year during the study period (Figure 8) (Perovich et al. 2007).

Figure 8. Map of the linear trend of annual solar heat input to the ocean from 1979-2005, with units of percent per year.
Source: Perovich et al. (2007): Figure 2.



Winter sea-ice cover is also declining significantly in the Bering Sea. Pacific walruses rely the Bering Sea ice during October-December as they migrate southward through the Being Strait to their winter breeding grounds, during the January-March breeding season, and during April-June as they migrate northward through the Bering Strait. A study of regional trends in sea-ice extent from 1979-2006 using pan-Arctic satellite data indicates that sea ice declined significantly by ~5% per decade in the Bering Sea during the March breeding season (Table 3) (Meier et al. 2007). In addition, significant losses of sea-ice extent occurred in fall, at a striking rate of -43% per decade in October and -20% per decade in November (Meier et al. 2007), which suggests that sea-ice resting platforms are less available for walruses on their southward migration and that the winter sea ice is forming later.

A second series of regional studies using satellite, field, and Yupik traditional ecological observations also indicates that seasonal sea-ice concentrations are declining throughout the Bering Sea (Grebmeier et al. 2006b). In the southeastern Bering Sea, sea ice monitored in a 1° rectangle of latitude (57-58°N) has exhibited two downward shifts. First, sea ice decreased in the mean number of days for which there was more than 5% ice cover after January 1, declining from 130 days during 1971-1976 to 67 days during 1977-1989 (Overland and Stabeno 2004). Beginning in 2000, there has been an almost complete absence of sea ice in this region (Overland and Stabeno 2004). In the northern Bering Sea, sea-ice concentrations in April, averaged for 2000-2004 from satellite measurements, were below 70% in the region between the Alaska coastline and St. Lawrence Island (Grebemeier et al. 2006).

Declining length of the ice season

The length of the sea-ice season, including the timing of sea-ice freeze-up and break-up, is another critical variable of immediate concern for the Pacific walrus, which makes biannual migrations between the Bering and Chukchi Sea to follow the sea ice. Several studies have found that the length of the ice season is shrinking throughout the Arctic. Using satellite passive microwave data from 1979 to 2005, Stroeve et al. (2006) detected a trend to an earlier onset of spring melt and a longer melt season, particularly in the region north of Alaska and Siberia, corresponding to large retreats of sea ice observed in these regions. Stroeve et al. (2006) also found that the Arctic is experiencing an overall lengthening of the melt season by 2 weeks/decade. All regions of the Arctic showed a statistically significant (99% confidence level or higher) lengthening of the melt seasons by more than 1 week/decade, except for the central Arctic which showed a statistically significant increase of 5.4 days/decade (Stroeve et al. 2006).

Similarly, Comiso (2006b) reported a shift to a delayed onset of Arctic ice growth between 1979 and 2005, which is resulting in a shorter ice season and longer melt season. Using pan-Arctic satellite data, Comiso (2006b) found that the length of the melt season has increased by 15.2 days/decade over sea ice, 1.5 days/decade over the Greenland ice sheet, 2.0 days/ decade over northern Eurasia, and 5.5 days/decade over northern North America. Of importance for the Pacific walrus, the duration of the melt season over sea-ice has increased by more than 5 weeks between 1979 and 2005. This equates to a shorter ice season and thinner sea ice.

Declining sea-ice thickness

The thickness of sea ice is an important factor for the Pacific walrus since sea ice must be thick enough to support the weight of large groups of animals while low enough to haul out on, and separated by leads and polynyas that allow access into and out of the water (Tynan and DeMaster 1997, Ray et al. 2006). Rothrock et al. (1999) detected a mean decrease in sea-ice thickness of 1.3 m in most of the deep water portion of the Arctic Ocean, from 3.1 m in 1958-

1976 to 1.8 m in the 1990s. The greatest decrease occurred in the central and eastern Arctic in a band from the Chukchi Sea to the Fram Strait (Rothrock et al. 1999, ACIA 2005). A more recent study assessed Arctic-wide changes in sea-ice thickness from 1982-2007 using satellite-derived estimates of sea-ice age and thickness (Maslanik et al. 2007b). Pack ice contains a mixture of first-year ice and multi-year ice. Multi-year ice has survived for one or more melt seasons and is typically thicker than first-year ice. This study found that the mean age and thickness of ice within the remaining multi-year ice pack has decreased due to the loss of the oldest ice types, and the remaining older, thicker ice is confined to a much smaller portion of the Arctic Ocean. Specifically, the area of ice greater than 5-years-old decreased by 56% between 1982 and 2007 (Maslanik et al. 2007). The most striking changes occurred in the central Arctic Ocean where coverage of ice greater than 5-years-old declined by 88% and ice older than 8 years essentially disappeared (Maslanik et al. 2007). The loss of older, thicker ice has resulted in a decrease in mean thickness of ice over Arctic Ocean from 2.6 m to 2.0 m between March 1987 and March 2007 (Stroeve et al. 2008).

Attribution of sea-ice loss to greenhouse gas forcing and natural variability

The observed losses of Arctic sea ice have been attributed to positive radiative forcing due to rising concentrations of greenhouse gases (greenhouse gas forcing) and to natural climate variability favoring sea-ice loss (Serreze et al. 2007). The most recent scientific consensus is that greenhouse gas forcing has contributed to and continues to contribute significantly to sea-ice loss; that rising temperatures from greenhouse gas forcing have acted synergistically with natural climate variability to accelerate sea-ice loss in recent decades; and that the impacts of greenhouse gas forcing on sea-ice loss are growing. Studies examining attribution of sea-ice loss to greenhouse gas forcing and natural climate variability are briefly reviewed below.

The loss of sea ice is influenced by the natural variability in large-scale atmospheric circulation regimes which drive winds and sea-ice circulation patterns. The Arctic Oscillation (AO) and closely related North Atlantic Oscillation (NAO) have been widely considered as the most dominant atmospheric circulation patterns affecting Arctic climate (Maslanik et al. 2007a). The AO and NAO refer to cyclical shifts in sea level pressure between the high latitudes and mid latitudes (ACIA 2005, Serezze et al. 2007). The AO enters a positive mode when sea level pressure over the Arctic is low and sea level pressure over mid-latitudes is high. Similarly, the NAO enters a positive mode when sea level pressure of the Icelandic Low pressure system is low and pressure of the mid-latitude Azores High is high. When the AO-NAO is in a positive phase, surface winds produce a counterclockwise motion of sea ice and a greater net transport of sea ice away from the Siberian coast. Sea ice is transported from Siberia, across the pole, and through the Fram Straight into the North Atlantic (i.e. an enhanced Transpolar Drift Stream). In short, a positive AO-NAO mode results in thinning of ice along the coast and the enhanced movement of ice out of the Arctic basin.

The AO-NAO was in a positive mode from 1970 to the mid-1990s and was particularly strong during 1989-1995 (Stroeve et al. 2007). The positive AO-NAO mode is thought to have acted synergistically with increasing temperatures from global warming to accelerate declines sea-ice thickness and volume from the late 1980s to mid-1990s (Lindsay and Zhang 2005, Rothrock and Zhang 2005). Lindsay and Zhang (2005) propose a three-part mechanism by which this occurred: (1) air temperatures (fall, winter, spring) over the Arctic Ocean increased due to greenhouse gas forcing, resulting in the thinning of the first-year ice at the start of summer (pre-conditioning); (2) a positive AO-NAO mode triggered the accelerated decline of sea ice by flushing some ice out of the Arctic basin, thereby reducing sea-ice thickness and increasing summer open water, (3) and subsequent increasing greenhouse gas forcing combined with the ice-albedo feedback prevented sea-ice recovery (i.e. increased absorption of solar radiation further melts ice and warms water, creating thinner first year ice; thinner ice provides less insulation and more heat loss to the atmosphere, leading to higher spring temperatures and earlier melt season). The most important aspects of this cycle are that increased warming pre-conditioned the sea ice for declines and that warmer temperatures contributed to the ice-albedo feedback after the AO-NAO cycle returned to more favorable conditions for ice growth.

While the positive mode of the AO-NAO is thought to have contributed to sea-ice decline until the mid-1990s, another unusual Arctic atmospheric circulation pattern appears to have influenced Arctic Basin winds and sea-ice transport since 2000 (Maslanik et al. 2007a, Stroeve et al. 2008). This circulation pattern, called the dipole pattern, is characterized by high sea level pressure over the Canadian Arctic and low pressure over the Siberian Arctic that leads to persistent southerly winds over the western Beaufort, Chukchi, and East Siberian Seas, and favors northward ice drift and warmer temperatures (Maslanik et al. 2007b). The net result is the transport of sea ice from the Pacific side to the Atlantic side of the Arctic basin (Maslanik et al. 2007a). The strengthening of the dipole pattern since 2000 is thought to have contributed to the loss of sea ice in the Chukchi, Beaufort, and East Siberian Sea, and was particularly persistent in the summer of 2007 (Maslanik et al. 2007b).

Although variability in atmospheric circulation patterns contributed to the loss of sea ice, there is strong scientific consensus that sea-ice extent would have declined due to greenhouse gas forcing even without the influence of natural climate variability (Francis et al. 2005, Lindsay and Zhang 2005, Rothrock and Zhang 2005). Three main lines of evidence support this consensus. First, Rothrock and Zhang (2005) simulated sea-ice thickness and volume changes during 1948-1999 and found a steadily downward trend in sea ice (-4% per decade) that occurred during both negative and positive phases of the AO-NAO cycle and which was best explained by rising Arctic surface temperatures. Similarly, Meier et al. (2007) examined Arctic sea-ice extent during 1979-2005 and detected a strong relationship between sea-ice extent and air temperatures (correlation of -0.74) throughout this period, while the AO did not seem to have a prevailing effect, especially after the late 1990s.

Secondly, Stroeve et al. (2007) partitioned out the variance in the observed sea-ice loss in summer and winter from greenhouse gas forcing and natural variability and found that greenhouse gas forcing contributed significantly to sea-ice declines. Stroeve et al. (2007) estimated that 33–38% of the observed September trend from 1953–2006 was forced by greenhouse gas warming, which grew to 47–57% from 1979–2006 despite the strong influence of the AO-NAO and the dipole pattern during that period. The trend in winter (March) sea-ice decline also showed a large and rising contribution from greenhouse gas forcing: 34-39% from 1953-2006 and 45-52% from 1979–2006. In a second study, Francis et al. (2005) found that greenhouse gas forcing explained most of the variability in the northern ice edge position in six marginal Arctic seas (East Siberian, Chukchi, Beaufort, Barents, Kara, and Laptev)–approximately 40%--and more than other thermal or dynamic explanatory factors.

Third, the observed declines in sea-ice extent are simulated by climate models only when greenhouse gas forcing is incorporated into the models. Specifically, Zhang and Walsh (2006) found that the models used in the IPCC Fourth Assessment Report, which incorporate a range of greenhouse gas emissions levels, produced a multi-model mean annual trend in sea-ice extent within 20% of the observed climatology from 1979–1999, with a good simulation of the seasonal cycle of more sea-ice loss in the summer than in the winter (Zhang and Walsh 2006).

A final important finding of these attribution studies is that the influence of greenhouse gas forcing on sea-ice extent has been consistently under-predicted by climate models. Stroeve et al. (2007) extended the above-cited analysis of Zhang and Walsh (2006) to a longer time period (1953-2006 versus 1979-1999) to evaluate how well the IPCC Fourth Assessment Report multi-model ensemble simulated observed sea-ice loss. Stroeve et al. (2007) found that the mean model forecast significantly underestimated the declining trend in September Arctic sea-ice extent. The most striking finding was that recent summer sea-ice minima are approximately 30 years ahead of the IPCC ensemble mean model predictions. Stroeve et al. (2007) hypothesized that the models used in this analysis appeared to under-represent the greenhouse gas response most likely due to short-comings of the models in representing important feedback processes in the Arctic. In support, the two models that best matched observations over the satellite record incorporated more sophisticated sea-ice models. Stroeve et al. (2007) concluded that "it appears that impacts of GHG loading on Arctic sea ice in September are strong, and growing, and have also impacted March ice extent."

Another aspect of understanding sea-ice loss in the range of the Pacific walrus is untangling the effects of greenhouse gas forcing and natural climate variability in the Bering Sea, which is influenced by a third atmospheric circulation pattern, the Pacific Decadal Oscillation (PDO). The PDO influences climate in the North Pacific, including the Bering Sea, and is thought to affect sea-ice melt in this region. While the AO and NAO affect the sea ice of nearly the entire basin, the PDO exerts a more localized influence on the Siberian sector of the basin and specifically on the Bering Sea. The PDO refers to the dominant mode of sea surface temperature in the North Pacific Ocean and oscillates between a warm, positive mode and a cool, negative mode during 20–30 year periods. During the positive phase, sea level pressure of the Aleutian low pressure system is lower than average and stronger easterly winds prevail in the Bering Sea. These easterly winds influence the edge of the winter sea ice (Francis and Hunter 2007).

The PDO entered a positive phase in 1976/77, and the Bering Sea shifted from a predominantly cold, Arctic climate to a warmer, subarctic maritime climate. The increase in easterly winds with the shift in the PDO has been linked to decreases in the winter sea-ice edge in the Bering Sea between 1979-1994 (Francis and Hunter 2007). However, the PDO entered a more neutral state after 1995, which is reflected in the weaker correlations between easterly wind anomalies and the ice-edge location during 1995-2005 (Francis and Hunter 2007). Despite the neutral state of the PDO, the position of the winter sea-ice edge appears has retreated northward on average since 1995 (Francis and Hare 2007: Figure 3). Francis and Hunter (2007) warned that continued retreat northward of the winter sea ice will produce large disruptions in the Bering Sea ecosystem:

> The winter ice in the Barents and Bering seas is thinner and more mobile than perennial or land-fast ice, resulting in an enhanced sensitivity to regional atmospheric and oceanic circulation features. As the oceans continue to warm and storminess increases in response to increasing concentrations of greenhouse gases, as predicted by state-of-the-art global climate models [Chapman and Walsh, 2007], winter ice extent will likely also continue to retreat northward, although the drivers will vary in different locations. Losses of perennial sea ice may be accelerated by the consequent reduction in ice volume at the beginning of the melt season, and normal life cycles of marine organisms will be profoundly disrupted (Francis and Hunter 2007: 5)

An analysis by the North Pacific Marine Science Organization (PICES) on the implications of climate regime shifts for North Pacific fisheries predicted that the Bering Sea will likely continue on a warming trajectory in which it is less sensitive to the intrinsic climate variability of the North Pacific (i.e. PDO), indicative of the strengthening influence of greenhouse gas forcing:

> We hypothesize that the overall climate change occurring in the Arctic, as indicated by warmer atmospheric and oceanic temperatures and loss of 15% of sea ice and tundra area over the previous two decades, is making the Bering Sea less sensitive to the intrinsic climate variability of the North Pacific. Indeed, when the waters off the west coast of the continental United States shifted to cooler conditions after 1998, the subarctic did not change (Victoria pattern), in contrast to three earlier PDO shifts in the twentieth century. Thus we project that the Bering Sea will more likely continue on its current warm trajectory, with biomes transitioning northward, allowing pollock a larger domain at the expense of cold and ice-adapted species, rather than transitioning back to a cold regime (PICES 2005: 124).

Tipping Point in Arctic Sea Ice

Numerous researchers have warned that the global warming may have already pushed the Arctic past a 'tipping point' beyond which continued declines in Arctic sea ice are unavoidable and which will not abate until greenhouse gas emissions are drastically reduced. Lindsay and Zhang (2005) identified 1989 as a potential tipping point for the Arctic ice–ocean system in which triggering events were able to initiate a process of continual rapid change:

> It is quite possible that the large changes initiated by the gradual winter warming and the atmospheric circulation anomalies of the early 1990s have forced the system into a new state in which very large extents of summer open water and winter first-year ice are the norm. The old regime may not be regained until there is either a prolonged cooling period or a prolonged period of very negative AO

> index and positive PDO index that can once again build the reservoir of thick ridged ice through strengthening the circulation of the Beaufort gyre. The gradually increasing winter air temperatures may reflect a global warming signal that will preclude a return to the old regime (Lindsay and Zhang 2005: 4893).

Meier et al. (2007) also point out that the sea ice may have passed a tipping point beyond which an ice-free Arctic summer is certain:

> The AO 'triggered' the accelerated decline of the sea ice by reducing the average thickness of the ice cover, and subsequent increasing temperatures have not allowed the ice to recover. This may have caused the sea ice to pass a tipping point, where further decline to the ice-free Arctic summer state is inevitable (Meier et al. 2007: 428).

Serreze and Francis (2006) concluded:

> [o]ur guarded interpretation of the available evidence is that the Arctic is in a state of 'preconditioning', setting the stage for larger changes in coming decades. This preconditioning is characterised by general warming in all seasons, a longer melt season, and retreat and thinning of sea-ice, upon which the effects of natural variability are superimposed. Before the projected widespread increase in surface temperatures over the Arctic Ocean can clearly emerge, more sea-ice must be removed. Extreme sea-ice losses in recent years seem to be sending a message: the ice-albedo feedback is starting. With greenhouse gas concentrations on the rise, there may be no counteracting mechanism in the climate system powerful enough to stop it (Serezze and Francis 2006: 68-69).

d. Observed Impacts to the Pacific Walrus from Global Warming

Researchers and native peoples have long noted the importance of sea-ice cover and climate conditions to the distribution and abundance of the ice-dependent Arctic pinnipeds (Vibe 1967, ACIA 2005). The Pacific walrus depends on sea ice throughout the year for essential life history behaviors including courtship, birthing, nursing, molting, as a resting platform between foraging bouts, and for passive transport to new foraging areas over the shelf. The loss of summer sea ice in the Chukchi Sea is already having significant impacts on the Pacific walrus. These impacts include the shift of females and young from the sea-ice edge in the Chukchi Sea to land-based haulouts as the summer sea ice disappears, high mortality at land-based haulouts, abandonment of calves at sea, and evidence of increasing physiological stress. Each of these impacts is described in more detail below.

- The disappearance of the summer sea-ice cover over the shallow Chukchi Sea shelf has deprived walruses of essential sea-ice resting platforms over their benthic foraging areas and has forced females and calves to abandon their at-sea foraging areas and haulout on land for extended periods in dense aggregations in the summer, where they are more vulnerable to death and injury through trampling, human disturbance, and predation. In 2007 when Arctic summer sea-ice extent reached a record low, Pacific walruses began hauling out on land in late July, a month earlier than usual (Joling 2007a). By August, several thousand animals were concentrated in anomalously high numbers at coastal haulout sites in Alaska from Barrow to Cape Lisburne, 300 miles to the southwest of Barrow (Joling 2007a). Walruses were also observed onshore at Kaktovik, 325 miles southeast of Barrow on the Beaufort Sea, which is far east of their normal range (Joling 2007a). In Russia, walruses also came ashore earlier and stayed longer at coastal haulouts, congregating in extremely dense herds numbering up to 40,000 at Point Shmidt on the Chukotka peninsula, a haulout not used by walruses for a century (Joling 2007b). Not only were walruses stranded at land-based haulouts at unprecedented numbers for up to three months in summer 2007, but females and calves were forced to come ashore at land-based haulouts which is a highly anomalous behavior. While mature males occupy coastal haulouts in summer especially along the northern Chukotka peninsula, adult female and young walruses remain at sea in summer, distributed near the ice edge in the Chukchi Sea (Fay 1982).

A telemetry study of females and dependent young in 2007 provides some insight into the response of walruses to the loss of Chukchi summer sea ice. Jay et al. (2008) attached satellite radio-tags to nine walruses in the eastern Chukchi Sea during the last week of June and first week of July of 2007 while the ice edge was still over the shelf. As the sea-ice edge retreated over deep water, the tagged walruses remained near shore over the eastern Chukchi Sea shelf in July by using small, remnant ice floes for hauling out (Joling 2007a, Jay et al. 2008). Because the satellite tags did not last through August, the researchers were not able to track the movements of these females during the month when most walruses came ashore to land-based haulouts.

- Walruses that were concentrated at dense land-based haulouts in 2007 suffered high mortality and injury from trampling during stampedes. When alarmed by human disturbance such as aircraft or hunters or by predators such as polar bears, walruses will stampede en masse to enter the safety of the water (Fay 1982). When walruses are aggregated in dense concentrations, calves are especially vulnerable to being crushed to death by stampeding animals due to the large numbers of animals racing towards the water and their small size. In the summer of 2007, 3,000 to 4,000 mostly young walrus died in stampedes at the extremely-dense, land haulouts on the Chukotka coast, which represents significant mortality (Joling 2007b). An unknown number of walruses may have died in stampedes at Alaskan haulouts that weren't regularly monitored. In contrast, when adult females and calves are distributed on sea-ice floes as is typical in summer, calves are less vulnerable to injury and death from stampedes because walruses are less exposed to disturbance on offshore floes, walruses congregate in smaller groups on sea-ice floes compared with land-based haulouts, large males are typically absent from summer sea-ice groups on floes, and walruses are often able to enter the water more easily from ice floes.

- As observed in 2004, the retreat of the Chukchi summer sea ice northward of the shelf may lead to higher calf mortality if calves are abandoned by their mothers while the females are searching for food in ice-free waters, providing no platform for the dependent calves to rest on. In July-August 2004, researchers observed nine Pacific walrus calves separated from adult females in waters as deep as 3000 m in the eastern Chukchi and western Beaufort Seas (Cooper et al. 2006). This region of the shelf of the Beaufort and Chukchi Seas is typically covered with sea ice during summer, but sea-ice cover was virtually absent (Cooper et al. 2006). Researchers detected a large plume of warm water, measuring 7°C and more than six degrees higher than temperatures at the same time and location in 2002, that likely contributed to rapid melting and northward retreat of the sea ice to deep water over the Arctic Ocean basin (Cooper et al. 2006). Researchers discovered the lone calves in areas 85 to 215 km from shore in water 200 to >3,000 m deep, in contrast to the region where researchers observed mothers and calves swimming together which was ~30 km from shore in water less than 100 m deep (Cooper et al. 2006). These observations of calves offshore without their mothers are unprecedented (Cooper et al. 2006).

Cooper et al. (2006) attributed the unprecedented number of separations of mother-calf pairs to the rapid loss of sea ice over the shelf, since the disappearance of sea-ice resting platforms would have prevented females from simultaneously foraging and caring for their young. Female-calf pairs may become more easily separated without sea-ice resting platforms in shallow waters where females can leave their calves while they feed. Cooper et al. (2006) warn that the Pacific walrus population may be ill-adapted to rapid seasonal sea-ice retreat off Arctic continental shelves:

> Our observations raise the possibility that rapid seasonal sea-ice retreat could create a crisis for the Pacific walrus population in the Bering, Chukchi, and Beaufort Sea region (Cooper et al. 2006: 101).

And further that:

> If walruses and other ice-associated marine mammals cannot adapt to caring for their young in shallow waters without sea-ice available as a resting platform between dives to the sea floor, a significant population decline of this species could occur (Cooper et al. 2006: 100-101).

- In years with low summer sea ice, walruses in the Bering Strait have been observed in poor physical condition, which has been linked to their decreased ability to forage in these years. Pungowiyi (2000) reported that walruses were in poor physical condition in 1996-1998 since they were underweight and exhibited low productivity. Their poor condition was attributed in part to reduced sea ice in the Chukchi Sea, which likely forced females to swim farther between their foraging grounds on the shallow shelf and their resting platforms on the sea-ice edge which had retreated far northward (Pungowiyi 2000). In contrast, in the spring of 1999, the walrus were in good condition following a cold winter with good ice formation in the Bering Sea (Pungowiyi 2000).

Each of these studies demonstrates the devastating population impacts that low sea-ice cover and early sea-ice melt can exert on the Pacific walrus.

e. Projected Climate and Environmental Changes

There is no credible scientific dispute that global warming will continue and may accelerate if greenhouse gas emissions are not reduced. All climate models in the IPCC and ACIA assessments predict significant warming in this century, with variation only as to the rate and magnitude of the projected warming (ACIA 2005). For its Fourth Assessment Report

("AR4"), the IPCC performed an unprecedented, internationally coordinated climate change experiment using 23 models by 14 modeling groups from 10 countries to project future climate conditions. This large number of models that range from simple to complex, running the same experiments, provides more accurate quantification of future climate conditions, the importance of different model parameters, and the uncertainty in the results. For projecting future climate change, the model experiments used an array of different emission scenarios. These include three of the six Special Report on Emissions Scenarios ("SRES'), B1, A1B, and A2 that represent low, medium and high greenhouse gas growth scenarios during this century, respectively. In addition, experiments included scenarios with CO_2 doubling and quadrupling and scenarios with different levels of greenhouse gas mitigation, including (1) constant composition commitment scenarios in which greenhouse gas concentrations are fixed at year 2000 levels, (2) zero emission commitment scenarios in which emissions are set to zero in the year 2100 and (3) overshoot scenarios in which greenhouse gas concentrations are reduced after year 2150 (Meehl et al. 2007). The ACIA utilized the climate models used in the IPCC's Third Assessment Report and is a comprehensively researched, fully referenced, and independently reviewed evaluation of Arctic climate change and its impacts for the region and for the world. It involved an international effort by hundreds of scientists over four years, and also included the special knowledge of indigenous people (ACIA 2005). This section reviews changes in climate condition in the Arctic and specifically in the range of the Pacific walrus that are projected by the IPCC and ACIA multi-model ensembles.

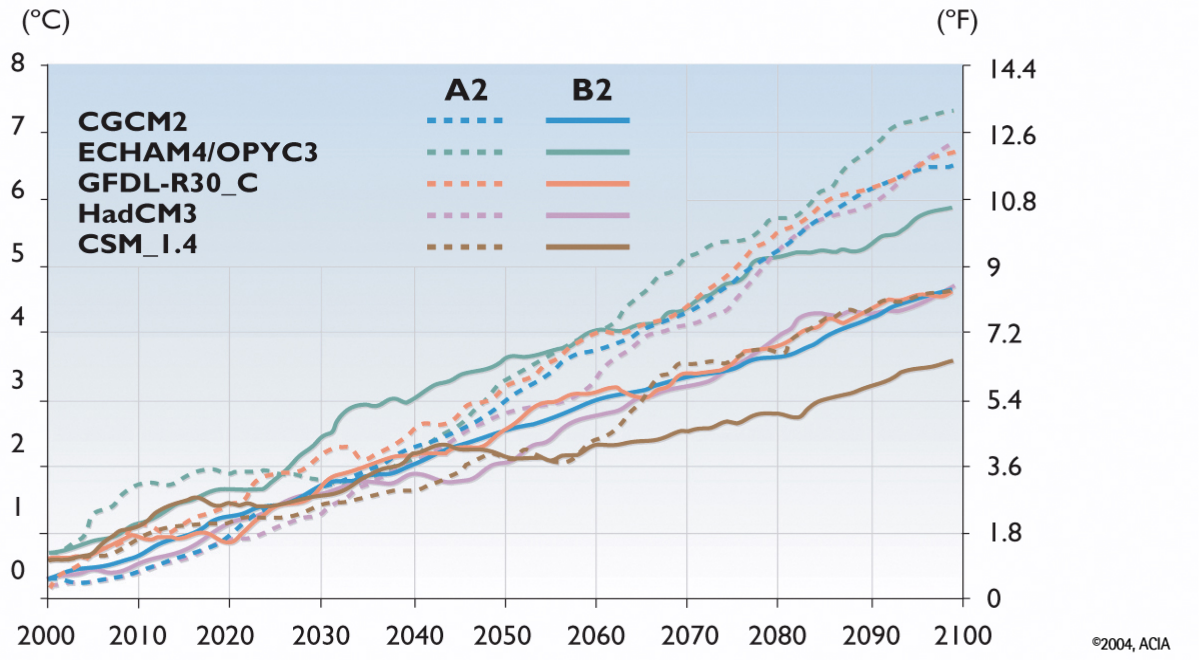
Surface air temperature, precipitation, and permafrost melt

Climate model projections are unanimous that temperatures will continue to rise throughout the 21st century and that warming will be the largest in the high northern latitudes of the Arctic (Serreze and Francis 2006, Christensen et al. 2007). According to the IPCC Fourth Assessment Report (IPCC-AR4), annual mean warming in the Arctic in this century will be more than twice the level of global annual mean warming, while Arctic winter warming will be four times the level of global mean warming (Christensen et al. 2007). By the end of the 21st century, annual Arctic temperatures are projected to rise by an average of 4.9°C under the A1B mid-level emissions scenario (also known as the "business-as-usual" scenario), based on the average from 21 models (range: 2.8-7.8°C) (Christensen et al. 2007: Table 11.1). Mean warming will be larger under the A2 higher-emissions scenario (5.9°C) and smaller under the B1 lower-emissions scenario (3.4°C). Notably, winter temperatures will rise more significantly (4.3-11.4°C) than in summer (1.2-5.3°C) (A1B scenario) (Christensen et al. 2007). In the marine realm, temperatures will rise by 5-7°C over the central Arctic Ocean, and warming in winter and autumn will be especially extreme due to reduced sea-ice cover (Christensen et al. 2007).

The ACIA (2005) projected that annual average temperatures will increase across the entire Arctic, with increases of approximately 3-5° C over land areas and up to 7° C over the oceans within this century under the B2 emissions scenario (Figure 9). Consistent with IPCC projections, winter temperatures will rise even more significantly, with increases of approximately 4-7° C over land areas and approximately 7-10° C over oceans (ACIA 2005). Patterns of temperature change predicted by regional climate models (RCMs) are quite similar to those simulated by the ACIA general circulation models. However, regional climate models project more warming along the sea-ice margins possibly because they better capture mesoscale weather systems and air-sea fluxes associated with the ice edge (ACIA 2005).

Figure 9. ACIA projected Arctic surface air temperature during 2000-2100 from 60°-90°N under the B2 and A2 emissions scenarios, expressed as the change from the 1981-2000 average.

Source: ACIA (2005: 27).



New (2005) projected that the average global temperature will have risen 2° C above pre-industrial levels sometime between 2026 and 2060, a result that is consistent with the results of the ACIA (2005) discussed above. A 2°C rise in average global temperature will translate into an average Arctic temperature increase of 3.2-6.6°C by mid-century, which will be greater in winter (4-10°C) and lower in summer (1.5-3.5°C) (New 2005).

Despite some variation among climate models and some remaining uncertainty regarding climate sensitivity, the salient point is that all models predict a warming climate in the relatively near future. The differences in the models are primarily only in the rate of change and occasionally geographic variation in the strength and timing of effects (ACIA 2005). Even using the lowest emissions scenario and the model that generates the least warming in response to atmospheric composition leads to a projection of warming in this century more than double that experienced in the last (ACIA 2005). All models project that the world will warm significantly as a result of human activities and that the Arctic is likely to experience this warming particularly early and intensely (ACIA 2005, Christensen et al. 2007).

Precipitation is projected to increase by ~18% (range 10-28%) over the Arctic by the year 2100 under the A1B scenario, with most of the increase falling as rain (Christensen et al. 2007). Projected precipitation increases are larger (22%) under the A2 scenario and smaller (13%) under the B1 scenario, but overall precipitation increases are robust among models (Christensen et al. 2007). The increase is projected to be largest in the winter and smallest in the summer, consistent with higher projected warming in the winter (Christensen et al. 2007). Regionally, precipitation is expected to increase over all land areas except southern Greenland (ACIA 2005). During the summer, precipitation will increase over northern North America and Chukotka, Russia (ACIA 2005).

Arctic snow cover will undergo widespread reductions during the 21st century under the IPCC model simulations, due to the strong association between higher air temperature and reduced snow cover (Meehl et al. 2007). Under the B2 emissions scenario, mean Arctic snow cover over land will decrease by 9-18% by the end of this century, in addition to the approximately 10% decline already observed over the past three decades (ACIA 2005). The decreases are projected to be greatest in spring and late autumn/early winter, suggesting a further shortening of the snow cover season (ACIA 2005, Meehl et al. 2007). Snow cover will decrease since the beginning of the snow accumulation season will start later and the beginning of the snow melt season will shift earlier (ACIA 2005, Meehl et al. 2007). Snow quality is also expected to change, including an increase in thawing and freezing in winter that leads to ice layer formation (ACIA 2005). Overall, projected decrease in snow cover over land and sea ice will continue to lower its surface albedo and accelerate ice melt (ACIA 2005).

Declining sea-ice extent

Climate models are in near universal agreement that Arctic sea-ice extent will decline through the 21st century in response to atmospheric greenhouse gas forcing (Stroeve et al. 2007). The largest declines will occur during the summer with the loss of the perennial sea-ice cover. Studies using the IPCC-AR4 models (Arzel et al. 2006, Zhang and Walsh 2006) predict losses of 50-80% of the summer Arctic-wide sea-ice extent within this century depending on the emissions scenario used. Some model projections indicate that summer Arctic sea ice could be gone by mid-century or before (Arzel et al. 2006, Holland et al. 2006). However, summer and winter sea-ice has been declining significantly faster than the IPCC-AR4 multi-mean ensemble predicts (Stroeve et al. 2007). Summer sea-ice extent in 2007 plummeted to a record minimum (NSIDC 2007b), which most climate models forecast would not be reached until 2050 while winter sea-ice extent in 2006 and 2007 declined to a minimum which most climate models forecast would not be reached until 2070 (Stroeve et al. 2007). Based on observed sea-ice trends, leading climate scientists have proposed that summer Arctic sea ice could disappear by 2030 (Stroeve et al. 2008) or even as early as 2012 (Amos 2007, Borenstein 2007).

Arctic-wide sea-ice declines

Using the IPCC-AR4 multi-model ensemble, Zhang and Walsh (2006) projected that mean summer (September) Arctic sea-ice area will decrease by 65.0% under the A2 scenario, 59.7% under the A1B scenario, and 45.8% under the B1 scenario by the end of this century. In a similar assessment of the IPCC-AR4 model ensemble, Arzel et al. (2006) found that September Arctic sea-ice extent will decrease by an average of 62% between 1981-2000 and 2081-2100, with a smaller 15% decrease in winter (March) sea ice under the A1B scenario. Half of the models exhibited an ice-free summer Arctic by 2100 (Arzel et al. 2006). One of the important implications of retreating perennial sea ice is that the average thickness of the ice cover becomes thinner and more vulnerable to future summer melt as the fraction of multi-year ice floes decreases and the fraction of seasonal ice floes increases (Comiso 2005).

Another series of IPCC-AR4 modeling efforts demonstrated that sea-ice extent is unlikely to decline linearly but may instead experience periods of abrupt and rapid declines. Holland et al. (2006) examined the potential for future abrupt transitions in Arctic summer sea-ice extent using a subset of models employed in the IPCC-AR4 analysis (seven ensemble members from Community Climate System Model, version 3) under an A1B scenario. Abrupt transitions, defined as periods of rapid sea-ice loss, commonly occurred in all of these 21st century model simulations, as early as 2015 (Holland et al. 2006). Abrupt reductions in sea ice were associated with thinning of the spring sea ice which increased the formation of open water and accelerated summer ice loss due to an enhanced ice-albedo feedback. An important result of this work was that lower greenhouse gas emissions decreased the severity and likelihood of abrupt transition events. Under the lower emission B1 scenario, 3 of 15 models show abrupt transitions lasting 3-5 years, whereas 7 of 11 models using a higher emissions A2 scenario showed abrupt transition lasting 3-10 years with larger rates of change (Holland et al. 2006).

Another study has projected the average Arctic perennial ice cover based on 25 years of continuous, spatially detailed satellite data (Comiso 2005) and the projection that a 2° C global warming will occur between the years 2026 to 2060 (New 2005). The results show "ever increasing open ocean areas in the Beaufort, Siberian, Laptev and Kara Seas. The impact of such a largely increasing open water area could be profound. It could mean changes in the ocean circulation, marine productivity, ecology, ocean circulation and the climate of the region" (Comiso 2005:53). This study also revealed that for each 1° C increase in surface temperature (global average), the area of the average perennial ice cover decreased by about 1.48 million km^2, an area over three times the size of the state of California (Comiso 2005).

However, the IPCC-AR4 models used in the above-cited studies have significantly under-represented observed trends in summer sea ice, which suggests that summer sea-ice will decline more rapidly than predicted. Recent summer sea-ice minima are approximately 30 years ahead of the IPCC-AR4 ensemble mean model predictions (Stroeve et al. 2007), while summer sea-ice extent in 2007 plummeted to a minimum that most climate models forecast would not be reached until 2050. Given the conservative climate model results and the record minimum sea-ice extent of 2007, Stroeve et al. (2008) proposed that a seasonally ice-free Arctic Ocean might occur as early as 2030. Other leading climate scientists believe that current climate models markedly underestimate important melting processes and that the Arctic Ocean could be mostly ice free by the late summer of 2012 (Amos 2007, Borenstein 2007).

Sea-ice declines in the Pacific walrus range

Regional projections of changes in sea-ice extent in the Pacific walrus range were recently forecast by Overland and Wang (2007), who used the IPCC-AR4 models to better understand how declining sea-ice extent will affect Arctic ecosystems on a regional scale. Overland and Wang (2007) used a subset of IPCC-AR4 models that best simulated observed sea-ice concentrations from 1979-1999 to predict sea-ice extent in the Arctic basin during summer (August–September) and in the more southerly seasonal ice zones during winter (March–April) by 2050 under an A1B emissions scenario. The models projected a consistent loss of summer sea-ice area greater than 40% by mid-century for the entire Arctic basin, including the Chukchi, Beaufort, and East Siberian Seas (Overland and Wang 2007). However, as discussed above, the IPCC-AR4 multi-model ensemble on which Overland and Wang (2007) based their work has significantly under-estimated observed losses in summer sea-ice extent (Strove et al. 2007), and the disappearance of summer sea ice Arctic-wide could occur as early as 2012 (Amos 2007, Borenstein 2007) or 2030 (Stroeve et al. 2008).

The Bering Sea was projected to lose 40% of its winter (March-April) sea-ice area by 2050 (Overland and Wang 2007). Thus, by mid-century, the Pacific walrus may lose 40% of its winter sea-ice habitat, and likely more, since the IPCC-AR4 multi-model ensemble has also under-estimated observed losses in winter sea-ice extent (Stroeve et al. 2007). The remaining sea-ice habitat in 2050 will be also be thinner and will likely not persist throughout the winter because the period of sea-ice melt will be longer (later fall sea-ice formation and earlier spring melt).

Feedbacks of sea-ice loss on the Arctic and global environment

The loss of sea ice will have important consequences for the Arctic and global climate. First, rising greenhouse gas concentrations may favor the positive mode of AO-NAO that promotes sea-ice loss (Serreze et al. 2007). If this occurs, the ice-albedo feedback would favor continued Arctic sea-ice loss until greenhouse gas concentrations in the atmosphere are reduced. Additionally, delayed autumn and winter sea-ice growth will promote large increases in surface air temperature over the Arctic by allowing a non-insulated ocean (low sea-ice cover) to lose heat to the atmosphere (Serreze and Francis 2006). Finally, sea-ice loss will affect regions outside the Arctic by influencing mid-atmospheric patterns of atmospheric circulation and precipitation (Sewall and Sloan 2004).

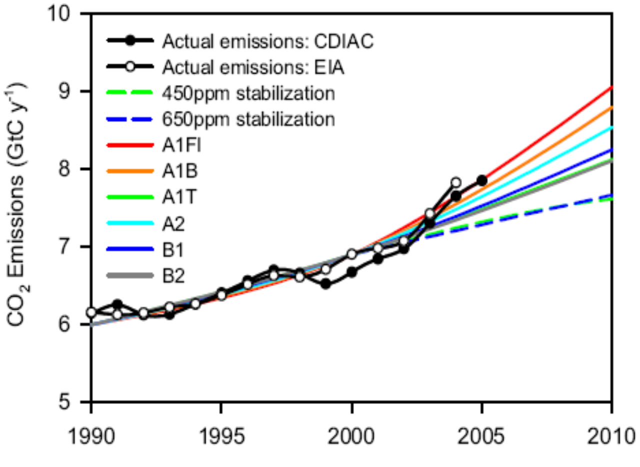
Dangerous Anthropogenic Climate Change and the Climate Commitment

Climate scientists are warning that we are rapidly approaching an emissions threshold beyond which "dangerous climate change" will be unavoidable. Warming of more than 1° C (1.8° F) above year 2000 levels has been defined as "dangerous climate change," with particular reference to species extinction and sea level rise (Hansen et al. 2006, Hansen et al. 2007). Beyond this point, climate feedbacks will greatly amplify the warming from anthropogenic emissions, leading to rapid additional temperature increases and catastrophic climate impacts. Leading scientists have previously reported that the atmospheric greenhouse gas level "ceiling" that must not be exceeded in order to prevent additional warming of more than 1° C (1.8° F) above year 2000 levels is 450-475 ppm of carbon dioxide, and have warned that this threshold may need to be revised downward. (Hansen et al. 2006). Most recently, Dr. James Hansen has reportedly stated that the evidence in fact indicates that the safe upper limit for atmospheric CO_2 is actually 350 ppm (McKibben 2007). With atmospheric carbon dioxide levels already over 380 ppm and increasing at over 2 ppm per year, and worldwide emissions continuing to increase each year, rapid and substantial reductions are clearly needed immediately.

One path to achieving the substantial emissions reduction needed to stay below the previously described threshold of 450-475 ppm is known as the “alternative,” as opposed to the “business as usual,” greenhouse gas emissions scenario (Hansen 2006, Hansen et al. 2006, Hansen et al. 2007). In the business as usual scenario, carbon dioxide emissions continue to grow at about 2% per year, and other greenhouse gases such as methane and nitrous oxide also continue to increase. In the alternative scenario, by contrast, carbon dioxide emissions decline moderately between now and 2050, and much more steeply after 2050, so that atmospheric carbon dioxide never exceeds 475 parts per million. The alternative scenario would limit global warming to less than an additional 1°C in this century (Hansen et al. 2006, Hansen et al. 2007).[4]

Since the year 2000, however, society has not followed the alternative scenario. Instead, the emissions growth rate has accelerated since 2000, rising from 1.1% per year from 1990-1999 to ~3.25 % per year from 2000-2004 (Raupach et al. 2007). The emissions growth rate since 2000 has even exceeded that of the most-fossil fuel intensive IPCC SRES emissions scenario, A1F1 (Figure 10) (Raupach et al. 2007). As a result, emissions since 2000 were also far above the mean stabilization trajectories needed in order to reach the 450 ppm stabilization target of the alternative scenario, and even well above a 650 ppm stabilization target (Raupach et al. 2007). If this growth continues for just ten more years, the 49% increase in CO_2 emissions between 2000 and 2015 will make it impractical if not impossible to achieve the alternative scenario (Hansen et al. 2006, Hansen et al. 2007). For this reason, it is essential that strong greenhouse gas limitations be enacted immediately.

Figure 10. Observed CO_2 emissions from U.S. Department of Energy Energy Information Administration (EIA) data (1980-2004) and U.S. Department of Energy Carbon Dioxide Information and Analysis (CDIAC) data (1751-2005), compared with six IPCC emissions scenarios and with stabilization trajectories describing emissions pathways for stabilization of atmospheric CO_2 at 450 and 650 ppm.
Source: Raupach (2007): Figure 1.



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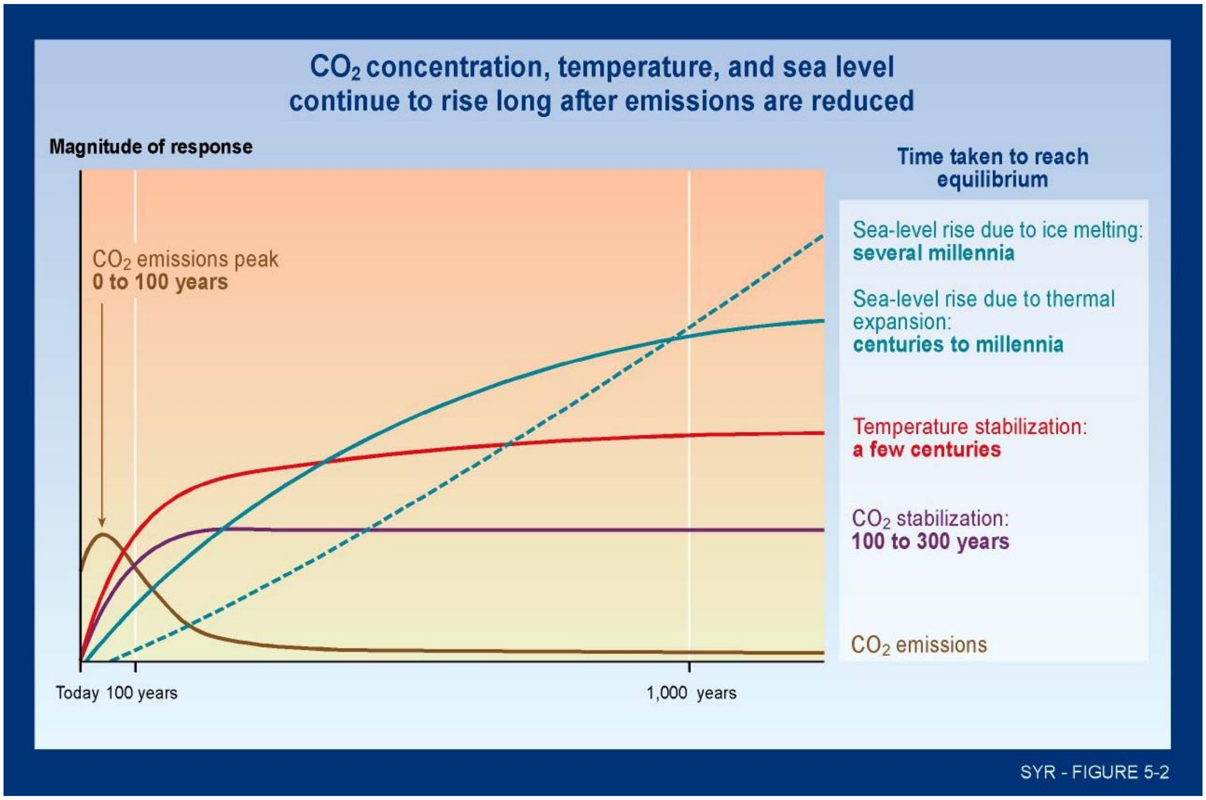
[4] The “tripwire” between keeping global warming to less than 1°C, as opposed to having a warming that approaches the range of 2-3° C, may depend upon a relatively small difference in anthropogenic greenhouse gas emissions (Hansen et al. 2006, Hansen et al. 2007). This is because warming of greater than 1 °C would likely induce positive climate feedbacks, such as the release of large amounts of methane from thawing Arctic permafrost, that will further amplify the warming (Hansen et al. 2006, Hansen et al. 2007).

Another difficulty in avoiding dangerous climate change is that the world is already committed to some level of continued warming and climate change for centuries to come even if greenhouse gas emissions were stabilized immediately (Figure 11). The interactions between variables including greenhouse gas emissions, total greenhouse gas levels in the atmosphere, temperature change, and melting of ice sheets create time lags in the climate system (IPCC 2001a). Slow transport of heat into the oceans and slow response of ice sheets are largely responsible for the long time periods needed to reach a new climate system equilibrium (IPCC 2001a). Even absent additional greenhouse gas emissions, this warming commitment equates to additional temperature rise of 0.6° C (1° F) that is already "in the pipeline" (Hansen et al. 2005). The IPCC multi-model climate change commitment experiments indicate that if greenhouse gases were stabilized for 100 years at year 2000, a further warming of 0.5°C (0.9°F) would occur in the 21th century (Meehl et al. 2007).

Figure 11. Relationships between carbon dioxide concentrations, temperature, and sea level rise. After CO_2 emissions are reduced and atmospheric concentrations stabilize, surface air temperature continues to rise slowly for a century or more.
Source: IPCC (2001(a)): Figure SPM-5.



Overall, the sooner greenhouse gas emissions are stabilized, and the lower the level at which they are stabilized, the smaller the overall temperature increase will be (IPCC 2001a). An important point is that stabilization of carbon dioxide emissions at current or near-current levels will not lead to stabilization of carbon dioxide atmospheric concentrations (IPCC 2001a). Stabilization of carbon dioxide concentrations requires reduction of global carbon dioxide net emissions to a small fraction of the current emission level (IPCC 2001a). As discussed in depth in the section on the "Inadequacy of Existing Regulatory Mechanisms," it is essential that strong greenhouse gas limitations be enacted immediately in order to give the Pacific walrus a chance for survival.

f. Future Threats to the Pacific Walrus from Global Warming

The Pacific walrus is dependent on Arctic sea-ice habitat for essential parts of its life cycle—resting between foraging bouts, passive transport to new foraging areas, courtship, giving birth, nursing pups, and molting. Without sea ice, the Pacific walrus faces an increased risk of extinction. Walruses have already experienced adverse impacts from sea-ice loss including shifts of females and young to land-based haulouts as the summer sea ice disappears, high mortality at land-based haulouts, abandonment of calves at sea, and evidence of increasing physiological stress. Arctic air temperatures will continue to increase by an average of 8°C during winter in this century under a mid-level emissions scenario (Christensen et al. 2007). This warming will accelerate the ice-albedo feedback, leading to continued loss and degradation of the Pacific walrus's sea-ice habitat by shrinking the length of the sea-ice season and through a relentless thinning of the remaining sea ice.

Researchers have consistently warned that the loss of the seasonal sea ice will prove devastating to ice-dependent Arctic pinnipeds (Tynan and DeMaster 1997, Kelly 2001, ACIA 2005, Learmonth et al. 2006, Simmonds and Isaac 2007). 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 highlights:1). The ACIA (2005) warned that changes in the timing of formation and disappearance of seasonal sea ice, in the quality of the sea ice, and in the extent of total coverage of both seasonal and multiyear ice will likely impact ice-dependent species. Based on its projections of sea-ice loss, the ACIA (2005) predicted that "negative consequences are very likely within the next few decades for Arctic animals that depend on sea ice for breeding or foraging" (ACIA 2005: 509). Moreover, "the worst-case scenarios in terms of reduced sea-ice extent, duration, thickness, and concentration by 2080 are very likely to threaten the existence of whole populations and, depending on their ability to adapt to change, are very likely to result in the extinction of some species" (ACIA 2005: 509).

The following section details the ways by which changing climate conditions in this century are expected to affect the Pacific walrus. Global warming will impact the Pacific walrus by degrading and eliminating critical sea-ice habitat, decreasing prey availability, altering interactions with predators and disease, and increasing human disturbance throughout the range.

Loss of sea-ice habitat

Summer sea-ice extent in the Chukchi Sea and fall and winter sea-ice extent in the Bering Sea have already experienced large declines in recent decades. For example, from 1979-2006, summer sea ice in the Chukchi Sea declined by 23.6% per decade in September, and fall-winter sea ice in the Bering Sea declined by 42.9% per decade in October and 4.8% per decade in March (Meier et al. 2007). Summer sea ice is projected to disappear as early as 2012 (Amos 2007, Borenstein 2007) or 2030 (Stroeve et al. 2008) throughout the Arctic. By 2050, the Bering

Sea is predicted to lose 40% of its winter sea ice under a "business-as-usual" A1B emissions scenario (Overland and Wang 2007). Because sea ice will be thinner and the period of sea-ice melt will be longer (later fall sea-ice formation and earlier spring melt), the remaining winter sea-ice habitat will likely be of lower quality. Habitat loss of this magnitude will undoubtedly commit Pacific walrus to population declines and to an increased risk of extinction. This section discusses the ways by which sea-ice loss will continue to impact the Pacific walrus.

(1) **Lost access to foraging grounds.** The loss of summer sea ice and significant reductions in winter sea ice will deprive the Pacific walrus of access to large portions of its foraging habitat on the Chukchi and Bering Sea shelves. By following the sea-ice edge from the Bering Sea to the Chukchi Sea from winter to summer, females, calves, and immature walruses continually access new benthic foraging areas in the shallow waters over the shelf. Without sea-ice resting platforms over the Chukchi Sea shelf in summer, females and young will be forced to use land-based haulouts during the summer months. Thus, instead of the population being distributed across the shallow shelf, the entire Pacific walrus population will be concentrated at land-based haulouts for extended periods of time in summer and will only be able to access benthic prey resources within a proscribed distance from shore before needing to return to land to rest. During the winter, the remaining sea ice in the Bering Sea will be smaller in extent and the sea-ice edge will continue to retreat farther northward. Therefore, the entire Pacific walrus population will have access to progressively smaller areas of the Bering Sea shelf for foraging in winter.

(2) Increased physiological stress due to loss of sea-ice haulouts. Pacific walrus adults and young are likely to experience increased physiological stress due to the loss of sea-ice haulouts since this will preclude them from resting at sea during foraging trips and from nursing their young and molting on safe, offshore sea-ice floes. The Pacific walrus uses an energetically efficient foraging strategy of feeding for several days followed by hauling out to rest on ice floes for several days (Ray et al. 2006). As females and young follow the sea-ice edge year-round, they are assured of having essential sea-ice platforms nearby for resting, nursing, and molting. In fall, winter, and spring, the reduction and thinning of sea ice will likely require females and young to swim farther before finding adequate sea-ice floes for these essential behaviors, increasing their energetic costs. During the summer, the loss of the summer sea ice will force females and young onto land-based haulouts, as observed in 2007. Concentrated groups of walruses can quickly deplete local benthic prey resources surrounding haulout sites, and walruses would be forced to swim progressively longer distances from shore to reach unexploited areas of benthic prey, which will increase their metabolic costs (Lowry 2000). In addition, females and young at land-based haulouts will likely face increased exposure to disturbances that cause them to enter the water during their resting and molting periods, also increasing metabolic stress. Increased physiological stress from these sources could have negative consequences for walrus fecundity and survival.

(3) Increased calf mortality due to loss of sea-ice haulouts. Calf mortality is also likely to increase as sea ice disappears as a result of increased metabolic stress during foraging trips and higher risk of abandonment. Walrus mother and calf pairs are closely bonded during the two-year period of calf dependency and constantly accompany each other on land and at sea (Fay 1982). Calves that accompany their mothers on foraging trips from land-based haulouts will not have sea-ice platforms for needed resting and nursing during these trips, heightening physiological stress. In addition, the risk of calf abandonment may increase, as observed in 2004 (Cooper et al. 2006), because females will not be able to leave their calves on or near sea-ice floes while they forage at the benthos. Groups of walruses appear to "home" on specific sea-ice floes during their foraging trips (Ray et al. 2006) and these may aid in preventing mother-calf separations.

(4) Increased mortality at land-based haulouts due to stampedes and predation. Walruses concentrated at land-based haulouts will likely suffer high mortality and injury from trampling during stampedes, as was observed in 2007. When alarmed by human disturbances or predators, walruses will stampede en masse to enter the safety of the water (Fay 1982). When walruses are aggregated in dense concentrations, calves are especially vulnerable to being crushed to death due to their small size. In addition, females and young may be at greater risk of predation by polar bears and terrestrial predators at land-based haulouts during summer (Kelly 2001).

(5) Interruption of breeding activities and seasonal cycle. The reduction of winter sea ice and shrinking length of the sea-ice season is likely to interrupt the timing and success of Pacific walrus breeding activities, including courtship, birthing, and nursing, with consequent negative impacts on fecundity (Tynan and DeMaster 1997). Pacific walrus migrations are closely linked to the seasonal cycle of sea ice (Fay 1982). The timing and pattern of onset of seasonal ice provide environmental cues for the entire Pacific walrus population to congregate at their breeding sites in the Bering Sea in winter. Using seasonal cues in fall, females summering in the Chukchi Sea and males summering in the Bering Sea migrate to the broken pack in two primary areas of the Bering Sea to initiate breeding during the peak of male spermiogenesis and female estrus. The delayed onset of the winter sea-ice season and northward retreat of the winter sea-ice edge may interrupt this seasonal migration and aggregation at the breeding grounds. Furthermore, walruses require winter sea ice for courtship displays, giving birth, and nursing. Reductions in quantity and quality of winter sea ice may negatively impact these activities, lowering reproductive success.

Reduced prey availability

Sea-ice loss and rising temperatures may alter the abundance and distribution of the benthic prey species that the Pacific walrus depends on.

An ongoing consequence of rising temperatures and sea-ice loss is that that the northern Bering Sea ecosystem is undergoing a shift from a benthic-dominated ecosystem rich in prey for Pacific walruses to one dominated by pelagic fish (Grebmeier et al. 2006a, Grebmeier et al. 2006b). This ecosystem shift will lower prey availability for the Pacific walrus if the loss of sea ice continues. The northern Bering Sea represents a transition region between the Arctic ecosystem of the northern Bering and Chukchi Seas, which are influenced by winter sea-ice cover, and the sub-Arctic ecosystem of the southern Bering Sea, which is an open-water region devoid of seasonal sea ice (Overland and Stabeno 2004). The presence or absence of sea-ice cover influences the timing of primary production which in turn plays a primary role in shaping ecosystem structure. The seasonally ice-covered Bering Sea currently experiences two blooms of primary production: an early "ice edge bloom" followed by a later "open-water bloom" after the ice has melted. The intense, spring ice-edge bloom follows the melting sea-ice edge, and the melting ice releases nutrients and fresh water that promote phytoplankton growth. Due to cold spring water temperatures, spring zooplankton populations are low and do not consume much of the organic matter before it settles the benthos. The net result of the high primary production over these shallow shelves and relatively low grazing pressure is that a heavy rain of organic matter settles to the sea floor where it supports a rich benthic community (Grebmeier et al. 2006b). The benthic-feeding Pacific walrus, bearded seal, gray whale, and seaducks are the primary consumers in the northern Bering Sea (Grebmeier et al. 2006b). In contrast, the southern, sub-Arctic Bering Sea experiences only one bloom—the later summer open-water bloom. Zooplankton and microbes, which are more abundant due to warmer summer ocean temperatures, graze most of the organic matter before it settles to the benthos. Upper-trophic-level fish and epifaunal invertebrates are the primary consumers in this pelagic-dominated ecosystem (Grebmeier et al. 2006b).

Due to rising temperatures and associated sea-ice loss, the Arctic–subarctic temperature front separating the northern and southern regions of the Bering Sea is moving northward, and the northern Bering Sea is losing its sea ice and the associated spring ice-edge bloom that supports high benthic production. As a result, the benthic ecosystem in the northern Bering Sea is shifting to a pelagic-dominated marine ecosystem less favorable for the Pacific walrus (Grebmeier et al. 2006a). As evidence of this shift, studies have detected decreased carbon supply to benthos, lower benthic biomass, and increases in pelagic fish abundance in the northern Bering Sea (Grebmeier et al. 2006b). The uptake of oxygen in the sediments provides an indicator of carbon supply to the benthos, and sediment oxygen uptake decreased from ~40 mmol O_2 m^{-2} day^{-1} in 1988 to sustained values of ~12 mmol O_2 m^{-2} day^{-1} from 1998 to 2004 in a region southwest of St. Lawrence Island (Grebmeier et al. 2006b). Benthic standing stock also decreased from ~40 g C m^{-2} to 20 g C m^{-2} during 1988 to 2004 in the same region, suggesting that prey for the benthic-feeding Pacific walrus is declining in the northern Bering Sea (Grebmeier et al. 2006b). Pelagic fish species also appear to be undergoing northern range expansions, including the movement of large numbers juvenile pollock (*Theragra chalcogramma*) to south of St. Lawrence Island in 2004 and increases in juvenile pink salmon (*Oncorhynchus gorbusha*) in the northern Bering Sea, which feed on pollock (Grebmeier et al. 2006b). Of importance for the Pacific walrus, an ecosystem shift away from a benthic-dominated community in the northern Bering Sea that lowers benthic prey availability would undoubtedly have negative consequences for reproductive success and survival since the rich productivity of the Bering Sea benthos supports the entire Pacific walrus population during winter and most mature males in Bristol Bay and Anadyr Bay during summer.

Secondly, loss of the sea ice will restrict the Pacific walrus's movements over the shelf and undoubtedly diminish its important ecological role in shaping benthic community structure and increasing productivity through its foraging activities (Ray et al. 2006). As described on pages 17-18, the Pacific walrus functions as a keystone species in the Bering and Chukchi Sea continental shelf ecosystem by restructuring benthic sediment while feeding and mobilizing nutrients from the sediments into the water column (Lowry 1984, Oliver et al. 1985, Ray and McCormick-Ray 2004, Ray et al. 2006). Through bioturbation, the Pacific walrus is thought to positively contribute to the high productivity of the Bering and Chukchi shelf ecosystem and increase the abundance of benthic invertebrates (Ray et al. 2006). The loss of the sea ice deprives the Pacific walrus access to much of the Bering and Chukchi Sea continental shelves, which will diminish its positive influence on the regeneration of the benthic community:

> Should sea ice continue to move northward as a result of climate change, the walrus' ecological role could be diminished or lost, the benthic ecosystem could be fundamentally altered and native subsistence hunters would be deprived of important resources (Ray et al. 2006: 1).

Changing interactions with predators and disease

Global warming is likely to increase depredation and disease occurrence in Pacific walrus populations. Of foremost concern, walruses that are forced to concentrate at terrestrial haulouts due to loss of sea ice may increase their risk of predation by polar bears and terrestrial predators including grizzly bears, wolves, and Arctic foxes (Lowry 2000, Kelly 2001). Female and calf pairs that typically spend the entire year associated with sea ice may be particularly vulnerable to increased predation at land-based haulouts in summer. The loss and early melt of winter sea ice in the Bering Sea will shift the Pacific walrus's distribution further northward during fall through early spring, which is likely to increase their contact during these months with polar bears which use the pack ice of the Chukchi, Beaufort, and northern Bering Seas (Simmonds and Isaac 2007). The break-up of the sea ice may also increase predation opportunities for killer whales that will be able to further penetrate the ice (Lowry 2000).

Global warming also poses a risk to Pacific walrus by improving conditions for disease spread (Harvell et al. 1999, ACIA 2005). Many wildlife pathogens are sensitive to temperature, rainfall, and humidity (Harvell et al. 2002). As the climate has warmed, these pathogens, in many cases, have expanded their ranges northward because warmer temperatures (1) have allowed their survival and development in areas that were previously below their temperature threshold, (2) increased their rates of development, (3) increased rates of reproduction and biting of their vectors, and (4) lowered the resistance of their hosts (Harvell et al. 2002, Parmesan 2006). Of concern for Pacific walrus, warming temperatures may increase the prevalence of diseases and disease vectors, exposing Pacific walruses to new diseases or increasing the transmission of existing diseases. For example, Rausch et al. (2007) argue that the Pacific walrus will be more likely to depredate or scavenge Arctic seals when their access to benthic prey becomes limited due to loss of sea ice. Shifting their diet to an increased consumption of seals may lead to a higher transmission and occurrence of the nematode parasite *Trichinella* in the Pacific walrus, which could affect the health of the walrus and the native subsistence hunters who contract trichinellosis by eating walrus meat infected with this parasite (Rausch et al. 2007).

Increased human disturbance in the Pacific walrus range

The disappearance of seasonal and perennial sea ice in the Arctic will encourage increased development and human traffic in previously inaccessible, ice-covered areas, which will increase impacts to Arctic marine mammals including the Pacific walrus (ACIA 2005).

Shipping activity and oil and gas exploration are expected to increase with declines in sea ice, and tourism and commercial fisheries are also likely to expand (AMAP 2003).

Increased shipping activity in Pacific walrus habitat is almost certain to occur with the opening of two international shipping routes—the Northwest Passage and the trans-polar route—and the expansion of the Northern Sea Route, all of which pass directly through Pacific walrus habitat in the Bering and Chukchi Seas. The Northwest Passage is a potential shipping route that has been historically blocked by perennial sea ice and which connects the Pacific and Atlantic Oceans through the Arctic Ocean along the northern coast of North America. The Northern Sea Route refers to the seasonally ice-covered marine shipping routes from Novaya Zemlya in the west, along the coast of northern Eurasia, to the Bering Sea in the east (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, although sea ice poses major challenges and requires specially reinforced ships as well as ice-breakers (ACIA 2005). A trans-polar route across the Arctic Ocean would connect the Atlantic and Pacific Oceans.

The navigation season for the Northern Sea Route is expected to increase from the current 20-30 days per year to 90-100 days per year by 2080, and the Northwest Passage was predicted to open sometime in the 21st century (ACIA 2005). However, expanding access to Arctic shipping routes is occurring much faster than predicted. In September 2007, the European Space Agency reported that the most direct route of the Northwest Passage was fully navigable due to the extreme loss of perennial sea ice, while the Northern Sea Route remained only partially blocked (ESA 2007).

Marine shipping vessels are already a significant source of oil pollution and greenhouse gas emissions, including carbon dioxide, nitrous oxides, and black soot (Earthjustice 2007). Increased shipping will heighten the risk of oil spills, increases emissions of greenhouse gases that with further accelerate Arctic warming, and increases emissions of black carbon that increase local melting of Arctic sea ice by reducing the ice albedo. Russian scientists also cite increasing use of a Northern Sea Route for transit and regional development as a major source of disturbance in the Russian Arctic (Belikov and Boltunov 1998). Ships involved in the expanded use of the Northern Sea Route would likely use leads and polynyas to avoid breaking ice and reduce transit time, and this loose ice with openings is preferred habitat for Pacific walruses and other ice-dependent pinnipeds. Overall, heavy shipping traffic on the Northern Sea Route, Northwest Passage, and trans-polar route is likely to disturb Pacific walrus reproductive and foraging activities, increase the risk of oil spills in critical Pacific walrus habitat, and further accelerate global warming.

Oil and gas exploration and commercial fisheries are also expected to expand into Arctic waters as the sea ice diminishes (AMAP 2003). The threats posed to Pacific walruses by oil and gas exploration and commercial fisheries are discussed beginning on pages 73 and 82, respectively.

B. Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Pacific walruses were overexploited by commercial hunting during the 18th, 19th, and 20th centuries, which resulted in significant decreases in population size and changes in population structure (Fay et al. 1989, Fay et al. 1997). Commercial hunting of the Pacific walrus was prohibited in the United States under the MMPA in 1972 and in Russia in 1991. Therefore, since 1992 harvest of Pacific walruses has been limited to subsistence catch by native communities in Alaska and Chukotka (Garlich-Miller et al. 2006). In the U.S., subsistence hunting occurs from all the Native villages near areas where walruses are found, but the bulk of the annual harvest is taken from the villages in and near Bering Strait, mainly Gambell, Savoonga, Nome/King Island, and Little Diomede Island. There is no limit on native subsistence harvest in the U.S., but the Eskimo Walrus Commission has supported the strengthening and expansion of harvest monitoring programs in Alaska and Chukotka as well as efforts to develop locally based subsistence harvest regulations (USFWS 2002). The Russian Federation sets harvest quotas for subsistence hunting of the Pacific walrus, which ranged from 2,000-3,000 individuals annually during 2002-2005 (Figure 2) (MMC 2007). Since 1999, USFWS and the Eskimo Walrus Commission have sponsored a walrus harvest monitoring project in Chukotka, which collects walrus harvest information from the eight primary walrus hunting villages: New Chaplino, Siriniki, Enmelen,Yanrakynnot, Lorino, Uelen, and Inchoun and Enurmino. Subsistence harvest levels in the U.S. and Russia from 1992 through 2002 ranged from 2,400 to 4,700 individuals annually (Garlich-Miller et al. 2006) , which does not include animals that were wounded but not retrieved. Because the USFWS has not updated stock assessment reports for the Pacific walrus since 2002, more recent harvest estimates have not been made readily available.

C. Disease or Predation

While likely not currently a threat to the viability of the Pacific walrus, global warming is likely to markedly increase depredation and disease occurrence in Pacific walrus populations as discussed in more detail above on page 62. Such impacts will likely act synergistically with other threats to the Pacific walrus to further increase the extinction risk for the species.

D. Inadequacy of Existing Regulatory Mechanisms

1. Regulatory Mechanisms Addressing Greenhouse Gas Pollution and Global Warming Are Inadequate

Greenhouse gas emissions and global warming are the greatest threats to the Pacific walrus and yet also the least well regulated. The primary international regulatory mechanisms addressing greenhouse gas emissions global warming are the United Nations Framework Convention on Climate Change and the Kyoto Protocol. While the entering into force of the Kyoto Protocol on February 16, 2005 marks a significant partial step towards the regulation of greenhouse gases, it does not and cannot alone adequately address the impacts of global warming that threaten the Pacific walrus with extinction. There are currently no legal mechanisms regulating greenhouse gases on a national level in the United States. As detailed below, all existing regulatory mechanisms are clearly inadequate to ensure the Pacific walrus's survival in the wild. The immediate reduction of greenhouse gas pollution is essential to slow global warming and ultimately stabilize the climate system while there is still suitable Pacific walrus sea-ice habitat remaining.

a. The United Nations Framework Convention on Climate Change

The United Nations Framework Convention on Climate Change ("UNFCCC") was adopted in May 1992 at the first Earth Summit held in Rio de Janeiro, Brazil, and entered into force in March 1994 (EIA 2004). 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 (EIA 2004). 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 a range of subsequent actions (UNFCCC 2004). The UNFCCC covers greenhouse gases not otherwise controlled by the Montreal Protocol on ozone-depleting substances (UNFCCC 2004).

The UNFCCC assigns differing responsibilities to its 189 parties, based on their differing levels of economic development (UNFCCC 2004). Annex I parties include 41 mostly developed countries. Annex I countries set a goal (but not a requirement) of returning their emissions by 2000 to 1990 levels (UNFCCC 2004). They are required to make regular reports on implementation, including reporting on levels of greenhouse gas emissions and policies and measures to reduce them (UNFCCC 2004). Annex II is a subset of Annex I countries which includes the 23 highly developed countries which are required to financially and otherwise support the efforts of the developing countries (UNFCCC 2004). Countries with economies in transition ("EITs") include 14 countries in Eastern and Central Europe and the former Soviet Union which are listed in Annex I but do not have the additional responsibilities of the other Annex I countries. Non-Annex I parties include all parties not included in one of the former categories and are mostly developing countries (UNFCCC 2004). Non-Annex I parties have general commitments to respond to climate change but have fewer obligations and are expected to rely upon external support.

The UNFCCC has not yet effectively controlled greenhouse gas emissions. The year 2000 has come and gone without the UNFCCC's goal of reducing greenhouse gas emissions from Annex I countries to 1990 levels being met. More than thirteen years after the UNFCCC came into force, "dangerous anthropogenic interference with the climate system" remains undefined (International Climate Change Taskforce 2005). There is a growing body of evidence, however, that anthropogenic greenhouse gas emissions have already caused "dangerous" climate change.

b. The Kyoto Protocol

In 1997 the Kyoto Protocol became the first additional agreement added to the UNFCCC to set emissions targets. The Kyoto Protocol set goals for developed countries only to reduce their emissions to at least 5% below their 1990 levels between 2008-2012, the "first commitment period" (UNFCCC 2004). The Kyoto Protocol required ratification by a minimum of 55 countries, encompassing at least 55% of the carbon dioxide emissions of Annex I countries before it would enter into force. Over seven years passed before this occurred. The Kyoto Protocol entered into force on February 16, 2005, 90 days after it was ratified by Russia (UNFCCC 2005).

The targets of the Kyoto Protocol's first commitment period are inadequate to prevent significant climate change, and consequently the decline to extinction of the Pacific walrus. First, the Protocol's overall emissions reduction targets for the first commitment period are highly unlikely to be met, due in large part to the continuing refusal of the United States to ratify the agreement. Second, even if the Kyoto targets were met, they are far too modest to impact greenhouse gas concentrations and global warming sufficiently to ensure the survival of the Pacific walrus. Third, negotiations for emissions reductions beyond 2012 are just beginning after being blocked for years by the U.S. Each of these issues is addressed in turn below.

The refusal of the United States to ratify the Kyoto Protocol, announced by the Bush Administration in 2001, is a major reason why Kyoto targets are unlikely to be met. Because the United States is responsible for over 20% of worldwide carbon dioxide emissions (EIA 2004), it is highly unlikely that overall targets can be met without U.S. participation. The Kyoto target for the U.S. was a 7% reduction in greenhouse gas emissions levels from 1990 levels by 2012 (EIA 2004). Between 1990 and 2001, United States emissions have in fact increased by 13%. Total United States emissions are projected to grow a staggering additional 43.5% through the period 2025 (GAO 2003a).

In addition to the outright intransigence of the United States, the overall and many country-specific Kyoto targets are unlikely to be met based on current progress and data. While some Annex I countries have achieved their Kyoto targets or at least some reductions, many other Annex I countries have seen their emissions increase substantially (Figure 12). Emissions also increased in many of the developing nations between 1990 and 2000 (UNFCCC 2004). In addition, although emissions of the EIT countries decreased significantly from 1990-2000 as a result of economic contraction in these countries, they increased from 2000 to 2001 and are projected to continue to do so (EIA 2004). Overall, the EIA estimates that worldwide carbon emissions in 2025 will exceed 1990 levels by 72% (EIA 2004).[5]

Even in the unlikely event that overall Kyoto targets were fully met by the year 2012, the reductions are far too small to substantially reduce global warming and improve the plight of the Pacific walrus. Implementation of the Kyoto Protocol would only slightly reduce the rate of growth of emissions – it would not stabilize or reduce atmospheric greenhouse gas concentrations (Williams 2002). Carbon dioxide levels currently stand at over 380 ppm, from pre-industrial levels of 280 ppm, and are increasing at more than 2 ppm per year (International Climate Change Taskforce 2005). Stabilizing carbon dioxide concentrations at 440 ppm (23% above current levels, and a level likely to lead to a greater than 2° C average global temperature rise) would require global emissions to drop below 1990 levels within a few decades, with emissions eventually declining to a very small fraction of current levels, despite growing populations and an expanding world economy. These cuts will not be achieved simply by compliance with Kyoto (Williams 2002). The IPCC SRES scenarios predict carbon dioxide

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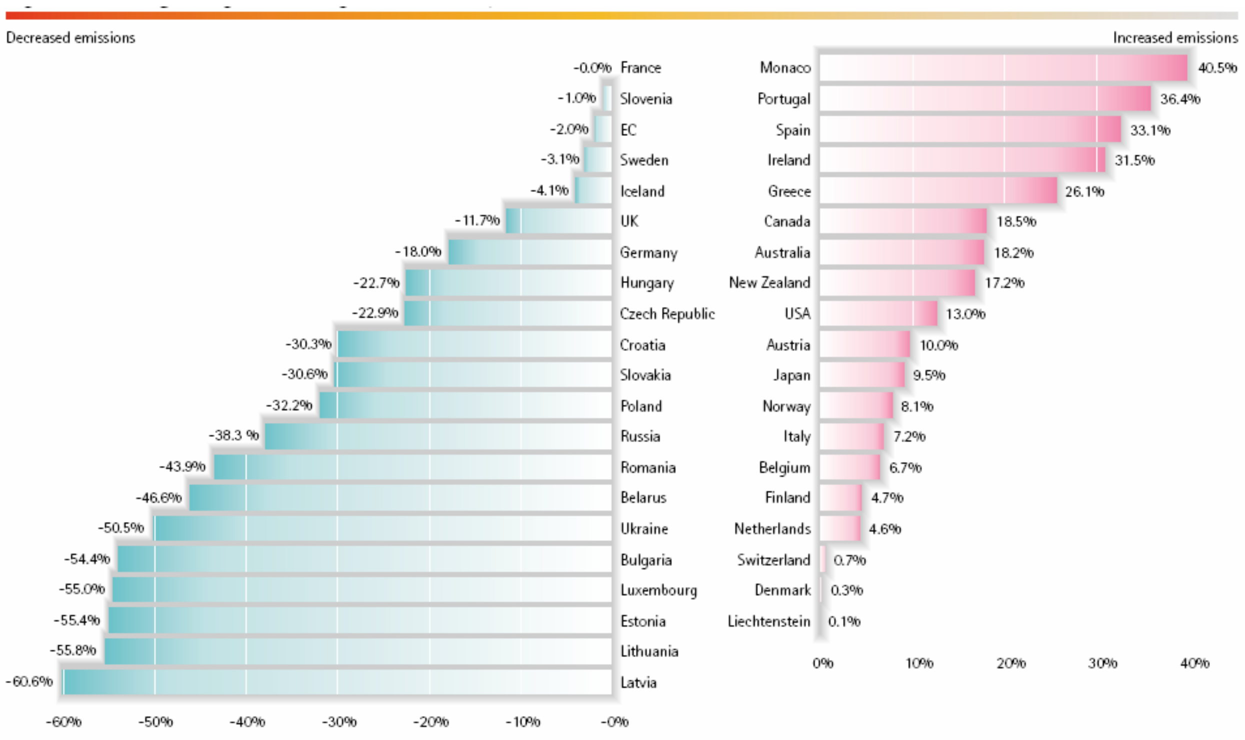
[5] EIA (2004) projections do not reflect the potential impacts of the Kyoto treaty, because it had not yet come into force when the projections were prepared (EIA 2004). Compliance with Kyoto or other measures to reduce greenhouse gases could cause actual emissions to differ from the projections (EIA 2004), however, as discussed above, compliance with overall Kyoto targets is unlikely.

concentrations of between 490 and 1260 ppm by 2100 (Albritton et 2001), and these scenarios all assume significant reductions in the rate of greenhouse gas emissions (Nakićenović et al. 2000).

Figure 12. Changes in greenhouse gas emissions by Annex I Countries, 1990-2001. Source: UNFCCC (2004: 25).



Additionally, the Kyoto Protocol's first commitment period only sets targets for action through 2012. There is no current regulatory mechanism governing greenhouse gas emissions in the years beyond 2012. Discussions for targets for the second compliance period from 2012-2016 began at the Bali, Indonesia, UNFCCC conference in 2007. While the European Union delegation attempted to begin discussions at the Conference of the Parties in Milan, Italy in 2003, in Buenos Aires in 2004, in Montreal in 2005, in Nairobi in 2006, not until Bali 2007 did the U.S. agree to a framework for the regulation of post-2012 emissions reductions. No binding or even voluntary agreement yet exists to deal with the cuts needed beyond the Kyoto Protocol.

c. United States Climate Initiatives are Ineffective

Because the United States is responsible for over 20% of global greenhouse gas emissions, regulation of United States emissions is essential to saving the Pacific walrus from extinction. Unfortunately, despite the nature and magnitude of the risks, and a variety of actions by Congress and the Executive Branch, there is still no regulation of greenhouse gas emissions on the national level in the United States.

Beginning in 1978, Congress established a "national climate program" to improve understanding of global climate change through research, data collection, assessments, information dissemination, and international cooperation. National Climate Program Act of 1978, 15 U.S.C. §§ 2901 *et seq.* Two years later, in the Energy Security Act, Congress directed the Office of Science and Technology Policy to engage the National Academy of Sciences in a study of the "projected impact, on the level of carbon dioxide in the atmosphere, of fossil fuel combustion, coal-conversion and related synthetic fuels activities" authorized by the Energy Security Act. Pub. L. No. 96-294, tit. VII, § 711, 94 Stat. 611, 774-75 (1980). In 1990, Congress enacted the Global Change Research Act, 15 U.S.C. §§ 2931-2938, which established a 10-year research program for global climate issues, directed the President to establish a research program to improve understanding of global change, and provided for scientific assessments every four years that analyze current trends in global change. *Id.* at §§ 2932, 2933, 2936(3). Congress also established a program to research agricultural issues related to global climate change. Pub. L. No. 101-24, tit. XXIV, § 2402, 104 Stat. 4058, 4058-59 (1990). Finally, two years later, in the Energy Policy Act of 1992, Congress directed the Secretary of Energy to conduct several assessments related to greenhouse gases and report to Congress. Pub. L. No. 102-486, § 1604, 106 Stat. 2776, 3002.

The Global Climate Protection Act of 1987 directed the Secretary of State to coordinate U.S. negotiations concerning global climate change. 15 U.S.C. § 2901 note; § 2952(a). Following those negotiations, President George H.W. Bush signed, and the Senate approved, the UNFCCC, which, as discussed above, has yet to effectively control greenhouse gas emissions.

Greenhouse gas emissions have also not yet been effectively regulated under the United States Clean Air Act ("CAA"). Section 103(g) directs the Environmental Protection Agency ("EPA") to establish a "basic engineering research and technology program to develop, evaluate, and demonstrate nonregulatory strategies and technologies for air pollution prevention" that would address substances including carbon dioxide. 42 U.S.C. § 7403(g). The CAA also states that nothing in Section 103(g) "shall be construed to authorize the imposition on any person of air pollution control requirements." *Id.*

In 2003, the EPA rejected a petition urging it to regulate greenhouse gas emissions from automobiles under CAA Section 202. In 2007, the Supreme Court overturned the EPA's refusal to regulate these emissions, and remanded the matter to the agency for further consideration. *Massachusetts v. U.S. EPA*, 127 S. Ct. 1438 (2007). The EPA has yet to act following the remand. Moreover, the EPA has denied California's request for a waiver to implement its Clean Vehicle Law, passed in 2002 (AB 1493, Pavley) which requires greenhouse gas reductions from automobiles sold in California, and is thus actively preventing this law from going into effect.

The George W. Bush Administration's climate initiative, revealed after the Administration renounced the Kyoto Protocol, plainly fails to effectively address global warming. This initiative is based entirely on voluntary measures which are incapable of effectively controlling greenhouse gas emissions. This climate plan, termed the Global Climate Change Initiative, also focuses only on reducing the amount of greenhouse gas emissions per unit of energy produced ("emissions intensity"), not the overall level of emissions (GAO 2003a). In the absence of new climate initiatives, United States emissions intensity is expected to decrease by 14% by 2012, while total emissions continue to increase (GAO 2003a). The Bush plan, if fully implemented and successful, would decrease emissions intensity by a mere additional 4%, for an overall reduction of 18%, but total emissions would still continue to increase. Even according to the Bush Administration's own arithmetic, full implementation and success of the plan will result in U.S. greenhouse gas emissions in 2012 that are 30% higher than 1990 emissions, as opposed to the 7% reduction called for by the Kyoto Protocol (Holdren 2003). Cumulative emissions between 2002-2012 will continue to grow and would be only 2% less with the plan than without it (GAO 2003a).

Moreover, the U.S. Government Accounting Office ("GAO") found that the Bush plan does not explain how even the modest 4% claimed reduction in energy intensity will be met. The Bush plan fails to provide any emissions savings estimates at all for 19 of the 30 plan elements (GAO 2003b). Of those 19, at least two seem unlikely to yield any emissions savings at all by 2012 (GAO 2003b). Of 11 initiatives for which savings estimates were provided, at least eight were not clearly attributable to the Bush plan, and there were problems with others as well (GAO 2003b). Overall, the GAO could confirm that emissions savings would be realized from only three of the Bush plan elements (GAO 2003b), an extremely inauspicious finding for the ultimate success of the already modest proposal.

In the absence of federal leadership, state and local governments have taken the lead in measures to reduce greenhouse gas emissions. While certainly a step in the right direction, unfortunately, these measures on their own are insufficient to prevent the extinction of the Pacific walrus. For example, the strongest law enacted to date is the California Global Warming Solutions Act of 2006. Signed into law in September, 2006, it is the nation's first mandatory cap on a state's overall greenhouse gas emissions. The California Legislature declared:

> Global warming poses a serious threat to the economic well-being, public health, natural resources, and the environment of California. The potential adverse impacts of global warming include the exacerbation of air quality problems, a reduction in the quality and supply of water to the state from the Sierra snowpack, a rise in sea levels resulting in the displacement of thousands of coastal businesses and residences, damage to marine ecosystems and the natural environment, and an increase in the incidences of infectious diseases, asthma, and other human health-related problems. (Cal. Health and Safety Code § 38501(a))

The Global Warming Solutions Act requires the reduction of greenhouse gas emissions to 1990 levels by the year 2020. *Id.* at § 38550. The law will be implemented through a series of California Air Resources Board (CARB) rulemakings including establishing emission source monitoring and reporting requirements, discrete early action emission reduction measures, and finally greenhouse gas emission limits and measures to achieve the maximum feasible and cost-effective reductions in furtherance of the greenhouse gas emission cap. *Id.* at § 38550. While the California Global Warming Solutions Act is a promising first step, like the Kyoto Protocol, it is insufficient on its own to slow global warming sufficiently to ensure the survival of the Pacific walrus.

For all the reasons discussed above, existing regulatory mechanisms relating to global warming are inadequate to ensure the continued survival of the Pacific walrus. Ensuring the Pacific walrus's survival requires immediate and dramatic action, particularly in the United

States, to reduce greenhouse gas emissions. Protecting the Pacific walrus under the Endangered Species Act will bring attention to its plight and encourage both voluntary and regulatory action.

2. Regulatory Mechanisms Addressing Other Threats to the Pacific Walrus Are Inadequate

Oil and Gas Development

The impacts of ongoing and proposed oil and gas development on the Pacific walrus are described starting on page 73. Existing regulatory mechanisms are inadequate to address these impacts. With the lease sales in the Beaufort, Chukchi, and Bering Seas that occurred under the 2002-2007 U.S. Oil and Gas Leasing Program and those scheduled under the 2007-2012 U.S. Oil and Gas Leasing Program (MMS 2007), a substantial proportion of the Pacific walrus's habitat subject to U.S. jurisdiction is now open for oil and gas leasing and development. The Minerals Management Service (MMS) is required to analyze the impacts of oil and gas lease sales and development on the Pacific walrus and other species while USFWS authorizes "take" of the species from such operations pursuant to the Marine Mammal Protection Act (MMPA). Unfortunately, neither agency is adequately considering the impacts of these activities on the Pacific walrus. Additionally, nearshore foraging areas and on land haulouts for the Pacific walrus are generally under the jurisdiction of the State of Alaska or other state, local or federal jurisdictions, none of which adequately protect walrus habitat from oil and gas activities.

The primary evidence of the inadequacy of MMS mechanisms for protection of the Pacific walrus (e.g. the Outer Continental Shelf Lands Act (OCSLA) and the National Environmental Policy Act (NEPA)) is the fact that MMS has offered or plans to offer the vast majority of Pacific walrus habitat in the Chukchi and Beaufort Seas and important walrus habitat in the Bering Sea for oil leasing. If these regulatory mechanisms had been adequate, important walrus habitats would have been deleted from MMS lease sales.

The implementation of the MMPA by USFWS also fails to adequately protect the Pacific walrus from oil and gas activities. In brief, the primary protection the MMPA provides is a prohibition against the unpermitted "take" (i.e. intentional killing or unintentional harassment) of marine mammals. This prohibition is similar to the ESA's Section 9 take prohibition. Authorization to allow take of Pacific walrus and other marine mammals is provided for in the MMPA pursuant to incidental harassment authorizations ("IHAs") or 5 –year incidental take regulations. USFWS has issued an IHA for Pacific walrus to Shell for seismic surveys in the Chukchi Sea in 2007 and issued a set of regulations giving in essence a blank check to all oil industry activities in the Beaufort Sea. FWS has proposed issuing similar regulations that would authorize take of virtually the entire Pacific walrus population in the Chukchi Sea for five years. In short, while the MMPA has a strong take prohibition, permits to allow take are freely given by USFWS to the oil industry.

Importantly, the MMPA lacks several provisions that the ESA has. The MMPA has no procedural requirement akin to Section 7 that requires agencies to affirmatively look at the impacts of their activities on marine mammals or to avoid jeopardy. The MMPA has no requirement to protect critical habitat. The MMPA has no requirement to develop a recovery plan for a species. Significantly, the MMPA does not have a citizen suit provision, so enforcement is left entirely to USFWS. This is no academic matter as from March 2005 until August 2006 no operative MMPA take authorizations for oil and gas operations existed in the Beaufort Sea in Alaska but industry activities likely resulting in take of Pacific walrus continued with no enforcement from FWS.

Additionally, no regulations are in place to protect Pacific walrus hauled out on land from disturbance due to oil and gas operations. As diminishing sea ice in the Chukchi Sea forces more walrus to land, the lack of such regulation presents a significant threat to the species.

Given the rapidly changing conditions in the Arctic, the precarious status of multiple ice-dependent organisms, and the numerous adverse impacts of oil and gas industry activities on these species, the only adequate regulatory mechanism to protect the Pacific walrus from oil and gas activities would be a moratorium on new oil and gas leasing and development in the Arctic. Such a moratorium should be implemented immediately and remain in effect until and unless such activity can be demonstrated to not have adverse impacts on the Pacific walrus and other ice-dependant species, and any greenhouse emissions directly or indirectly associated with such activities are shown to be consistent with a comprehensive national plan to reduce CO_2 and non-CO_2 pollutants to levels determined necessary to avoid the continued loss of sea ice. However, to date the U.S. has not undertaken any of these actions and the impacts of oil and gas development on the Pacific walrus and its sea-ice habitat continue to accrue.

Shipping

Existing shipping regulations both domestically and internationally are inadequate to protect Pacific walruses and their habitat from harm. First, the U.S. Environmental Protection Agency (EPA) does not regulate greenhouse gas and black carbon emissions from ships although the Clean Air Act gives it this authority (Earthjustice 2007). The EPA has the authority to regulate emissions from marine shipping vessels, because, consistent with the threshold determinations required under section 213(a)(4) of the Clean Air Act, greenhouse gas and black carbon emissions from marine engines and vessels significantly contribute to global climate change, which may be reasonably anticipated to endanger public health or welfare. 42 U.S.C. § 7547(a)(4).

In addition, the current and projected impacts of shipping on the Arctic are almost wholly unregulated. The U.S. should work in appropriate international forums such as the International Maritime Organization (IMO) and the Arctic Council to prevent the establishment of new shipping routes in the Arctic. Simultaneously, the U.S. should require that any vessel transiting Arctic waters subject to U.S. jurisdiction apply for and operate consistent with take authorizations under the MMPA and ESA so as to minimize direct impacts to the Pacific walrus. However, to date the U.S. has not undertaken any of these actions nor have the IMO or any other relevant international body taken action to protect Arctic resources from shipping.

Ocean acidification

As discussed below, ocean acidification represents a significant threat to the Pacific walrus and its prey base. Because ocean acidification is driven by anthropogenic carbon dioxide emissions, and, as described above, no adequate mechanisms are in place domestically or internationally to reduce such emissions, regulatory mechanisms to address ocean acidification must also be deemed inadequate.

E. Other Natural and Anthropogenic Factors

1. Ocean Acidification

Ocean acidification poses an ever-increasing risk to the Pacific walrus because of its deleterious effects on its prey species. The world's oceans have been absorbing large volumes of carbon dioxide from the atmosphere and cycling it through various chemical, biological, and hydrological processes. In the past few decades, the oceans have absorbed approximately 30% of carbon dioxide released by human activities (Feely et al. 2004). The world's oceans, in fact, store about 50 times more carbon dioxide than the atmosphere (WBGU 2006), and most carbon dioxide released into the atmosphere from the burning of fossil fuels will eventually be absorbed by the ocean (Caldeira and Wickett 2003). As the ocean absorbs carbon dioxide from the atmosphere it changes the chemistry of the sea water by lowering its pH. The oceans' uptake of these excess anthropogenic carbon dioxide emissions, therefore, is causing ocean acidification (WBGU 2006).

Surface ocean pH has already dropped by about 0.1 units on the pH scale from 1750-1994 -- a rise in acidity of about thirty percent (Orr et al. 2005). The pH of the ocean is currently changing rapidly and may drop by another 0.3 or 0.4 (100 – 150% increase in the concentration of H+ ions) by the end of this century (Orr et al. 2005, Meehl et al. 2007). If carbon dioxide emissions continue unabated, resulting changes in ocean acidity could exceed anything experienced in the past 300 million years (Caldeira and Wickett 2003). Even if carbon dioxide emissions stopped immediately, the ocean would continue to absorb the excess carbon dioxide in the atmosphere, resulting in further acidification until the planet's carbon budget returned to equilibrium.

Ocean acidification from unabated anthropogenic carbon dioxide emissions poses a profound threat to marine ecosystems because it affects the physiology of numerous marine organisms, causing detrimental impacts that may ripple up the food chain. Changes that have been observed in laboratory experiments include impacts to the photosynthesis of phytoplankton, metabolic rates of zooplankton and fish, oxygen supply of squid, reproduction of clams, nitrification by microorganisms, and the uptake of metals (WBGU 2006). King crab and silver seabream larvae exhibit high mortality rates in CO_2-enriched waters (Ishimatsu et al. 2004, Persselin 2007). Exposure of fish to lower pH levels can cause decreased respiration rates, changes in blood chemistry, and changes in enzymatic activity. Sea urchins raised in lower-pH waters show evidence of inhibited growth due to their inability to maintain internal acid-base balance (Kurihara and Shirayama 2004).

Perhaps most importantly, increasing ocean acidity reduces the availability of carbonate ions that many marine plants and animals rely on to build their shells and skeletons (Feely et al.

2004, Orr et al. 2005). Marine organisms including phytoplankton (coccolithophores and foraminifera), coralline algae, corals, echinoderms (sea urchins and starfish), and mollusks (snails, clams, oysters, and squid) are impaired in producing their shells with increasing ocean acidity (Kleypas et al. 2006). Normally, ocean waters are saturated with carbonate ions that marine organisms use to build skeletons (WBGU 2006). However, the acidification of the oceans shifts the water chemistry to favor bicarbonate, thus reducing the availability of carbonate to marine organisms (WBGU 2006). Acidic waters also dissolve existing protective carbonate skeletons and shells (Orr et al. 2005). Because calcifying organisms are at the base of the food web, negative impacts on these organisms will have a cascading effect on other species that rely on these organisms.

Of importance to the Pacific walrus, the mollusk species on which it principally feeds are likely to be impaired in calcifying their shells due to rising ocean acidification. Calcification rates of the blue mussel (*Mytilus edulis*) and Pacific oyster (*Crassostrea gigas*) decline linearly with increasing CO_2 sea water concentrations (Gazeau et al. 2007). Gazeau et al. (2007) found that mussel and oyster calcification rates could decrease by 25 and 10%, respectively, by the end of the century, under the IPCC IS92a emissions scenario (740 ppm in 2100) (Gazeau et al. 2007). Berge et al. (2005) also found that increased CO_2 sea water concentrations impair shell growth of the blue mussel. In addition, the North Pacific has conditions less favorable for calcification due to the increased solubility of calcium carbonate at lower temperatures and the inflow of CO_2-rich waters from deep ocean basins (Persselin 2007). Therefore, the mollusk prey species of the Pacific walrus are likely to suffer declines due to their decreasing ability to build their carbonate shells.

Ocean acidification and its impacts on marine biota will worsen in this century due to the continuing rise in atmospheric carbon dioxide concentrations. By the close of this century, the acidification of the ocean is likely to have significant effects on the principal prey species of the Pacific walrus if greenhouse gas emissions are not abated.

2. Oil and Gas Exploration and Development

The Pacific walrus faces severe and immediate threats from growing offshore oil and gas development that has the potential to destroy or modify large portions of its foraging and breeding habitat and exert lethal and sub-lethal impacts on populations from oil and noise pollution. Specifically, the adverse impacts of oil industry activities on the Pacific walrus include (1) contact with and ingestion of oil from acute and chronic spills; (2) industrial noise pollution from ice-breakers, aircraft, and seismic surveys; and (3) harassment from aircraft, ships, and other vehicles that can disrupt breeding, foraging, resting, and breathing activities (Fair and Becker 2000). Additionally, increased oil and gas production translates into higher greenhouse gas production, which furthers global warming's impact on the Pacific walrus and its habitat. This section describes the existing and projected oil and gas exploration and development in the Pacific walrus's range and the effects from resulting oil and noise pollution.

a. Existing and projected oil and gas exploration and development

United States (Alaska)

Both onshore and offshore oil and gas exploration and development activities have been extensive in the U.S. Arctic. Current and growing large-scale offshore leasing for oil and gas development in the Chukchi, Beaufort, and Bering Seas poses a significant threat to the Pacific walrus. In 2003 the National Research Council noted that "[c]limate 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" (NRC 2003). Since the NRC report, both the impacts of global warming on sea-ice dependent species and the cumulative impacts of oil and gas activities have greatly accelerated.

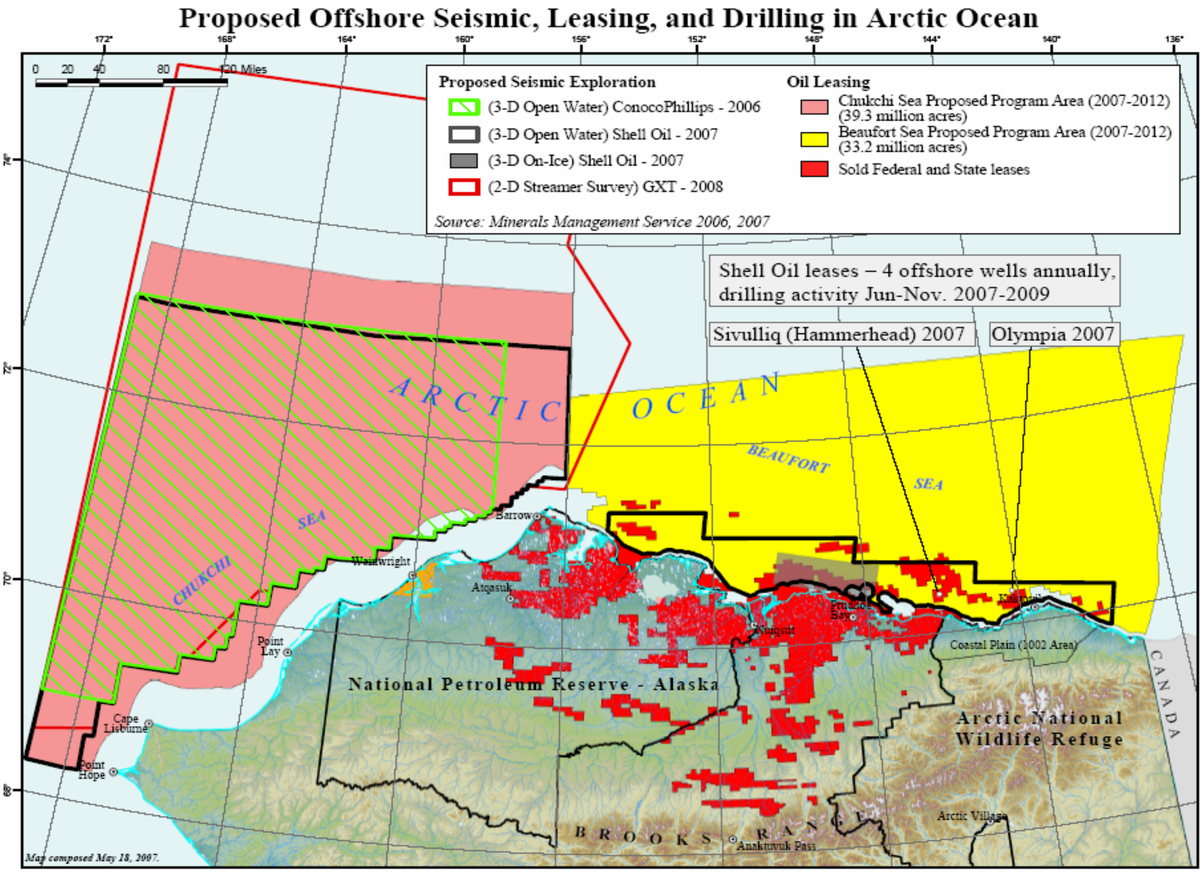
In April 2002, Secretary of Interior Norton issued the Proposed Final 2002-2007 Oil and Gas Leasing Program for the Outer Continental Shelf which resulted in four lease sales in Pacific walrus habitat: one in Norton Sound in northern Bering Sea and three on the Beaufort Sea outer continental shelf which leased ~1,280,000 acres overall (Table 4). In June 2007 Secretary of Interior Kempthorne approved the 2007-2012 Offshore Oil and Gas Leasing Program. In this Program, lease sales in Pacific walrus habitat are planned in the Chukchi Sea in 2008, 2010, and 2012, in the Beaufort Sea in 2009 and 2011, and in Bristol Bay in the southeastern Bering Sea in 2011 (Table 4, Figure 13) (MMS 2007). Chukchi Lease Sale 193, occurred on February 6, 2008, with a substantial portion of prime Pacific walrus foraging habitat on the Chukchi continental shelf ultimately being leased to oil companies, thereby opening oil and gas development in a significant portion of the Pacific walrus's summer range. Bristol Bay was cleared for development in January 2007 when President Bush reversed the presidential withdrawal of this region from oil and gas development that was instituted from 1998-2012 to protect its rich biological diversity. In addition to planned lease sales, activity on existing offshore leases is scheduled or now underway, including exploration drilling by Shell Offshore, Inc. and BP's planned development of the Liberty prospect in the Beaufort Sea. With the lease sales in the Beaufort, Chukchi, and Bering Seas that occurred under the 2002-2007 U.S. Oil and Gas Leasing Program and those scheduled during 2007-2012 (MMS 2007), a substantial proportion of Pacific walrus habitat subject to U.S. jurisdiction is now open for oil and gas leasing and development. Moreover, lease sales on land and in State waters have exposed numerous important walrus foraging or haulout areas to potential oil development. For example, the state Alaska Peninsula lease sale in 2005 resulted in leases being issued on or adjacent to important walrus haulouts in Bristol Bay.

Table 4. Lease Sales for Oil and Gas Development in the Pacific walrus Range completed and proposed by the Minerals Management Service in 2002-2012.
Source: Minerals Management Service.

Previous 5-Year Program (2002-2007)	
Sale Location and Number	**Sale Year**
Beaufort Sea Sale 186	2003
Norton Basin Sale 188	2004
Beaufort Sea Sale 195	2005

Beaufort Sea Sale 202	2007
Chukchi Sea Sale 193	Delayed
Current 5-Year Program (2007-2012)	
Sale Location and Number	**Proposed Sale Year**
Chukchi Sea Sale 193	2008
Beaufort Sea Sale 209	2009
Chukchi Sea Sale 212	2010
Beaufort Sea Sale 217	2011
North Aleutian Basin Sale 214	2011
Chukchi Sea Sale 221	2012

Figure 13. Proposed Offshore Seismic, Leasing, and Drilling in the Chukchi and Beaufort Seas during 2007-2012.
Source: Minerals Management Service.



The pace of the industrialization of America's Arctic by oil and gas development shows no signs of slowing and, in fact, is being actively promoted by the U.S. government (NRC 2003). Since oil and gas production began on Alaska's Arctic Slope in the early 1970s, about 14 billion barrels of oil have been extracted from underground deposits (NRC 2003). As much as 20 billion additional barrels of oil may be extracted in the future (NRC 2003). In 2001, President Bush issued Executive Order 13212 which directed U.S. departments and agencies to take appropriate actions to expedite projects that increase the production, transmission, or conservation of energy (MMS 2003, 2004). Of concern for the Pacific walrus, offshore oil development in particular is expanding now and will continue to do so in the future. Thus far, offshore oil development has accounted for only a small percentage of oil production on Alaska's Arctic slope – only about 0.429 billion barrels have been produced offshore compared to approximately 13.256 on shore as of December 2001 (NRC 2003). In total, 7 of 31 producing oil fields on Alaska's Arctic Slope were offshore (MMS 2004). However, reasonably foreseeable future development includes 16 discoveries, 9 of which are offshore oil fields that may undergo some development-related activities such as site drilling, permitting, appraisal drilling, or construction, within the next 15-20 years (MMS 2004:Table V1a). Therefore, offshore oil development represents a large proportion of reasonably foreseeable future development in the U.S. Arctic.

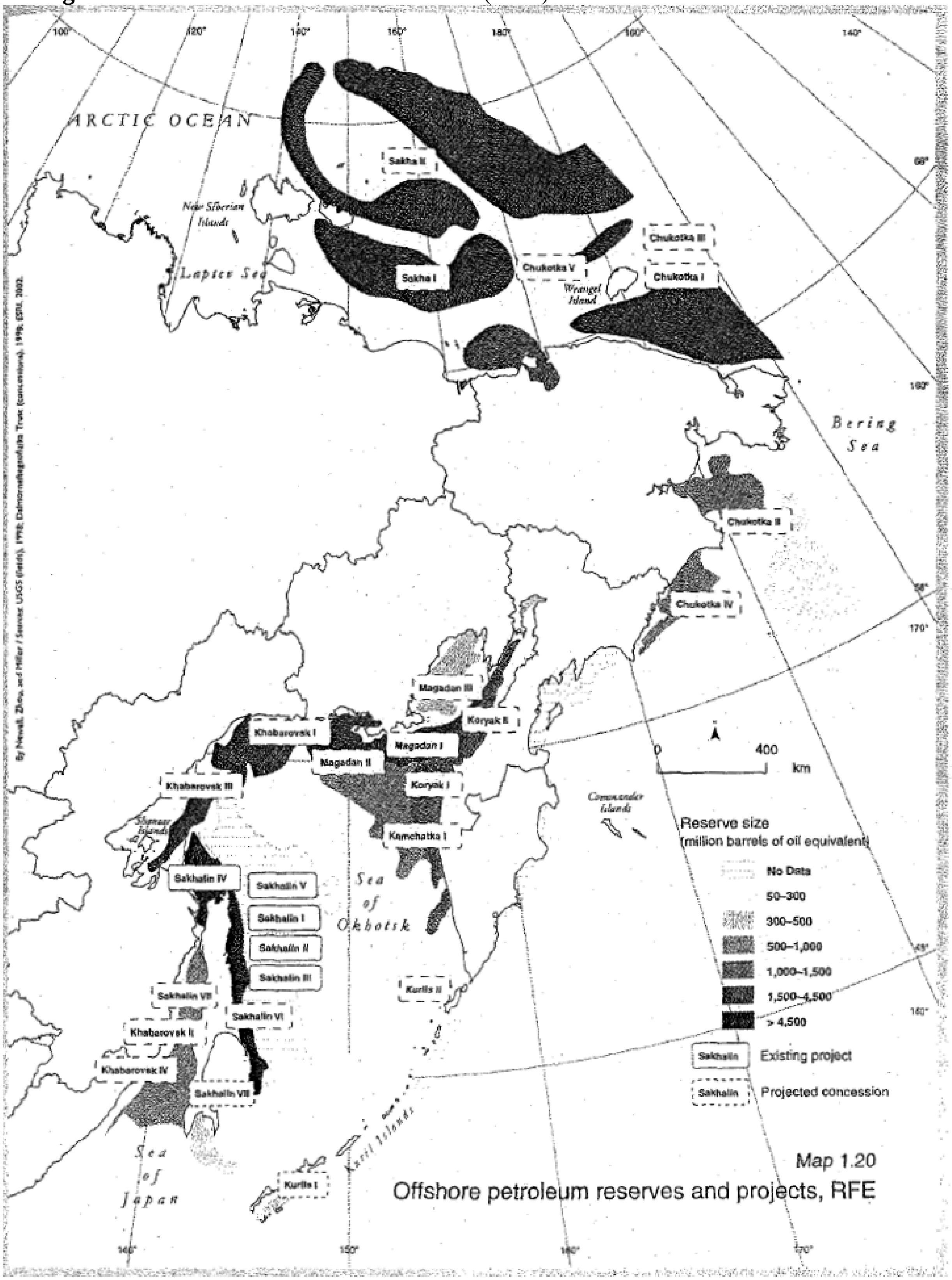
Russia

Growing oil and gas development in the Bering and Chukchi Seas in Russian Federation waters represent a grave threat to the Pacific walrus. In particular, a large oil spill could have catastrophic impacts on the large winter breeding population in the northwestern Bering Sea and on summer haulout aggregations in the Anadyr Bay in the Bering Sea and along the northern Chukotka peninsula in the Chukchi Sea. Oil and gas companies have already begun or are planning ambitious development projects in the Chukotka region of the Bering and Chukchi Seas in important areas of Pacific walrus breeding and foraging habitat (Figure 14) (Lapko and Radchenko 2000, Chernenko 2007). Five prospective petroleum basins in the Chukotka Autonomous District and offshore zones have been identified: Anadirsky, East-Khatirsky, South-Chukotsky, North-Chukotsky and East-Siberian. The total volume of reconnoitered gas stocks equals 11.8 billion m^3 (Chernenko 2007). The company Sibneft-Chukotka has been finishing work on drilling and exploratory well in the Anadirsky petroleum basin for the purpose of identifying its oil and gas content (Chernenko 2007). According to the newspaper *Kommersant*, the quaterly report "Gazprom of oil" indicates that Sibneft-Chukotka completed geologic exploration of the Bering and Central blocks on April 1, 2007 (Chernenko 2007).

Offshore oil and gas development off Siberia has already resulted in a large oil spill in 1999, and future oil spills are very likely. Lapko and Radchenko (2000) warned against the future impacts from oil spills and dredging in Russian waters on the marine ecosystem:

> Unfortunately, oil exploration and development on the shelf cause dredging, leaking oils and oil pollution. Already by the end of September 1999 an accident on one production complex resulted in a spill of about 3.5 t of oil. No doubt other cases will occur in the future. This kind of industrial activity, as well as the commercial fisher, can seriously degrade the marine ecosystem (Lapko and Radchenko 2000: 186).

Figure 14. Offshore petroleum reserves and projects in Russian Federation waters of the Bering and Chukchi Seas. Source: Chernenko (2007): Exhibit 1.



Canada

Intense offshore oil and gas exploration occurred in the Canadian Beaufort Sea in the 1970s and 1980s, including 85 offshore exploration programs that resulted in significant oil and gas discoveries (Devon Canada Corporation 2004). After a lull of two decades, activity is once again increasing. The Canadian government has granted the Devon Canada Corporation Exploration License ("EL") 420 to conduct petroleum exploration in the Southern Beaufort Sea (Devon Canada Corporation 2004). Devon has identified nine offshore drilling targets within the landfast ice zone (Devon Canada Corporation 2004). Under Canadian law, Devon must commence drilling at least one well in each of the four areas by the end of the license period on August 15, 2009, or lose the license in that area, with rights reverting back to the federal government (Devon Canada Corporation 2004). Devon plans to drill the first well during the winter of 2005-2006, and one well per winter season thereafter through 2009 (Devon Canada Corporation 2004). Although the Canadian Beaufort Sea is not in the core of the Pacific walrus's range, Pacific walruses do occur in this region, making offshore oil and gas development in the Beaufort Sea a relevant threat.

b. Impacts of Oil Pollution on Pacific Walruses

The threat posed to the Pacific walrus by oil spills is increasing with the rapid growth in offshore oil and gas development and shipping across its range. Oil spill clean-up in the broken ice and open water conditions that characterize the Pacific walrus's habitat is largely ineffective (Fischer and Larned 2004), making Pacific walruses highly susceptible to injury and mortality even if an oil spill is detected and clean-up is attempted. In particular, walruses are sensitive to human disturbance while hauled out (Fay 1982), and oil spill response and clean-up activities are likely to cause stampedes at sea-ice and land-based haulout sites that may result in injury or death of calves and adults. As detailed below, oil spills can produce population-level impacts on pinnipeds such as the Pacific walrus by decreasing their survival and reproductive success, inhibiting foraging and other behaviors, and exerting deleterious effects on their health. Of added concern, the Pacific walrus has several characteristics that make it particularly vulnerable to oiling.

The Pacific walrus is particularly vulnerable to oil spills due to its social and migratory behavior. Due to its gregarious social behavior, the Pacific walrus aggregates in groups on the sea ice, typically numbering from tens to hundreds of individuals, to several thousand at major terrestrial haulouts (Ray et al. 2006). These dense concentrations of animals increase the risk of a large portion of the population being oiled due to a spill. For example, during the reproductive season (January-March), all Pacific walruses are concentrated in two regions on the Bering Sea sea ice (Figure 1). During spring and autumn, walruses, including all pregnant females and females with young calves, migrate in large groups through the Bering Strait, which increases the possibility of a large portion of the population moving through a potentially contaminated area at the same time (St. Aubin 1990).

Pacific walrus fecundity and calf survival can be adversely affected by oil exposure in multiple ways. Pregnant females exposed to oil contamination may be at a higher risk for spontaneous abortions (St. Aubin 1990). Therefore, the walrus population may suffer from a decrease in overall fertility rates with repercussions felt for years after the spill. Walrus calves are the portion of the population most likely to suffer the effects of oil contamination (St. Aubin 1990). Calves are normally born on the edge of the pack ice, which increases their vulnerability to an oil spill because of the tendency for oil to pool at the ice edge (St. Aubin 1990). Walrus calves can swim almost immediately after birth and often accompany their mother in the water, increasing the calf's probability of being oiled. An oiled calf may be unrecognizable to its mother either by sight or by smell and be abandoned (St. Aubin 1990). Exposure to oil may also interfere with the calf's locomotion. Davis and Anderson (1976, cited in St. Aubin (1990)) observed two gray seal pups drowning because their flippers were stuck to the sides of their bodies, preventing them from swimming.

Oil spills may also impair the Pacific walrus's foraging activities and decrease the availability of its benthic prey. When oil is present in the sea, pinnipeds are reluctant to enter into the water (St. Aubin 1990), reducing their foraging opportunities. Benthic invertebrates in the vicinity of an oil spill would either be killed immediately by oiling or would likely become contaminated from oil in bottom sediments. Bivalve mollusks are not effective in processing hydrocarbon compounds, which results in highly concentrated accumulations and long term retention of the contamination within individuals (Neff 1987). This would likely result in further declines of prey populations since oil contamination in mollusks has been found to impair growth, fertilization, and development of embryos, kill gill tissue, and encourage cancerous growths (Neff 1987). Furthermore, many of the Pacific walrus's bivalve mollusk prey species are long-lived and slow-growing, meaning that prey populations may take a long time to recover from oil impacts (Hansen 1992), forcing walrus to attempt to find other food resources.

Contact with oil and inhalation of hydrocarbon fumes poses a health risk to the Pacific walrus. Petroleum hydrocarbons are extremely irritating to the mucous membranes that surround the eyes and line the oral cavity, respiratory surfaces, and anal and urogenital orifices of pinnipeds (St. Aubin 1990). Contact with oil can damage the skin of pinnipeds since the oil that penetrates the skin can cause inflammation and death of some tissue, creating ulcers (St. Aubin 1990). Walruses may be more susceptible to skin irritation in areas where hair is thin or lacking. Oil contamination in the eyes can also cause severe conjunctivitis, swollen nictitating membranes and corneal abrasions and ulcers (Smith 1975). Inhalation of hydrocarbon vapors can be toxic for pinnipeds, and lead to pulmonary hemorrhage, inflammation and congestion after exposure to concentrated hydrocarbon fumes for a period of 24 hours (St. Aubin 1990). In particular, free-ranging pinnipeds stressed by parasitism or other metabolic disorders may be susceptible to even brief exposure to relatively low concentrations of hydrocarbon vapors. The exposure may even be fatal if combined with other factors that could elicit a major adrenal response (St. Aubin 1990). Parasitized lungs, a relatively common finding in pinnipeds, can exacerbate the effects of even mild irritation of respiratory tissues (St. Aubin 1990).

Some of the components of petroleum are toxic if ingested (St. Aubin 1990). Ingested hydrocarbons irritate and destroy epithelial cells in the stomach and intestine, affecting motility, digestion and absorption (St. Aubin 1990). Ingestion of petroleum hydrocarbons has been the cause of several deaths of gray and harbor seals along the coast of France (St. Aubin 1990). Apparently all pinnipeds have enzymatic systems that help them convert absorbed hydrocarbons into polar metabolites that can be excreted in urine, and extraordinary concentrations of "detoxifying" enzymes have been found in the liver and kidney of oil-exposed seals (St. Aubin 1990). These enzymatic systems help pinnipeds tolerate the toxic effects of oil. However, the activation and production of these enzymes could represent an energetic cost that could reduce pinniped reproduction or survival, and some portion of the ingested oil is stored in blubber (St. Aubin 1990). This may present a problem during times of increased metabolic stress such as molting or pregnancy/lactation, when those blubber stores are used, releasing the hydrocarbons into the system of the animal, or passing them to a calf through the mother's milk (St. Aubin 1990). Ingestion of hydrocarbons by calves is a serious threat because they have significantly less of the enzymes needed to break down the hydrocarbons and thus may have a much stronger reaction than an adult walrus (St. Aubin 1990).

c. Impacts of Noise Pollution on the Pacific Walrus

Pacific walruses are easily disturbed by anthropogenic noise, making the increase in anthropogenic noise under water and in air from oil and gas exploration a cause for concern (Kastelein et al. 2002). Anthropogenic noise has several impacts on walruses, including lowered survival and breeding success: (1) Low-flying aircraft, vessel noises, firearm shots, and other loud noises regularly and predictably cause hauled-out walruses to move into the water, disrupting the animals' normal behavior and constituting an additional and unnecessary energy expenditure (Lowry 1984). When large numbers of walruses are hauled out, especially on land, stampedes may cause the death or injury of numerous animals due to crushing, especially calves (Lowry 1984). For example, a mass stampede on Wrangell Island in response to an aircraft flying at 800 m above the rookery caused the deaths of 102 animals of all ages and sex classes (Ovstanikov et al. 1994). Vessels approaching walruses hauled out on ice at a range of hundreds of meters have also been observed to cause the herd to stampede into the water, sometimes leaving calves stranded on the ice which makes them more vulnerable to abandonment and depredation (Fay et al. 1984); (2) Low-frequency noise may cause walruses to abandon their feeding, breeding, or resting grounds (Lowry 1984). Waterborn sounds of certain frequencies and intensities are likely to cause walruses to avoid their source which could cause significant disturbance in their traditional migratory routes and feeding areas (Lowry 1984); (3) Noise can mask important communications with conspecifics (Kastelein et al. 2002); (4) Noise can interfere with detection of ambient sounds useful for spatial orientation (Kastelein et al. 2002); (5) Prolonged noise disturbance can increase stress levels, resulting in declines in body condition that may increase susceptibility to disease or lower reproductive success (Kastelein et al. 2002); and (6) Moderate to very loud noise and chronic noise may induce temporary or permanent hearing threshold shifts in walruses, which have been observed in other pinnipeds (Kastelein et al. 2002).

Activities associated with oil and gas drilling and exploration that produce anthropogenic noise under water and in air that could affect the Pacific walrus include seismic surveying, drilling, offshore structure emplacement, offshore structure removal, and production-related activities, including helicopter and boat activity for providing supplies to the drilling rigs and platforms. Studies of the Pacific walrus's hearing sensitivity under water and in air confirm that the Pacific walrus is sensitive to most underwater and aerial anthropogenic noise, including those produced by oil and gas drilling and exploration activities (Kastelein et al. 2002). The Pacific walrus's underwater hearing sensitivity ranges from 1–12 kHz and its aerial hearing sensitivity ranges from 0.5–8 kHz (Kastelein et al. 2002). Sources of underwater anthropogenic noise in the 0.1-1 kHz band come from shipping, explosives, seismic surveying sources, aircraft sonic booms, construction and industrial activities, and naval surveillance sonars, while the noise from nearby ships and seismic air-guns can extend up into the 1-10 kHz band (Ocean Studies Board 2003). Therefore, Kastelein et al. (2002) recommended that bottom trawl fishing, tanker routes and drilling platforms should be planned far enough away from areas that are important to Pacific walrus ecology. In addition, these researchers note that determining a 'safe distance' necessitates an examination of several factors, including the general ambient noise level, water depth, ocean floor sediment, and the spectrum, source level and duration of anthropogenic noise (Kastelein et al. 2002).

3. Contaminants

Many Arctic marine mammal species, as long-lived apex predators with high lipid content, have a high potential to accumulate contaminants and carry high contaminant loads (Tynan and DeMaster 1997, Becker 2000, AMAP 2002). The Arctic contains high concentrations of many toxic pollutants that are transported by air, ocean currents, and ice from distant sources (AMAP 2002). Important sources of anthropogenic contaminants for Arctic marine ecosystems include the atmospheric transport of semi-volatile organic compounds such as lipophilic organochlorine compounds (polychlorinated biphenyls, PCBs), chlordanes, and toxaphene from industrial and agricultural areas; coastal mining; and circumpolar runoff particularly from the north-flowing rivers of Siberia that discharge large volumes of freshwater containing suspended contaminants derived from large drainage basins (Becker 2000). Of concern for the Pacific walrus, increasing precipitation and ice melt as a result of global warming will increase the potential for large introductions of river-borne pollutants and contaminants trapped in sea ice into Arctic marine ecosystems (Tynan and DeMaster 1997, ACIA 2005).

Pacific walruses are likely to bioaccumulate contaminants because they are long-lived (up to 40 years) and forage primarily on contaminant-concentrating benthic bivalve and gastropod mollusks (Seagars and Garlich-Miller 2001). Even low-level chronic exposure to contaminants can produce deleterious sub-lethal effects on marine mammals. For example, low-level chronic exposure to PCBs have been linked to decreased fecundity and heightened susceptibility to disease leading to population declines (Becker 2000, Seagars and Garlich-Miller 2001).

Contaminant studies of the Pacific walrus have detected high levels of cadmium in the liver and kidney and high levels of mercury in the liver at levels thought to be hazardous to walrus health (Taylor et al. 1989, Becker 2000). Walruses likely bioaccumulate cadmium and mercury via the food web through the mollusks they consume (Becker 2000). In addition, while most Alaskan Arctic pinnipeds have liver lead concentrations less than 0.05 μg/g wet weight, Pacific walrus liver concentrations sampled from the Bering and Chukchi Seas ranged considerably above this at 0.109 ± 0.458 μg/g wet weight (Becker 2000). Although researchers have detected elevated concentrations of cadmium, mercury, and lead in the Pacific walrus, studies to document their potential health effects on walruses and identify the sources of these contaminants are lacking (Becker 2000). Contaminant studies of the Pacific walrus from the Bering Sea during the early 1980s through mid-1990s also found that concentrations of organochlorine compounds were at relatively low levels during this time period (Taylor et al. 1989, Seagars and Garlich-Miller 2001, Kucklick et al. 2006). However, ongoing monitoring of levels of these contaminants is important to detecting changes in persistent organic pollutants and other contaminants as a result of increases in anthropogenic activity in the Bering and Chukchi Seas (Seagars and Garlich-Miller 2001).

4. Commercial Fisheries

Commercial fisheries pose a threat to the Pacific walrus by causing direct mortality through incidental take as fisheries bycatch and have the potential to impact walruses by depleting essential prey resources. As sea-ice extent in the Bering and Chukchi Seas decreases, there will be new opportunities for commercial fisheries in previously inaccessible regions (AMAP 2003) which could increase Pacific walrus mortality and stress.

In the U.S., bycatch of the Pacific walrus in the Alaska-based commercial groundfish fisheries has fluctuated from relatively high mortality in the 1980s to lower mortality since the mid-1990s. Woodley and Lavinge (1991) reported that 58 Pacific walruses were killed as bycatch in the domestic trawl fishery in the Bering Sea and Gulf of Alaska during 1985-1987 while 79 Pacific walruses were killed by the joint venture trawl fishery in the Bering Sea and Gulf of Alaska during 1983-1987. Pacific walrus mortality during the 1980s was almost certainly higher since these records were based on voluntary reporting and a limited number of years (Woodley and Lavigne 1991). More recently, bycatch levels in the U.S. Bering Sea/Aleutian Islands groundfish trawl, longline, and pot fisheries were monitored by NMFS observers during 1996-2004. From 1996-2004, nine Pacific walrus mortalities were reported due to bycatch in the Bering Sea/Aleutian Islands groundfish trawl fishery, with 0, 2, 1, 0, 2, 0, 2, 0, 2 individuals killed for each year between 1996 and 2004, respectively, with only part of the fishery monitored (NMFS 2002, Perez 2006). Perez (2006) estimated that 1.68 Pacific walruses were killed annually as bycatch in the Bering Sea/Aleutian Islands flatfish trawl between 2000-2004. Although recent bycatch levels in these monitored U.S. fisheries appears to be quite low, other unmonitored U.S. fisheries that might result in walrus bycatch are the set and drift gill-net fisheries targeting salmon that operate in the Bristol Bay and Aleutian Islands regions. Bycatch of pinnipeds is typically highest in gill-net and drift-net fisheries (Read et al. 2006), so bycatch should be monitored in these U.S.-operated gill-net fisheries. In addition, bycatch estimates of the Pacific walrus in international commercial fisheries are not available, including fisheries operated by Russia and Japan.

Commercial fisheries have the potential to impact the Pacific walrus by competing with them for prey resources. At this time, marine bivalves do not appear to be widely exploited by U.S. fisheries in the Bering Sea. The primary commercial bivalve fishery in the range of the Pacific walrus in U.S. waters is the Alaska weathervane scallop (*Patinopecten carinus*) fishery in the Bering Sea north of Unimak Island (Woodby et al. 2005). The weathervane scallop fishery uses heavy dredges to target scallop beds on the continental shelf at depths from 37 to 229 m, with the highest catch rates at depths of 73 to 110 m, typically making repeated tows until catch rates fall off and the dredge moves to another bed (Woodby et al. 2005). Therefore, this fishery has the potential to deplete bivalve prey species on the continental shelf foraging grounds used by the Pacific walrus. The status of international bivalve fisheries operating in the Pacific walrus range is unknown.

Critical Habitat

The ESA mandates that, when USFWS lists a species as endangered or threatened, the agency generally must also concurrently designate critical habitat for that species. Section 4(a)(3)(A)(i) of the ESA states that, "to the maximum extent prudent and determinable," USFWS:

> shall, concurrently with making a determination . . . that a species is an endangered species or threatened species, designate any habitat of such species which is then considered to be critical habitat . . . .

16 U.S.C. § 1533(a)(3)(A)(i); *see also id.* at § 1533(b)(6)(C). The ESA defines the term "critical habitat" to mean:

> i. the specific areas within the geographical area occupied by the species, at the time it is listed . . . , on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and
>
> ii. specific areas outside the geographical area occupied by the species at the time it is listed . . . , upon a determination by the Secretary that such areas are essential for the conservation of the species.

Id. at § 1532(5)(A).

Petitioner expects that USFWS will comply with this unambiguous mandate and designate critical habitat concurrently with the listing of the Pacific walrus. We believe that all current and historic areas utilized by the species for reproduction, resting, molting and foraging meet the criteria for designation as critical habitat and must therefore be designated as such.

Conclusion

For all the reasons discussed above, Petitioner Center for Biological Diversity requests that USFWS list the Pacific walrus as a threatened or endangered species because it is currently in danger of extinction in all or a significant portion of its range or likely to become so in the foreseeable future. Delaying protection of this species until populations have declined further will only undermine any future conservation efforts. If, however, federal regulatory forces can be mustered to protect this ice-dependent species from multiple ongoing threats, then it will have a renewed chance at survival. Listing the Pacific walrus now will allow the necessary conservation mechanisms to be implemented to the fullest extent possible.

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[6] All references are provided in pdf format on the accompanying compact disk except for those denoted with an asterisk. We are happy to provide USFWS with copies of any references upon request.

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